Contents

Article                                                                 Page
Construction Health and Safety Awareness of Nigerian Undergraduate Quantity Surveyors
Okorie, V.N. and Ogbu, C.P.                                             203 – 213
Development of a Manual Assembly Line for a 950kw Single Stroke Generator
Oladeinde M. H. and Edokpia R.O.                                       214 – 221
An Application of the Cobb-Douglass Production Function in the Quantitative Assessment of the Productivity of a Manufacturing Firm in Nigeria
Edokpia R.O. and Oladeinde M. H.                                       222 – 229
Yam Peels as Adsorbent for the Removal of Copper (Cu) and Manganese (Mn) in Waste Water
Isagba E.S., Kadiri S. and Ilaboya I.R                                  230 – 243
Flood Vulnerability Mapping of Lagos Island and Eti-Osa Local Government Areas Using a Multi-Criteria Decision Making Approach
Olayinka D.N. and Irivbogbe H.E.                                       244 – 255
Biodegradation Potentials of Bacterial Isolates from Auto-Mechanic Workshops in Oluku, Edo State, Nigeria
Oshoma C.E., Eze E.E., and Omonigho S. E.                              256 – 264
Strength and Durability Performance of Slag Blended Cements in High Temperature Environments
Ogirigbo, O. R. and Inerhunwa, I.                                       265 – 272
Application of Least Squares Estimation Techniques in 2D Conformal Coordinates Transformation from Local to National
Ehigiator M. O., Oladosu S. O. and Ehigiator-Irughe R.                  273 – 286
Densification of (GNSS) Control Points for Cadastral and Mapping Purposes
Ehigiator M. O., Oladosu S. O. and Ehigiator-Irughe R.                  287 – 298
A Comparison of Monte Carlo Simulation and Discounted Cash Flow Investment Appraisal Techniques Using an Office Building in Akure, Nigeria
Akinbogun S. P., Binuyo O. P. and Akinbogun O. T.                      299 – 308
Maintenance Practice and Occupant’s Satisfaction in Public Housing Estates: An Osobgo, Nigeria Perspective
Ige V. O., Binuyo O. P. and Jimoh D. A.                                 309 – 317
Residents’ Perception and Response to Development Control Activities in Nigerian Cities: The Case of Ibadan and Akure, South-West, Nigeria
Agbonta W. A. P. and Olowoporoku O. A.                                 318 – 329
Improving Roadway Operations and Safety for Large Truck Vehicles by Optimizing some Critical Geometric Design Parameters
<table>
<thead>
<tr>
<th>Application of GIS to Oil and Gas Pipeline Management (A Case Study of South-South Nigeria)</th>
<th>Epuh E.E., Ufot A.I. and Orji M.J.</th>
<th>337 – 348</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Article</strong></th>
<th><strong>Page</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The Role of the Federal University of Technology, Akure Cooperative Multipurpose Society in Housing Finance</td>
<td>Ojo B. and Rotowa O. O.</td>
</tr>
<tr>
<td>Comparison between Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) Assessment of Vegetation Indices</td>
<td>Makinde E.O. and Obigha A.D.</td>
</tr>
<tr>
<td>Accident Prediction Model at Unsignalized Intersection Using Multiple Linear Regression Method</td>
<td>Oghoyafedo N. K., Ehiorobo J. O. and Nwankwo E.</td>
</tr>
<tr>
<td>Estimation of Hydrological Outputs using HEC-HMS and GIS</td>
<td>Olayinka D. N. and Irivbogbe H. E.</td>
</tr>
</tbody>
</table>
Construction Health and Safety Awareness of Nigerian Undergraduate Quantity Surveyors

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ABSTRACT

Construction is particularly an accident-prone and disease-causing process. Quantity surveyors render professional financial management services with regards to the entire construction value chain—including in construction health and safety (H&S) management. However, the adequacy of the construction H&S content of quantity surveying undergraduate programmes in Nigerian universities is uncertain. This study examined undergraduate quantity surveyors’ knowledge of construction H&S. The study used purposive sampling technique for the selection of five universities in southern Nigeria offering bachelor’s degree in quantity surveying. Copies of the study questionnaire were given to 400 and 500 levels students from the five selected universities. Interviews were conducted with registered practicing quantity surveyors, and one quantity surveying lecturer in each of the universities in order to validate the results of the survey. The data were analysed using mean scores. The results revealed that undergraduate students of quantity surveying in the universities covered by the study are insignificantly aware of quantity surveyors’ construction H&S roles. An examination of the course contents of the undergraduate quantity surveying programmes of the universities did not reveal any separate course module for construction H&S. The interviews supported the findings from the survey carried out on the students. They revealed that there is need to include construction H&S in quantity surveying undergraduate programmes in Nigerian universities. Undergraduate quantity surveying students should be taught construction H&S in order to equip them for their future H&S management roles in the construction industry.

Keywords: Construction, Education, Health and Safety, Quantity Surveying

1.0. Introduction

Education is meant to inculcate in the individual the appropriate skills required to face tomorrow’s challenges. Ofoegbu (2004) contended that education is the acquisition of the right values, attitudes, ethics, discipline, knowledge and skills for life’s adventure. Education and training play a key role in the development of awareness and understanding of the specific hazards and risks associated with construction operations and its environment (Olore, 2010; Lutchman, Maharaj & Ghanem, 2012). In the construction context, education empowers future construction managers to act proactively in the management of health and safety (H&S) (Hughes & Ferrett, 2010). Stressing the importance of construction H&S education among the built environment professionals, Haupt (2010) stated that it is a vehicle that drives workplace H&S culture. Lingard and Rowlinson (2005) and Hughes and Ferrett (2010) asserted that inadequate H&S education impacts negatively on students’ competencies, skills, knowledge and H&S awareness. As pointed out by Smallwood (2004), construction H&S education is not only beneficial to the employers, but it also leads to a positive attitudinal orientation of the built environment undergraduates who are the future professionals and managers in the construction industry. In Luria’s (2011) opinion, H&S education and training is a prerequisite for an appropriate level of awareness relative to H&S, which in turn is a prerequisite for the development of an optimum H&S culture. Inadequate safety education has been identified as one of the causes of failure of H&S in construction projects (Nishgaki, 1994). In Nigeria, the level of awareness of construction H&S roles by undergraduate quantity surveyors has not been adequately researched. Health, Safety and Executive (HSE) (2010) affirmed that it is necessary to develop a ‘safety-first mindset’ among students long before they get into the workplace in order to be adequately prepared for their future H&S roles.
Corroboratively, HSE (2011) stated that education and training create awareness and engender behavioural change among workers and designers. HSE (2010) maintained that a preventative H&S culture should be one that incorporates H&S into the educational system of construction industry’s future professionals and managers. Thus, quantity surveying undergraduate students in Nigeria should be trained to understand both national and international laws, regulations and conventions of construction H&S in order to be fit for their future roles.

Despite the importance of H&S education and training, construction H&S is not specified as a separate course in the curriculum of quantity surveying programmes at the undergraduate level in Nigeria [National Universities Commission (NUC), 2007]. The effects of this situation on Nigerian quantity surveyors’ awareness of construction H&S management remains poorly studied. Poor level of awareness of the importance of construction H&S by quantity surveying students could be one of the factors contributing to site accidents in Nigeria. Quantity surveyors often act as cost allocators in construction projects as they distribute the total cost to specific items in a project. Evidently, their knowledge of construction H&S affects the financial provision for H&S in most construction projects. Inadequate financial provision for construction H&S management will result in problems such as continuous absenteeism of workers due to injury and low productivity, and consequently, a reduction in contractors’ profit margin (Hinze, 2006; Okorie, 2014). On the clients’ side, it will possibly lead the client to paying higher insurance premiums and being inundated with claims. Globally, the estimated cost of poor H&S management is 4% of the world’s gross domestic product (GDP) [International Labour Organisation (ILO), 2011]. Hinze (2006: 34) rightly observed that, ‘injuries cost, safety pays.’ Safe work practices not only pay in terms of financial gain, but also in terms of company corporate image, which is equally very important (ILO, 2010). Much has been researched on H&S management and causes of construction site accidents in Nigeria (Idoro, 2008; Udo, Usip & Asuquo, 2016), but scarcely has any research been conducted that explored the awareness of construction H&S by Nigerian quantity surveying undergraduates.

Smallwood (2004) and Gambatese (2008) held the opinion that H&S education and training are the important tools for increasing the general awareness, knowledge and understanding of the concepts of hazards and risks, and how they may be controlled in construction sites. After over 200 visits to design offices in 2008/09, HSE (2010) concluded that designers, including quantity surveyors, had an inadequate understanding of construction safety, health and welfare. The report further stated that the majority of designers were unaware of the ‘General Principles of Prevention’ and that only 12% of designers had H&S qualification. Mohd-Kamar, Lop, Mat-Salleh, Mamter and Suhaimi (2014) studied contractors’ awareness of occupational safety and health (OSH) management systems in the construction industry. They found that majority of the class A contractors were aware of the importance of construction H&S. The study did not focus on undergraduates, and so it differs from the present study, even though both studies are similar in investigating the level of awareness of construction H&S. Need exists, therefore, to ascertain the extent to which university education prepares student quantity surveyors for roles in construction H&S management. A research conducted in South Africa by Smallwood (2004) on the need for inclusion of construction H&S course in architectural curriculum concluded that not only is H&S important to architectural students, but it is also vital to other built environment programmes such as building, construction management and quantity surveying. Additionally, the study stated that the students need an appreciation of construction H&S management in their formative years as an essential tool for the overall construction industry H&S improvement. Studies have shown that a large percentage of contractors who do not provide personal protective equipment (PPE) to site workers do not make provision for H&S in their tenders (Hinze, 2006). Also, Okorie (2014) found that inadequate allocation of financial resources for H&S by quantity surveyors during the project planning or at the tendering stage is a serious challenge to H&S improvement. Famakin and Fawehinmi (2012) sought to assess quantity surveyors’ perception of construction health and safety regulations in Nigeria, and concluded that construction H&S regulations have direct impact on project delivery in Nigeria. Nevertheless, the study did not answer the question whether the direct impact is related to the construction H&S education of the professionals involved in the projects. Okoye et al., (2016) examined the H&S knowledge and compliance of building construction workers on sites in Anambra State, Nigeria. It was found that a strong positive correlation exists between construction H&S knowledge and the performance of the projects covered by the study. However, the study was not
focused on quantity surveyors, and it remained silent on how the respondents gained the knowledge of construction H&S. European Agency for Safety, Health and Welfare at Work (2011) held that occupational H&S has become an integral part of business management, and that all future managers and professionals need relevant H&S education. Consequently, quantity surveying students need to have an appreciation of both national and international H&S laws and regulations during their undergraduate studies. The objective of this study is to examine undergraduate quantity surveyors’ level of awareness of construction H&S management roles of quantity surveyors with a view to making policy recommendations for the training of quantity surveyors in Nigeria.

1.1. Importance of Construction H&S Management

Construction sites have very poor reputation for safety (Mohamed, 2002), and unsatisfactory compliance with H&S standards has been reported in the Nigerian construction industry (Okoye, Ezeokonkwo & Ezeokoli, 2016). The implications of these are enormous. For example, most construction firms in Nigeria are small and medium scale indigenous construction firms that are struggling to survive. When accidents occur in projects handled by such firms, they can erode the firms’ entire profit. Accidents at construction sites have the potential to take 30% off company annual profits, and failure to manage safety has a much larger social cost (Arewa & Farrell, 2012). Health and safety, therefore, is an economic as well as humanitarian concern that requires proper management control (Muiruri & Mulinge, 2014:1). This connection between construction H&S and project profitability underscores quantity surveyors’ construction H&S education.

One obvious effect of poor construction sites H&S is the human suffering caused workers’ families, which cannot be compensated with money. The other potential effect is the high compensation paid to the workers or to their families. There are grievous economic consequences on the families for losing their dear ones. Apart from this, poor site H&S management tarnishes a contractor’s image (Spangenberg, 2009). The tarnished image is often accompanied with adverse publicity, which results in a contractor losing future tenders. Given this scenario, undergraduate quantity surveyors should be knowledgeable enough about construction H&S to offer prudent construction H&S cost management advices to their firms upon graduation. The skill to give such professional advice may determine the employability of graduate quantity surveyors in Nigeria. Sodipo (2014) observed that most Nigerian graduates are found unemployable due to skill deficiencies, and construction H&S is one of such skills for graduate quantity surveyors. Ayudhya and Israngkura (2011) showed that poor construction H&S management may lead to lengthy construction disputes. With the economic and social implications of poor construction H&S on workers, their families, contractors and governments, there is need to examine the Nigerian undergraduate quantity surveyors’ awareness of construction H&S.

1.2. Quantity surveying education in Nigerian Universities

A quantity surveyor is a professional consultant appointed by the client to advise him (the client), architects and engineers on all financial and contractual matters arising from the commencement of a construction project to its completion (Yakubu, 2013). Nigerian Institute of Quantity Surveyors (NIQS) (2015) defined quantity surveying as a profession within the building and engineering construction sector of the economy concerned with cost and procurement management from conception to close-out of any construction project. Ashworth and Hogg (2007) described quantity surveying as the profession concerned with the prudent management of resources of the construction industry. Majorly, a quantity surveyor oversees the allocation of construction resources to the various work items of a project. Thus, a quantity surveyor may be understood as a construction economist and manager responsible for the economic and prudent allocation and utilisation of construction resources in construction projects of all ramifications. The 21st century construction process demands that all the key project participants, including quantity surveyors, should demonstrate visible leadership and commitment to matters concerning workers’ health, safety and wellbeing.

The National University Commission (NUC) of Nigeria is responsible for benchmarking minimum academic standards for all undergraduate programmes in Nigeria including that of quantity surveying. A review of the NUC’s benchmark minimum academic standard (BMAS) for the quantity surveying
undergraduate degree programme (NUC, 2007) reveals that construction H&S is neither among the core courses nor among the elective courses prescribed. However, it should be noted that Nigeria’s National Policy on Education enjoins universities to determine the courses to be taught in line with the minimum standards stipulated by regulatory agencies [Nigerian Educational Research and Development Council (NERDC), 2013] like the NUC and the and the Quantity Surveyors Registration Board of Nigeria (QSRBN). The NUC did not stipulate any separate construction H&S module for the undergraduate quantity surveying programme in the 2007 BMAS, likewise the QSRBN. QSRBN (2017) stated that the Board “monitors teaching, learning and research in quantity surveying in higher institutions of learning to ensure they conform to laid down standards”, uncertainty exists as to what standards the QSRBN expects, especially, with respect to construction H&S. Jagboro (2013) observed that irrespective of the lofty visions of universities with respect to teaching and learning, it appears that no concerted effort is being made to harness and consolidate R&D efforts in the quantity surveying profession. The impact of this policy gap on Nigerian quantity surveying graduates as it relates to construction H&S remains a matter of conjecture.

It would appear that Nigeria does not take construction H&S seriously. For instance, Idoro (2008) pointed out that frequent references are made to international occupational health and safety standards in the Nigerian construction industry. This anomaly which persists till today, coupled with the absence of a dedicated construction H&S course module in NUC’s first degree programme in quantity surveying, betrays a neglect of construction H&S whose impact at the site level in Nigeria has scarcely been investigated.

Wallerstein and Weinger (1992:619) identified three issues that must be addressed before worker H&S education can advance, namely: the lack of clarity and consensus on the goals of worker education, the lack of standards for effective teaching methods, the lack of skills in these methods of the people who deliver the trainings. Nigeria’s case appears to be dominated by the first issue. As argued by Idoro (2008), apart from the Factories Act of 1987 (CAP F1, Laws of Federation of Nigeria, 2004), which draws heavily from the United Kingdom's Factories Act of 1937 (Hameed, 2013), no other international construction H&S regulation has the force of law in Nigeria. In any case, the Factories Act has so far been poorly enforced (Abubakar, 2015). Additionally, the Act does not make any reference to tertiary education training of would-be construction professionals. Thus, construction educators may be inadequately incentivised to develop a course content for construction H&S that is tailored to the needs of Nigeria. The final outcome of this situation will be sets of quantity surveying graduates that are unaware and unprepared for construction H&S cost management. This could have grave consequences for construction H&S in Nigeria since construction H&S training and education is critically important to the H&S performance of projects (Sawacha, Naoum, & Fong, 1999). HSE (2008) and Gambatese (2008) observed that construction H&S education improves the H&S performance of projects by ensuring positive attitudinal and cultural changes by practitioners in the industry, including quantity surveyors. Jagboro (2016) pointed out that quantity surveyors’ roles are becoming more vital for the attainment of sustainable national development goals, including in the area of health, safety and welfare of the workforce, than when it was originally established in England in 1785. The focus of this study, therefore, is to examine the level of awareness of construction H&S by undergraduate quantity surveyors in Nigeria.

2.0. Materials and Methods

In order to achieve the objective of this study, a field survey involving 400 and 500 levels undergraduate quantity surveying students in five federal universities in Southern Nigeria was conducted. These levels of undergraduates are in the penultimate and final years of their studies respectively. Since the data was collected for each university during the second semester, the students must have also completed the mandatory student industrial work experience scheme (SIWES) programme. Thus, they are supposed to understand construction H&S-related issues. Southern Nigeria was chosen for this study given that it has a higher concentration of higher education institutions than northern Nigeria (Bamiro, 2012).

The universities were selected purposively. Copies of the questionnaire were distributed to 150 students of the stated category. The main purpose of the questionnaire was to determine respondents’ level of awareness of the importance of construction H&S. Of the 150 copies of the questionnaire distributed, only eighty copies (n=80, 53%) were returned. The response rate achieved for this research is similar to that achieved in other similar surveys (Sutrisna, 2009; Collins, 2008). It could be inferred from
Sutrisna (2009) and Dainty (2008) that performing a statistical analysis in a survey within the response rate equal to or above the threshold of thirty (30) is acceptable. Thus, the 53% response rate achieved in this survey provides reasonable data for analysis. The gathered data were analysed using mean scores (MS). The significance of each variable was ascertained based on the MS average of 2.5. Hence variables having MS≥2.5 were considered to be informative, while variables with MS<2.5 were considered unimportant.

In order to confirm the findings of the survey, interviews were also conducted with practicing quantity surveyors and one quantity surveying lecturer from each of the five universities covered by the study. The selection of quantity surveying practitioners and academics for the interviews took account of a number of factors including academic qualifications and years of experience. An interview is an interaction between two or more people to gain insight relative to problems (Leedy & Ormrod, 2010).

The study further examined the course contents of the quantity surveying programmes of the surveyed universities in order to ascertain whether a separate course module was designated for construction H&S.

3.0. Results and Discussion

The analysis of questionnaire survey shows that 37.5% of the respondents were female while 62.5% were male. The respondents were between the ages of 18 and 30 years. In view of their years of study in the universities, they were considered academically qualified to comprehend the questions and provide reliable answers.

3.1. Inclusion of construction H&S in quantity surveying undergraduate programme

Despite the contents of the Benchmark Minimum Academic Standards for Undergraduate Programmes in Nigerian Universities (BMAS) for environmental sciences, Nigerian universities are allowed to complement the standard courses with other relevant courses to make for better quality graduates. This necessitated the inquiry into whether construction H&S is included as a separate course in the curriculum of the B.Sc QS programme of any of the universities of which the students are aware.

The students were asked, “Kindly indicate how construction H&S is taught in your degree programme in this university”

Table 1 indicates the respondents’ responses in terms of ‘as a separate course’ ‘included in other courses’ not taught in our programme’ and ‘Not sure’. The data analysis shows that 62.5% of the students stated that construction H&S is taught as an integral part of other courses, while 30% answered, ‘not taught in our programme’ 7.5% of the respondents were not sure whether construction H&S is included in the degree programmes or not. None of the students indicated that construction H&S is a separate course in any of the universities. Further, this study’s search on the course contents of the quantity surveying programmes of the universities did not reveal any separate course title for construction H&S.

Thus, both the NUC and the universities studied did not allow for construction H&S as a separate course in the undergraduate quantity surveying programme. This implies that the training of undergraduate quantity surveyors does not place high emphasis on construction H&S. Dodo (2014) and Umeokafor, Umeadi, and Igwegbe (2014) revealed that the Federal Ministry of Labour and Productivity which was assigned the responsibility of monitoring compliance to the Factories Act 1987 is not doing so effectively. Consequently, construction companies are not under any pressure to evaluate the construction H&S competences of their quantity surveying employees. Although the quantity surveying practitioners interviewed expressed the opinion that construction H&S should be made a separate module, this viewpoint has not gathered sufficient support to compel universities to single out construction H&S as a separate course of study. Indicatively, one of the goals of education in Nigeria which is to ensure periodic review, effectiveness and relevance of the curriculum at all levels to meet the needs of society and the world of work (NERDC, 2013) has not been achieved in this particular regard.
3.2. Awareness of quantity surveyors’ H&S roles in construction H&S management

Further, the students were asked to indicate quantity surveyors’ construction H&S management roles of which they are aware. The findings are shown in Table 2. The questions were framed in the negative to ensure that the students are sure of the answer before answering. Secondly, the intention was to minimise social desirability bias in the responses (Fisher & Tellies, 1998). As shown in Table 2, most of the students rated the negative statements related to quantity surveyors’ construction H&S roles high with all the MSs being >3.00. Clearly, the result shows that the students are not aware of QS’s roles in construction H&S. This is related to the non-inclusion of construction H&S as a separate module in their curriculum.

Mohd-Kamar et al. (2014) found the level of awareness of construction H&S to be high for class A contractors in Kelantan, Malaysia. This is not supported by the present study. Firstly, it should be noted that Mohd-Kamar et al. (2014) focused on firms, while the present study focused on individuals. Secondly, while Mohd-Kamar et al. (2014) did not reveal the professions of the staff of the firms covered who responded to the questionnaire, this study’s questionnaire was administered on quantity surveying undergraduates. Even though class A contractors in Kelantan, Malaysia are highly aware of the importance of construction H&S, undergraduate quantity surveying students in southern Nigerian universities are mostly unaware of the roles of quantity surveyors in construction H&S. During the interview, the practicing quantity surveyors and lecturers showed support for the idea that undergraduate quantity surveyors should be trained in construction H&S. However, the practicing quantity surveyors were not all in agreement that construction H&S knowledge is one of the criteria for the employment of graduate quantity surveyors.

Table 2: Awareness of quantity surveyors’ H&S roles in construction H&S management

<table>
<thead>
<tr>
<th>Statement</th>
<th>MS</th>
<th>Rank</th>
</tr>
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<tr>
<td>Inadequate provision of Sections of Standard Form of Contract Clauses related to H&amp;S</td>
<td>3.63</td>
<td>1</td>
</tr>
<tr>
<td>Failure to ensuring that contractors made adequate financial provision in tenders</td>
<td>3.61</td>
<td>2</td>
</tr>
<tr>
<td>Non-inclusion of an H&amp;S in bills of quantities (BoQs)</td>
<td>3.56</td>
<td>3</td>
</tr>
<tr>
<td>Lack of commitment in preparation of periodic valuation certificate</td>
<td>3.50</td>
<td>4</td>
</tr>
<tr>
<td>Inadequate facilitation of financial provision for H&amp;S in the preliminary and general conditions of the BoQs</td>
<td>3.34</td>
<td>5</td>
</tr>
<tr>
<td>Lack of pre-qualification of contractors on H&amp;S</td>
<td>3.30</td>
<td>6</td>
</tr>
<tr>
<td>Poor choice of procurement system</td>
<td>3.15</td>
<td>7</td>
</tr>
<tr>
<td>Inadequate estimation of project duration</td>
<td>3.10</td>
<td>8</td>
</tr>
</tbody>
</table>

3.3. Importance of effective construction H&S management

Table 3 indicates the extent to which the respondents rated importance of construction H&S management in terms of mean scores. All the MSs are above the mid-point of 2.50 (MSs >4.20 ≤ 5.00), which indicates that the identified statements are very important.

Overall, the result shows that the students consider effective construction H&S management to be important. Although they ranked reduction of injuries and disease highest (MS=4.58), and ranked tarnished contractor’ image least (MS=4.24), all the statements have MS>4.00. The findings of this study suggest that even though most of the students do not know the roles of quantity surveyors in the
construction H&S management of projects, they are highly aware of the importance of construction H&S.

The findings of Mohd-Kamar, et al. (2014) is supported by this section’s results. Student quantity surveyors, just like the firms in Mohd-Karmar, et al.’s (2014) study, are aware of the importance of construction H&S, what is lacking is their understanding of the roles of quantity surveyors in the management of construction H&S. Muiruri and Mulinge (2014) recommended that massive education campaigns be launched to arouse awareness among all parties with direct or indirect bearing on accidents occurrence and their prevention. The current study’s findings suggest that such a campaign should also focus on universities in the southern part of Nigeria, and specifically, at informing undergraduate quantity surveyors on what their future roles will be in terms of construction H&S management.

Table 3: Importance of effective construction H&S management

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<thead>
<tr>
<th>Factor</th>
<th>MS</th>
<th>Rank</th>
</tr>
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<tbody>
<tr>
<td>Reduction of injuries and disease</td>
<td>4.58</td>
<td>1</td>
</tr>
<tr>
<td>Significant reduction in loss of human lives</td>
<td>4.54</td>
<td>2</td>
</tr>
<tr>
<td>Reduction of damage to plant and equipment</td>
<td>4.42</td>
<td>3</td>
</tr>
<tr>
<td>Reduction in workers absenteeism</td>
<td>4.41</td>
<td>4</td>
</tr>
<tr>
<td>Decrease in productivity and profit margin</td>
<td>4.35</td>
<td>5</td>
</tr>
<tr>
<td>Reduction in compensation paid to injured workers</td>
<td>4.33</td>
<td>6</td>
</tr>
<tr>
<td>Reduction in disputes and litigation</td>
<td>4.30</td>
<td>7</td>
</tr>
<tr>
<td>Tarnished contractors’ image</td>
<td>4.24</td>
<td>8</td>
</tr>
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3.4. Interview results

The interview results show that quantity surveying practitioners are aware of the importance of H&S and roles quantity surveyors play in construction H&S management.

However, there were different perceptions among lecturers on the inclusion of construction H&S as a course module rather than to be offered as integral parts of other courses. A lecturer from one of the universities stated that “construction H&S is taught alongside other courses such as workshop practice, fire prevention, control and equipment”. This corroborates the findings of this study with respect to the inclusion of construction H&S in the quantity surveying undergraduate programme. In contrast, another lecturer emphatically stated that “there is a need to include construction H&S as course module in quantity surveying curriculum especially in Nigeria”. He stated that “quantity surveyors as construction cost experts who advise clients and architects on the implications of their design decisions should have knowledge of the national and international H&S legislations and regulations”. While every other interviewee agreed with this perspective, this study’s finding is that construction H&S is not a separate module in the course content of the quantity surveying programmes of the universities surveyed.

All the practicing quantity surveyors interviewed indicated that there is need to include construction H&S as a course module in quantity surveying programmes in tertiary institutions in Nigeria. One of the interviewees stated “I will carry this message to the next Nigerian Institute of Quantity Surveyors (NIQS) Lagos State Branch meeting”. He stated further that, “It is high time the Nigerian quantity surveyors contributed to construction industry H&S improvement, not limiting their roles only to the preparation of bills of quantities”. All the interviewees agreed that quantity surveyors, as financial experts in the construction industry can contribute significantly to the industry’s H&S performance. Literature review corroborated the views of the practicing quantity surveyors that quantity surveying students need an appreciation and understanding of construction H&S for their future H&S critical roles and to develop a safety-first mindset (HSE, 2008).

4.0. Conclusion and Recommendations

The education of future quantity surveyors is fundamental to the desired cultural change for construction industry H&S improvement. This is the rationale behind this study that sought to examine the
construction H&S awareness of undergraduate quantity surveying students in universities in southern Nigeria.

This study has revealed that the knowledge of construction H&S management is important to students of quantity surveying. From the research findings and interviews, it is apparent that H&S is not included as a course module, but taught as an integral part of other courses. Construction H&S is, therefore, not designated as an area of separate study for quantity surveying undergraduates in the universities covered by this study. It was, however, determined that the students are aware of the importance of construction H&S in the construction industry, although they were found not to know exactly the construction H&S roles of quantity surveyors. This knowledge gap has implications for the effective management of construction H&S in Nigeria.

Based on the findings of this study, the NUC should include construction H&S as a separate course module for quantity surveying undergraduate programmes with a view to abating the rate of H&S failures in the Nigerian construction industry. Universities in the study area should include construction H&S as one of the courses to be taught at the undergraduate level for quantity surveying students, even if the NUC does not do so. In addition, excursions and similar means should be adopted in the construction H&S training of undergraduate quantity surveying students. The NIQS should develop quantity surveying based best practice manual/note in the area of construction H&S management for circulation to undergraduate students.

References


Development of a Manual Assembly Line for a 950kw Single Stroke Generator

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ABSTRACT

In this paper, a manual assembly line for the assembly of a 950KW gasoline generator has been designed. A part list of a purchased generator was generated after the machine was disassembled. Work measurement technique was used to generate an assembly process for the machine. The duration for assembly of each component was obtained using stop watch and then standardized. The cycle time of the manual assembly line was determined and subsequently, the distribution of load amongst the ten station line was balanced out using the ranked positional weight technique. Computations reveal that a fairly high labour efficiency of 0.804 is obtained. The line balancing efficiency obtained equal 0.849 implying a balance delay of 0.151.

Keywords: Manual assembly line, line balancing, ranked positional weight, generator, cycle time, efficiency

Nomenclature:

D annual demand  
E line efficiency (uptime proportion)  
E₀ line balancing efficiency  
Eᵣ repositioning efficiency  
Hₜ number of hours per week  
Oₜ number of operating weeks  
Rₜ ideal cycle time  
Rₚ hourly production rate  
Sₜ number of shifts per week  
Tₙ cycle time (mins)  
Tₛ service time (mins)  
Tₚ work content time (mins)  
w* minimum number of work stations  
WL workload

1.0. Introduction

Epileptic public power supply and household quest to obtain power from alternative sources has become a daily occurrence in Nigeria according to Olaleye and Akinbode (2012). The reliance of most households on power supply using the 950Kw generator has continued to increase. The Nigerian economy is predominantly middle class; consequently purchase of heavy duty generating sets is beyond their reach. The 950 Kw gasoline generator popularly known as “I better pass my neighbor” is available in most households in Nigeria. The major reason advanced for its purchase is its fuel economy and portability. Currently, the assembly of generators is done in a single station manual assembly cell. A single workstation is one in which all of the assembly work is accomplished on the product or on some major subassembly. Even though this practice is known to result in greater worker satisfaction, it is comparatively slower than line production. Consequently, the need to develop multi station manual assembly line for the assembly of the generators is evident. In spite of the major advances in the
automation of assembly processes, there are still many assembly systems which mainly or completely rely on manual labour.

Lit and Delchambre (2011) stated that assembly lines are the most commonly used method in mass production environments because they enable assembly of complex products by workers with limited training. An assembly line consists of workstations that produce a product as it moves successively from one workstation to the next along the line (Hamza and Al-Manaa, 2013). The cardinal purpose of assembly systems designers is to increase production line efficiency by optimizing the ratio between throughput and required costs. This is achieved by ensuring that the workload is distributed amongst the various stations in an even way. Line balancing is an effective tool to improve the throughput of assembly line while reducing non-value-adding activities and cycle time. Amardeep et al (2013) stated that line balancing is the problem of assigning operation (s) to workstation along an assembly line in such a way that assignment is optimal in some sense. Additionally, Salveson (1995) described the assembly line balancing problem (ALBP) as assigning tasks to an ordered sequence of stations such that the precedence relations among the tasks are satisfied and some performance measure is optimized.

Many previous approaches to analyzing and developing the performance of assembly systems such as the works of Eryuruk et al (2008), Kamlekar et al ((2012), Edokpia and Okonta(2013) and Edokpia and Owu (2013), have focused on the balancing and rebalancing of existing assembly systems. According to Kitaw et al (2010), balancing refers to the procedure of adjusting the operation times at work centers to conform as much as possible to the required cycle time. A few studies have focused on generating empirical data for subsequently developing and analyzing manual assembly lines. One of the most important approaches to studying line balancing with work stations characterized by manual operations is work measurement according to Longo et al (2006). A key step in the development of a manual assembly line is the preparation of a Work Standard. A Work Standard is a list of all the assembly operations that have to be performed to produce a finished product, with each of the operations taking place at a different position along the assembly line.

In this study, method study and work measurement techniques have been used to obtain a precedence relationship among the various tasks necessary for the complete assembly of a 950 Kw gasoline generator. The task times have also been standardized to account for the variability in task times due to differences in skill level of human operators. The developed manual assembly line was balanced using the ranked positional weight technique and operating characteristics of the line determined.

2.0. Methodology

In this section, the methodology for the development of the manual assembly line for 950 Kw gasoline generators is presented. The first step was to completely disassemble all the components necessary to assemble all the parts and sub-assemblies of the gasoline generator. A list of part names of the generator was developed. Method study technique was subsequently used to develop an assembly procedure for the generator. The assembly procedure established was then used to completely assemble the various components by three different operators who have had at least 5 years’ experience in generator repair and a stop watch used to determine the times taken to perform the various work elements necessary for the complete assembly of a complete unit of the generator. The mean of the three observed times was recorded as the task assembly time for each component. Certain constraints were considered in the course of assembling the generator. They are;

i. Creation of sub-assemblies components of the gasoline generator

ii. A Sub-assembly is generated only when sensitive properties of that part are paramount to the functionality of the generator and must not be damage by human hands and excessive force. The sub-assemblies were carburetto assembly, dash-board assembly, and crank-shaft part.

iii. Each component of the generator has a corresponding assembly task to be performed.

iv. Only one single operation can be performed at a time

v. A part can only be assembled to the whole if the initial assemblage has an interconnecting side with that component
2.1. Standardization of Task Times

The use of standard times which accounts for the fact that workers have great variations in level of skill and aptitudes for certain jobs. A performance rating of 115% was used to convert the observed times to normal times. A total allowance of 20% was made to the normal times leading to the standard times used for the analysis of the manual assembly line. The standardized task times are presented in Table 2.

2.2. Generator Part List

The generator was carefully stripped and a part list of the various components, assembly and sub-assemblies drawn up. The part list is presented in Table 1.

Table 1: Part description of the 950kw Gasoline Generator

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Part Names</th>
<th>Part Number</th>
<th>Part Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crank shaft and bearings</td>
<td>15</td>
<td>Inlet valve</td>
</tr>
<tr>
<td>2</td>
<td>Left crank casing</td>
<td>16</td>
<td>Carburetor</td>
</tr>
<tr>
<td>3</td>
<td>Right crank casing</td>
<td>17</td>
<td>Throttle and springs</td>
</tr>
<tr>
<td>4</td>
<td>Motor coil</td>
<td>18</td>
<td>Dash board</td>
</tr>
<tr>
<td>5</td>
<td>Armature</td>
<td>19</td>
<td>Dash board/panel cover</td>
</tr>
<tr>
<td>6</td>
<td>Armature cover</td>
<td>20</td>
<td>Flywheel-starter coil</td>
</tr>
<tr>
<td>7</td>
<td>Piston rings</td>
<td>21</td>
<td>Flywheel</td>
</tr>
<tr>
<td>8</td>
<td>Engine block</td>
<td>22</td>
<td>Recoil starter/pulley/spring</td>
</tr>
<tr>
<td>9</td>
<td>Engine-cylinder packing</td>
<td>23</td>
<td>CDI</td>
</tr>
<tr>
<td>10</td>
<td>Top cylinder</td>
<td>24</td>
<td>Capacitor/switch</td>
</tr>
<tr>
<td>11</td>
<td>Spark plug</td>
<td>25</td>
<td>Socket</td>
</tr>
<tr>
<td>12</td>
<td>Exhaust</td>
<td>26</td>
<td>Stator wires</td>
</tr>
<tr>
<td>13</td>
<td>Engine cover</td>
<td>27</td>
<td>Ignition coil</td>
</tr>
<tr>
<td>14</td>
<td>Inlet Valve packing</td>
<td>28</td>
<td>Fuel tank</td>
</tr>
</tbody>
</table>

Table 2: Standard times of the tasks

<table>
<thead>
<tr>
<th>Task Number</th>
<th>Standard Time [seconds]</th>
<th>Process description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66</td>
<td>Crank shaft assembly</td>
</tr>
<tr>
<td>2</td>
<td>146</td>
<td>Assemble left crank case on shaft</td>
</tr>
<tr>
<td>3</td>
<td>123</td>
<td>Assemble right casing</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>Assemble motor coil inside Crank case</td>
</tr>
<tr>
<td>5</td>
<td>83</td>
<td>Insert armature</td>
</tr>
<tr>
<td>6</td>
<td>148</td>
<td>Assemble Armature cover</td>
</tr>
<tr>
<td>7</td>
<td>31</td>
<td>Put rings on piston</td>
</tr>
<tr>
<td>8</td>
<td>106</td>
<td>Assemble engine block</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>Put cylinder packing</td>
</tr>
<tr>
<td>10</td>
<td>108</td>
<td>Assembly top cylinder</td>
</tr>
<tr>
<td>11</td>
<td>17</td>
<td>Tighten spark plug into engine subassembly</td>
</tr>
<tr>
<td>12</td>
<td>70</td>
<td>Assembly exhaust</td>
</tr>
<tr>
<td>13</td>
<td>44</td>
<td>Assemble engine cover</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>Place valve packing on half engine</td>
</tr>
<tr>
<td>15</td>
<td>73</td>
<td>Assemble inlet valve on crank case</td>
</tr>
<tr>
<td>16</td>
<td>33</td>
<td>Attach carburetor to inlet valve.</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>Connect throttle to carburetor</td>
</tr>
<tr>
<td>18</td>
<td>110</td>
<td>Assembly dash board-carburetor subsystem on valve</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>Place panel cover</td>
</tr>
<tr>
<td>20</td>
<td>33</td>
<td>Assemble chassis into half engine</td>
</tr>
<tr>
<td>21</td>
<td>71</td>
<td>Assembly flywheel</td>
</tr>
<tr>
<td>22</td>
<td>95</td>
<td>Assemble starter cap</td>
</tr>
<tr>
<td>23</td>
<td>17</td>
<td>Connect CDI and flywheel/ switch</td>
</tr>
<tr>
<td>24</td>
<td>18</td>
<td>Connect CDI and motor coil wire</td>
</tr>
<tr>
<td>25</td>
<td>15</td>
<td>Connect coil wire to capacitor/socket</td>
</tr>
<tr>
<td>26</td>
<td>21</td>
<td>Connect flywheel starting coil and motor coil</td>
</tr>
<tr>
<td>27</td>
<td>21</td>
<td>Connect ignition coil on spark plug</td>
</tr>
<tr>
<td>28</td>
<td>207</td>
<td>Assembly Fuel tank</td>
</tr>
</tbody>
</table>

A flowchart showing the sequence in which the assembly work takes place in the manual assembly line is shown in Figure 1.
2.3. Theoretical Considerations

2.3.1. Production Rate

The manual assembly line must be designed for a particular value of annual demand \( D \). Assuming the following notation for line operational characteristics; \( S_w \) = number of shifts per week, \( H_h \) = number of hours per shift, \( Q_o \) = number of operating weeks, the hourly production rate \( R_p \) which guarantees the annual demand is calculated using

\[
R_p = \frac{D}{S_w Q_o H_h}
\]

(1)

The production rate can be converted cycle time using the Equation. (2). The determination of the cycle time in Equation (2) accounts for the inevitability of production time losses due to a myriad of issues relating to for example labour problems, equipment failures and power outages. Consequently, only a proportion of the shift time will be available. Line efficiency (uptime proportion) for manual production, \( E \), assumes values in the range 0.9-0.98 according to Groover (2008).

\[
T_c = \frac{60E}{R_p}
\]

(2)

The cycle time obtained in Equation (2) is related to the ideal cycle time of the line by Equation (3)

\[
R_c = \frac{60}{T_p}
\]

(3)

The line efficiency \( E \) can be calculated as

\[
E = \frac{R_p}{R_c} = \frac{T_c}{T_p}
\]

(4)

The workload to be accomplished \((WL)\) is related to the production rate \((R_p)\) and the work content time \((T_w)\), defined as the total time of all work elements that must be performed to produce one unit of the work unit, by the expression

\[
WL = R_p T_w
\]

(5)

The theoretical minimum number of stations that will be required on the line to produce one unit of the work unit \( w^* \) is computed using

\[
w^* = \text{minimum integer} \geq \frac{T_w}{T_c}
\]

(6)
3.0. Analysis of Results and Discussion

3.1. Analysis of Single Model Assembly Line

The manual production line was designed for a total production volume of complete units of the complete generator per annum. According to the nomenclature adopted \( D_a = 32,000 \). The annual demand designed for will be obtained for 50 weeks working year, 5 working days per week and 8 working hours per day.

Based on the design data and using Equation (1), the production rate which guarantees the annual production volume is;

\[
R_p = \frac{32000}{50 \times 5 \times 8} = 16 \text{ units per hour}
\]

The total work content \((T_{wc})\) of the assembly process is a summation of all the task times is;

\[
T_{wc} = \sum_{i=1}^{28} T_i = 30 \text{minutes}
\]

The minimum number of stations \((w)\) required to produce one unit of the product assuming uptime efficiency \((E)\) is 0.96 is

\[
w = \text{minimum integer} \geq \frac{R_p T_{wc}}{60E} \geq \frac{16 \times 29.91}{60 \times 0.96}
\]

\[
w = 9 \text{ stations}
\]

The cycle time \((T_c)\) of the assembly process is determined by Equation (2)

\[
T_c = \frac{60 \times 0.96}{16} = 3.6 \text{ minutes}
\]

Assuming that the time required to move the product from one work station to the adjacent work station \((T_r)\) is 4 seconds, the service time \((T_s)\) which is the available time in each cycle for the worker to work on the product is equal to

\[
T_s = T_c - T_r = 3.6 - 0.05 = 3.55 \text{ minutes}
\]

The available time for work is therefore 213 seconds at each station.

3.2. Line Balancing Using Rank Positional Weight

A cycle time of 216 seconds has been determined from the previous section. The tasks needed to completely assemble a unit of the generator have been arranged according to their positional weights from the highest to the least and is presented in Table 3.

Based on the tabulation of the tasks Rank Positional Weights, the manual assembly line has been balanced with a cycle time of 213 seconds. The tasks in each station, total station time as well as idle time is presented in Table 4.
Table 3: Ranked position weights of tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Task duration [seconds]</th>
<th>RPW</th>
<th>Predecessor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66</td>
<td>1802</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>146</td>
<td>1736</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>163</td>
<td>1590</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>1427</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>83</td>
<td>1382</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>148</td>
<td>1299</td>
<td>5</td>
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<tr>
<td>7</td>
<td>31</td>
<td>595</td>
<td>6</td>
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<tr>
<td>8</td>
<td>106</td>
<td>564</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>547</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>108</td>
<td>446</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>17</td>
<td>338</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>70</td>
<td>321</td>
<td>11</td>
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<tr>
<td>13</td>
<td>17</td>
<td>338</td>
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<td>14</td>
<td>19</td>
<td>301</td>
<td>18</td>
</tr>
<tr>
<td>15</td>
<td>73</td>
<td>535</td>
<td>14</td>
</tr>
<tr>
<td>16</td>
<td>33</td>
<td>462</td>
<td>15</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>429</td>
<td>16</td>
</tr>
<tr>
<td>18</td>
<td>110</td>
<td>411</td>
<td>17</td>
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<tr>
<td>19</td>
<td>95</td>
<td>394</td>
<td>21</td>
</tr>
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<td>71</td>
<td>465</td>
<td>20</td>
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<tr>
<td>21</td>
<td>33</td>
<td>462</td>
<td>15</td>
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<tr>
<td>22</td>
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<td>548</td>
<td>8</td>
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<td>17</td>
<td>299</td>
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<td>282</td>
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<td>27</td>
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<td>13,16</td>
</tr>
<tr>
<td>28</td>
<td>207</td>
<td>207</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 4: Works stations showing tasks and total station time

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Tasks</th>
<th>Task times</th>
<th>Station time</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>66</td>
<td>212</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>163</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td>4</td>
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</tr>
<tr>
<td>3</td>
<td>5</td>
<td>83</td>
<td>83</td>
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<tr>
<td></td>
<td>6</td>
<td>148</td>
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<td>73</td>
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<td></td>
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<td></td>
<td>17</td>
<td>13</td>
<td></td>
</tr>
<tr>
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<td>10</td>
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</tr>
<tr>
<td></td>
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<td>95</td>
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</tr>
<tr>
<td>7</td>
<td>18</td>
<td>110</td>
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</tr>
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<tr>
<td></td>
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<td>17</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
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<td>155</td>
</tr>
<tr>
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<td>21</td>
<td></td>
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<tr>
<td></td>
<td>27</td>
<td>21</td>
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<tr>
<td>9</td>
<td>28</td>
<td>207</td>
<td>207</td>
</tr>
<tr>
<td>10</td>
<td>28</td>
<td>207</td>
<td>207</td>
</tr>
</tbody>
</table>
The repositioning efficiency \((E_r)\) of the line is

\[
E_r = \frac{3.55}{3.60} = 0.986
\]

The line balancing efficiency \((E_o)\) is determined as

\[
E_o = \frac{30}{10 \times 3.53} = 0.849
\]

The balance delay of the assembly line is therefore 0.151.

Using the uptime efficiency, repositioning efficiency and the line balancing efficiency, the labor efficiency of the assembly line is computed to be

usage efficiency = \(0.96 \times 0.986 \times 0.849 = 0.804\)

Using the computed value of labor efficiency, a more realistic value of the number of workers on the assembly line is

\[
w = \text{minimum integer} \geq \frac{30}{0.849 \times 3.55} = 10
\]

3.3. Discussion of Results

The manual assembly line designed has a maximum production volume of 32000 units per annum. This annual production volume is achievable by hourly production rate of 16 complete units per hour. Extensive experimentation shows that on the average it takes about half an hour to completely assemble a unit of the generator. Theoretical analysis put forward that a minimum of nine work stations is required to assemble the product. Based on a cycle time of 213 seconds which took into account repositioning time as well four seconds provision for transporting the semi-finished product from one station to the adjacent station, line balancing using the ranked positional weight technique yielded a total of 10 work stations, each manned by a worker. The line and labor efficiencies computed for the line based on the operating conditions were 0.849 and 0.804 respectively. These values are fairly high and demonstrate an attractive productivity for the designed assembly line.

4.0. Conclusion

The key output of this research is the design of a manual assembly system for assembly of a commonly used petrol generator. The serial ten station assembly line is manned by one worker per station. The tasks to be carried out at each work station have been determined using the ranked positional weight technique. The line efficiency determined is meritorious showing potential of high worker productivity.

References


An Application of the Cobb-Douglas Production Function in the Quantitative Assessment of the Productivity of a Manufacturing Firm in Nigeria

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ABSTRACT

The focus of this study is the use of the Cobb-Douglas’ production function to evaluate the productivity of a manufacturing firm. In order to achieve our aim, secondary data of the production line of the firm, were used. These data include the production output data and cost data, which covered a period from 1991 to 2010. A production frontier was established for every manufacturing year using the production function. Business cycle was also used to analyze the deviation between the actual production and the production frontier. The results indicated that for 80 percent of the years under study, the firm operated above the production frontier, and therefore considered technically efficient for those years, with the exception of the years 1994, 2005, 2007 and 2008 where the firm operated below the production frontier. Also the deviation between the actual production and the production frontier followed the business cycle. The trend of actual production curve showed that there is a tendency of low productivity in the future.

Keywords: Output Elasticity, Labour, Capital, Cobb-Douglas Model, Production Function, Recession and Depression

Nomenclature:

GDP = Gross Domestic Product
K = Capital input (the amount of money invested in a year)
L = Labour (The total number man–hour worked in a year)
Q = Total production for a year
b = Total factor productivity
pL = price of labour per unit hour
PK = Price of capital per unit hour
α and β are the output elasticity of labour and capital respectively.
₦ = Naira

1.0. Introduction

In fact, the manufacturing sector, according to the report on Vision 2020 NTWG on Manufacturing Thematic Area (2009), has performed woefully and failed to deliver on its high potentials as reflected by low capacity utilization, minimal economic contribution to the country’s GDP (from 8.8% in 1990 to 4.1% as at 2008) and low employment share in comparison to other sectors. Over the years, estimated cost of production in the Nigeria has risen considerably due to the high cost of doing business. The Nigerian economy depends on oil revenue and the country has large oil reserves and therefore has great potential to build a strong and vibrant economy from huge revenues generated from this sector. In fact, it has been reported that as at 2009, 95% of the country’s foreign exchange earnings derives from oil. However, these revenues failed to improve the poverty level of the country and it was among the world’s poorest countries until 2002 (Ku et al, 2010). In order to accelerate the growth of its economy, the country should reduce her dependence on oil and concentrate on the development of other sectors like agriculture, energy and, transport and manufacturing.
However, the performance of the manufacturing sector in Nigeria shows that there are some vital problems that have and are still inhibiting the growth of the sector. It has also been argued that some basic limitations are impeding the growth and development of the sector despite past studies and solutions proffered.

Complete analysis of the Nigerian manufacturing sector is complex due to inadequate data about the productivity levels of the Nigerian economy. It has however been reported that the overall productivity level of the manufacturing sector from 1980-1989 has seen very increase and most of the companies even faced a decline in productivity. The report expressed low expectations of improvement in the situation. Studies conducted in the 1990s and 2000s confirmed this expectation of negative trend in productivity level of the sector (Ku et al, 2010).

Meagher (2006) identified the problem of the Nigerian manufacturing sector from the perspective of inadequate academic research and development from the Nigerian universities and other institutions. He recommended that the research institutions in the country be adequately funded by the Nigerian government, public, private and even multinational organisations in order that the decaying manufacturing sector be revived through the researches that will be engaged in. It is against this backdrop that this research becomes a matter of necessity.

The performance of a manufacturing firm is often identified with the growth rate of potential output. However, in a non-manufacturing firm, potential output is not observed in reality but can be approximated. Measuring performance has been part and parcel of a successful manufacturing firm. It has to be strategic in that the survival of any organization depends on its performance. In other words, management uses performance measurement to evaluate the overall health of the organization.

The output of a firm is dependent mainly on factors of production, classified as labour and capital. The firm has to confront the problem of determining how much labour and capital to employ to produce the most efficient output. Every production manager wants to increase production level to the maximum point at the available factors of production. The right combination of these two factors to maximize output (productivity) of a production firm forms the basis of this study. The indigenous bottle manufacturing company under study has been in operation for over 25 years. The company is situated in Delta State of Nigeria. It comprises various departments, ranging from cold end department, printing department, mould department, quality control department, and process maintenance department. They operate a flow or mass production system. This means continuous production.

There is no doubt, that there is a link between potential output and its input variables. But the problem of establishing the right relationship between the input variable and the output variable (firm performance) still exist. When studying the growth of a nation’s economy, the economists have established the link between input and output of the nation. But most of the individual firms in the economy have not been able to establish similar relationship that exists between the input and output of their production line. This study therefore establishes such a relationship using the Cobb-Douglas.

Some studies have been conducted using this model in different areas of research. The qualitative and quantitative explanation, the merits of the Cobb-Douglas production function and its use for analyzing production process because of the advantage it possesses which outweighs its advantages were identified by Bhanumurthy (2002). Effiong and Umoh (2010) used the Cobb-Douglas model based on stochastic profit frontier to estimate and the relevant indices determining efficiency levels for egg-laying industry in Akwa Ibom state in Nigeria while (Banaeian and Zangeneh, 2011) used the model to obtain the relationship between agricultural inputs and walnut yield in view of energy input in Iran. Adinya et al (2011) examined the constraints militating against the profitability potentials of snail production by small-scale farmers in Cross River State, Nigeria utilising the model. (Bhagwat and Debruine, 2011) utilized the production function approach to study the concomitant effect of Research and Development (R and D) and advertising expenditures on the revenue of pharmaceutical firms. Essi (2011) used the model to establish how the role played by production function in economics can be enhanced when they are correctly specified. Khater (2012) established a new index for human development based on the Cobb-Douglas function, for the purpose of measuring and assessing development among different overrates in Egypt. He also compared it with available indices and
discovered that it outperformed them. However, literature that reported on using the model to analyse the productivity of the manufacturing sector in Nigeria is scarce hence the need for this study.

The aim of this study is to evaluate the productivity (firm’s performance) of an indigenous bottle manufacturing firm located in Nigeria using Cobb-Douglas production function which will serve as a basis for future improved models to be developed for the company and similar outfits. The data used covered a period of 20 years (1991-2010). In addition to developing the production function for the company under study, the function is also optimized in order to get the least cost combination of input resources for a desired level of output. This study is intended to give a better understanding of performance measurement, serve as a guide to manufacturing as well as service companies and as a reference material for future research in this area for the manufacturing sector since lack of adequate information and data have been reported.

1.1. Theoretical Framework

The Cobb-Douglas production function expresses the relationship between productivity and factors of production. The model presents a simplified view of the economy in which production output is determined by the amount of labour involved and the amount of capital invested. In this regard, a lot of studies have been undertaken. The function is of the form:

\[ Q(L, K) = b L^\alpha K^\beta \]  

(1)

1.1.1. Assumptions made in the Model

If the production function denote by \( Q = q(L, K) \), then the partial derivative \( \frac{\partial Q}{\partial L} \) is the rate at which production changes with respect to the amount of labour. Economists called it marginal productivity of labour. Likewise the partial derivative \( \frac{\partial Q}{\partial K} \) is the rate at which production changes with respect to capital and is called the marginal productivity of capital (Bao Hong, 2008). In this term the assumption made by Cobb-Douglass can be state as follows:

i. If either labour or capital vanishes, then so will production.

ii. The marginal productivity of labour is proportional to the amount of production per unit of labour.

iii. The marginal productivity of capital is proportional to the amount of production per unit of capital.

Because the production per unit of labour is \( \frac{P}{L} \), assumption 2 says that

\[ \frac{\partial Q}{\partial L} = \alpha \frac{Q}{L} \]  

(2)

Finally, \( Q(L, k) = C_1(K_0)L^a \)  

(3)

Where \( C_1(k_0) \) is the constant of integration and we can write it as a function of \( k_0 \) since it could depend on the value of \( k_0 \).

Similarly, assumption 3 says that

\[ \frac{\partial Q}{\partial k} = \beta \frac{Q}{k} \]

Keeping \( L \) constant (\( L = L_0 \)) this differential equation can be solve to get

\[ Q(L_0, K) = C_2(L_0) K^\beta \]  

(4)

Finally, combining equation (3) and equation (4), we have

\[ Q(L_0, K) = bL^a K^\beta \]  

(5)

Where \( b \) is a constant that is independent of both \( L \) and \( K \).
Assumption 1 shows that $\alpha > 0$ and $\beta > 0$. From Equation 1, if labour and capital are both increased by a factor $M$, then,

$$Q(ML, MK) = b(ML)^{\alpha} (MK)^{\beta} = M^{\alpha + \beta} Q(L, K)$$  \hspace{1cm} (6)

From the theory of return to scale, if $\alpha + \beta = 1$, $Q(ML, Mk) = MQ(L, K)$ which means that production is also increased by a factor of $M$.

From equation 1,

$$\log Q = \log b + \alpha \log k + \beta \log L$$  \hspace{1cm} (7)

Where $Y = \log Q$, $P = \log b$, $X_1 = \log K$, and $X_2 = \log L$.

For a multivariate linear regression analysis we use the model below:

$$Y = P + \alpha X_1 + b X_2$$  \hspace{1cm} (8)

1.2. Business Cycle

Business cycle refers to a phenomenon of cyclical booms and depression. In a business, there are wave-like fluctuations in aggregate output. Business cycle has four phases namely: Prosperity, Recession, Depression and Recovery. Prosperity is a period in which output is at the highest peak. While recession starts when there is descent from the peak, which is of short duration. Depression is the lowest peak; it is as a result of the general decline in economic activity. There is a considerable reduction in the production of goods. When depression has lasted for some time then it will begin to rise, this phase is known as recovery.

2.0. Methodology

This research work involves the assessment of the productivity of a glass bottle manufacturing firm using the Cobb-douglass’ Model with labour and capital as input variables to develop a multi-regression prediction model. This will be achieved by using secondary production input and output data obtained from the firm, covering a period of 20 years (1991 to 2010). The production function developed will be used to establish a production frontier against which actual production will be evaluated. Using Lagrange multipliers, the model can be optimized in order to get the least cost combination of input resources.

2.1. Data Collection

The assumption made by Cobb-Douglass limited the factor of production to labour and capital as the input and the output of their production line. The labour index in this research work was obtained by summing the number of hours worked by those employees in the production floor. In this firm the employees work seven hours a day for shift workers and for straight day employees work eight hours a day.

To obtain the capital index, we need the cost of production which includes the salary of workers in the production floor, money used to purchase raw material, and the book value of the machines that were used in the production process. Since most of the machines were not purchased during the period under study, and that they have passed through depreciation stages, we had to compute depreciation account to get the book value of the machines. In the production line of the firm, the different equipment used in the production process are listed thus:

1. Ande printing machine
2. Palletizing machine
3. Furnace
4. Isebeg machine
5. Maipo stitching machine
6. Ringler rapping machine
7. Ximing power plants (1 and 2)
8. Fork lift
9. Howitt layer
10. Vensingh washing machine
11. Moser mixer machine
12. Panama driller
These machines are fixed assets which are purchased for the production process. To know the cost of production, then we must know the monetary worth of these machines. Table 1 shows some basic history of these equipment. Table 1 displays information about cost, useful life as well as salvage value and the date of purchase of equipment used in the production process as obtained from accounts department of the company.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Date of Purchase</th>
<th>Asset Cost (₦)</th>
<th>Useful Life (yrs)</th>
<th>Salvage Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>05/01/1991</td>
<td>15,00,000</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>01/06/1999</td>
<td>5,000,000</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>27/12/1980</td>
<td>50,000,000</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>30/12/1989</td>
<td>1,000,000</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>31/05/1997</td>
<td>200,000</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>10/01/2000</td>
<td>4,000,000</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>7 (Power Plant)</td>
<td>21/01/1984</td>
<td>8,000,000</td>
<td>15</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>(PowerPlant 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>01/06/2000</td>
<td>12,000,000</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>01/07/2000</td>
<td>2,000,000</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>30/11/1992</td>
<td>1,500,000</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>15/01/1998</td>
<td>150,000</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>15/06/1998</td>
<td>5,000,000</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>25/01/1990</td>
<td>9,000,000</td>
<td>20</td>
<td>5</td>
</tr>
</tbody>
</table>

### 3.0. Data Analysis, Results and Discussion

The figures in Table 1 were used to obtain the depreciation account for the period they served, starting with the year of purchase. The data was organized using the information available from the company. Table 2 shows the output and input figures for the period under study. The Double Declining Balance technique was used for depreciation since it is the company’s policy.

#### 3.1. Depreciation Account

The annual depreciation is calculated as follows:

\[
\text{Annual depreciation} = \text{Depreciation rate} \times \text{book value at the beginning of the year}
\]

The depreciation rate (Collier and Glagola, 1998) = \(\frac{2}{\text{Useful life}}\) \hspace{1cm} (13)

Purchase of depreciable asset is equal to book value at time zero and the cause of depreciation is mostly due to wear, which accumulates as a function of hours of use, severity of use and the level of preventive maintenance.

<table>
<thead>
<tr>
<th>Year</th>
<th>((Q) \times 10^8)</th>
<th>((L)) (\times 10^7)</th>
<th>((K) \times 10^8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2.12675</td>
<td>6.99876</td>
<td>2.46739</td>
</tr>
<tr>
<td>1992</td>
<td>2.00564</td>
<td>5.67250</td>
<td>2.32985</td>
</tr>
<tr>
<td>1993</td>
<td>2.044598</td>
<td>5.93498</td>
<td>2.29515</td>
</tr>
<tr>
<td>1994</td>
<td>1.14398</td>
<td>4.96819</td>
<td>1.96248</td>
</tr>
<tr>
<td>1995</td>
<td>2.09484</td>
<td>6.19454</td>
<td>1.99606</td>
</tr>
<tr>
<td>1996</td>
<td>2.11199</td>
<td>6.81410</td>
<td>1.98143</td>
</tr>
<tr>
<td>1997</td>
<td>2.10671</td>
<td>6.20325</td>
<td>2.61265</td>
</tr>
<tr>
<td>1998</td>
<td>2.07154</td>
<td>6.40017</td>
<td>4.92822</td>
</tr>
<tr>
<td>1999</td>
<td>2.06981</td>
<td>6.57259</td>
<td>2.02132</td>
</tr>
<tr>
<td>2000</td>
<td>2.03180</td>
<td>5.56691</td>
<td>2.20062</td>
</tr>
<tr>
<td>2001</td>
<td>2.01905</td>
<td>5.66494</td>
<td>2.28092</td>
</tr>
<tr>
<td>2002</td>
<td>2.08104</td>
<td>6.75498</td>
<td>2.23576</td>
</tr>
<tr>
<td>2003</td>
<td>2.07213</td>
<td>6.61760</td>
<td>2.18136</td>
</tr>
<tr>
<td>2004</td>
<td>2.00937</td>
<td>5.73978</td>
<td>2.23649</td>
</tr>
<tr>
<td>2005</td>
<td>1.14080</td>
<td>5.18900</td>
<td>1.98752</td>
</tr>
<tr>
<td>2006</td>
<td>2.13837</td>
<td>6.34180</td>
<td>1.78799</td>
</tr>
<tr>
<td>2007</td>
<td>1.15287</td>
<td>5.01213</td>
<td>1.66944</td>
</tr>
<tr>
<td>2008</td>
<td>1.13901</td>
<td>7.09935</td>
<td>2.05942</td>
</tr>
<tr>
<td>2009</td>
<td>2.15937</td>
<td>7.17010</td>
<td>1.87993</td>
</tr>
<tr>
<td>2010</td>
<td>2.07964</td>
<td>6.57259</td>
<td>2.02267</td>
</tr>
</tbody>
</table>
The data obtained were analysed using the ordinary least square multiple regression technique to establish the relationship between the output variable and the input variables given as:

\[ \sum y = 205.30740, \sum X_1 = 155.75568, \sum X_2 = 166.83115, \sum X_1^2 = 1213.03697, \sum X_2^2 = 1391.83255, \sum YX_1 = 1598.88138, \sum YX_2 = 1712.5758 \text{ and } \sum X_1 X_2 = 1299.25911. \]

Solving the regression equations (equations (9) to (12)) with the data gives: 

\[ \alpha = -0.35639, \beta = 0.55603 \text{ and } P = 8.40275 \]

From equation 9, \( b = 10^p \) hence, \( b = 2.51189 \times 10^8 \).

Substituting these estimators into equation 1, we have:

\[ Q = 2.51189 \times 10^8 L^{-0.35639} K^{0.55603} \tag{14} \]

Table 3 shows the percentage deviation between the actual and theoretical production.

<table>
<thead>
<tr>
<th>Years</th>
<th>Actual Production ( Q \times 10^{10} )</th>
<th>Theoretical Production ( q \times 10^{10} )</th>
<th>Percentage Deviation ( \frac{Q-q}{Q} \times 100 )</th>
<th>Business Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2.12675</td>
<td>1.90830</td>
<td>10.27154</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1992</td>
<td>2.00564</td>
<td>1.99239</td>
<td>0.66064</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1993</td>
<td>2.04597</td>
<td>1.95444</td>
<td>51.16555</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1994</td>
<td>1.43936</td>
<td>1.92060</td>
<td>67.89048</td>
<td>Depression</td>
</tr>
<tr>
<td>1995</td>
<td>2.09484</td>
<td>1.71294</td>
<td>18.23050</td>
<td>Recovery</td>
</tr>
<tr>
<td>1996</td>
<td>2.11199</td>
<td>1.80216</td>
<td>1.88601</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1997</td>
<td>2.10671</td>
<td>1.82097</td>
<td>13.56333</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1998</td>
<td>2.07154</td>
<td>1.80326</td>
<td>12.90755</td>
<td>Prosperity</td>
</tr>
<tr>
<td>1999</td>
<td>2.06981</td>
<td>1.76222</td>
<td>14.86078</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2000</td>
<td>2.03180</td>
<td>1.99348</td>
<td>51.16555</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2001</td>
<td>2.01905</td>
<td>1.94831</td>
<td>67.89048</td>
<td>Depression</td>
</tr>
<tr>
<td>2002</td>
<td>2.08104</td>
<td>1.78703</td>
<td>18.23050</td>
<td>Recovery</td>
</tr>
<tr>
<td>2003</td>
<td>2.07213</td>
<td>1.85672</td>
<td>13.56333</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2004</td>
<td>2.00937</td>
<td>1.97094</td>
<td>1.88601</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2005</td>
<td>1.11408</td>
<td>1.79563</td>
<td>12.90755</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2006</td>
<td>2.13837</td>
<td>1.67058</td>
<td>14.86078</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2007</td>
<td>1.15287</td>
<td>1.77421</td>
<td>51.16555</td>
<td>Prosperity</td>
</tr>
<tr>
<td>2008</td>
<td>1.13901</td>
<td>1.83886</td>
<td>67.89048</td>
<td>Depression</td>
</tr>
<tr>
<td>2009</td>
<td>2.15957</td>
<td>1.67842</td>
<td>22.27989</td>
<td>Recovery</td>
</tr>
<tr>
<td>2010</td>
<td>2.07964</td>
<td>1.70623</td>
<td>17.95551</td>
<td>Prosperity</td>
</tr>
</tbody>
</table>

3.2. Optimization of Function

The objective function is (Ekanem and Iyoha, 1999):

\[ Q = P_L L + P_K K \tag{15} \]

If the firm desires to produce an output of \( 250 \times 10^8 \) units, how many units of input of labour and capital should the firm employ to achieve their target if the unit price of labour per hour is \( \text{₦}250 \) while that of capital per unit hour is \( \text{₦}300 \)?

The Lagrange function is

\[ Q = 2.51189 \times 10^8 L^{-0.35639} K^{0.55603} + \lambda (250 \times 10^8 - 250L - 300K) \tag{16} \]

\[ \frac{\delta Q}{\delta L} = -8.95 \times 10^9 L^{0.64369} K^{-0.55603} - 250 \lambda \tag{17} \]

\[ \frac{\delta Q}{\delta K} = 1.396 \times 10^8 L^{-0.35639} K^{0.44397} - 300 \lambda \tag{18} \]

\[ \frac{\delta Q}{\delta \lambda} = 250 \times 10^8 - 250L - 300K \tag{19} \]

From which we obtain, \( L = 984634521 \text{ man hr and } K = \text{₦}1280409 \text{ unit} \)
Under elasticity of substitution isoquant curve are generally convex to the origin its slope is always negative thus the sign of elasticity is negative. Economist conventionally eliminates this negative sign by multiplying through with -1. More importantly, it is the absolute size that is of significance to the economist.

3.3. Discussion of Results

From eq. 14, \( \alpha + \beta < 1 \) implying decreasing return to scale i.e. successive application of equal additional unit of variable input unto the existing fixed input will yield progressively less and less additional output.

The production frontier characterizes the maximum output with various input combination. To establish the theoretical output for a particular manufacturing year, the inputs for that year will be substituted into the production function. This is the production frontier against the actual production is evaluated. For a particular year, if the firm operates above the production frontier (if the actual production is more than the theoretical production) for a manufacturing year, the firm is technically efficient, otherwise, the firm is technically inefficient.

Table 3 indicated that for 80 percent of the years under study, the firm operated above the production frontier, meaning that they were technically efficient in their use of input resources. With the exception of 1994, 2005, 2007 and 2008 where the firm operated below the production frontier.

From the foregoing, it is noticed that there is difference between what was actually produced and the computed production. The deviation between the actual production and theoretical production follows the Business cycle. According to Baxter and King (1999), positive deviations indicate prosperity, while negative deviations indicate recession.

Production was at its peak in 2009 with an output of \( 215.9 \times 10^8 \) units followed by 2006 with an output of \( 213.8 \times 10^8 \) and 1991 with an output of \( 212.7 \times 10^8 \). A careful look at the chart showed that there was a sudden drop in production for the years 1994, 2005, 2007, and 2008 with an output of \( 114.4 \times 10^8 \) \( 111.4 \times 10^8 \) 115.3 \times 10^8 \) and \( 113.9 \times 10^8 \) unit. Productivity fluctuates between \( 200 \times 10^8 \) unit and \( 220 \times 10^8 \) unit within the years 1995 and 2004. Looking closely at the trend on the graph shows from times series analysis that production has the tendency to decrease as time goes on.

There were positive and negative deviations. Its highest positive deviation occurred in the year 2009 with peak deviation of 22.28 percent and the lowest deviation occurred for the year 1994 with a deviation of -67.89 percent deviation and the trend line indicates a decrease in the near future.

The productivity of each factor can be examined when one of the factor input is held constant. As the unit of labour increase and capital held constant, production will increase. But if labour is held constant while capital is increase, then production will decrease. It implies that more of labour and less capital will result in output growth.

The unit of labour and capital that the firm needs to employ to achieve a desired output of \( 250 \times 10^8 \) units is 984634521 man-hr and ₦1280409. Anything less than this value will result in a different output.

4.0. Conclusion

The production function of the indigenous firm under study has been developed and optimised. With the model we were able to evaluate and come to the conclusion that for 80 percent of the years under study the firm’s output performance was efficient with the exception of 1994, 2005, 2007, and 2008. With the desired output of \( 250 \times 10^8 \) and with unit price of labour to be ₦250 per hour and that of capital is ₦300, the model has been used to estimate the amount of input (labour and capital) to be applied to the production line to achieve the desire output. The amount of labour that should be applied is 984634521 hours and that for capital is ₦1280409.
References


Yam Peels as Adsorbent for the Removal of Copper (Cu) and Manganese (Mn) in Waste Water

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\textbf{ABSTRACT}

This paper investigated the use of yam peel as a natural adsorbent for the removal of Copper (Cu) and Manganese (Mn) from waste water. The yam peels were thoroughly washed with distilled water, dried, pulverized and carbonized. The carbonized yam peel was then characterized for its particle sizes, moisture content, ash content, volatile matter, Methylene Blue number, Iodine number. The raw yam peels were prepared using the same procedure, but was not carbonized. The adsorption of Mn(II) and Cu(II) ions were investigated using adsorption experiment at room temperature. The effect of contact time, metal ion concentration and dosage were evaluated. The residual concentrations of the metal ions were determined by Atomic Absorption Spectrophotometer (AAS). Experimental data obtained were analyzed using Kinetic models and Isotherms such as Pseudo- First order kinetic models, Pseudo-second order kinetic models, Langmuir isotherms and Freundlich isotherm. The analysis showed that the pseudo-second order kinetic model best described the adsorption of the metal ions; (Cu; $r^2 = 0.991$ for RYP and $r^2 = 0.834$ for AYP) and (Mn; $r^2 = 0.958$ for RYP and $r^2 = 0.896$ for AYP) and the experimental data best fit the Freundlich model; (Cu; $r^2 = 0.564$ for RYP and $r^2 = 0.871$ for AYP) and (Mn; $r^2 = 0.685$ for RYP and $r^2 = 0.736$ for AYP). Finally, optimum removal efficiencies of 30.54\% for Mn(II) and 39.62\% for Cu(II) were obtained for AYP at concentrations of 50mg/l and mass dosage of 1.0g, 120 minutes contact time and a pH of 6.8.

\textbf{Keywords}: Activated Yam Peel; Raw yam Peel; Adsorption; Cu; Mn; Kinetics; Isotherm

\textbf{1.0. Introduction}

Water is essential for life. All known forms of life depend on water, and water safe and suitable for drinking is called Potable Water. There is a lack of Potable water in Africa, most of our water is unsafe for consumption. An important step towards resolving this global crisis is to understand its magnitude of how many people lack access to safe drinking water and sanitation (WHO and UNICEF 2000). Despite widespread recognition of the importance of improved water and sanitation and heavy investment by international donors and governments in developing countries in extending water supply systems, more than half the population of rural areas still lack access to clean drinking water. Due to this distressed situation people in rural areas are forced to use traditional sources of water that are polluted (WHO and UNICEF 2000).

Contaminated drinking water and inadequate supplies of water for personal hygiene and poor sanitation are responsible for about 4 billion cases of diarrhoea each year that cause 2.2 million deaths, mostly among children under the age of five (WHO 2003) These waters are contaminated by metals which find their way into drinking water via industrial and consumer waste or from acidic rain, breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater. These metals, if found at high levels is detrimental to human health. Hence, there is a need for ways to improve our drinking water to make them safer for consumption.

There is an increasing need for the use of safer materials and eco-friendly materials to be used in the treatment process of our drinking water. This has given rise to the use of natural adsorbents from
agricultural waste materials which are highly effective in the treatment of waste water and drinking water especially in the removal of heavy metals (Badmus et al 2007). However, the availability of these materials for use as natural adsorbents is highly affected by seasonal variation. The use of rice husk, coconut shell, corn cobs, palm nut chaff among others are agricultural waste materials that have been used in the productions of adsorbents but are available in appreciable amount in the rainy season. Hence, the need to find adsorbents whose availability is not strongly affected by climate. This paper will therefore determine the potential of yam peels as natural adsorbents for removal heavy metals from water.

2.0. Materials and Methods

2.1. Equipment/Materials/Chemicals

Equipment, materials and chemicals used for this research work are presented as shown in Tables 1, 2 and 3.

Table 1: Equipment used

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Model</th>
<th>Manufacturer</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic Adsorption Spectrophotometer (AAS)</td>
<td>SOLAR 969</td>
<td>UNICAM SERIES</td>
<td>2010</td>
</tr>
<tr>
<td>Weighing Balance</td>
<td>Kern 001</td>
<td>England</td>
<td>2010</td>
</tr>
<tr>
<td>Hot Plate with Magnetic Stirrer</td>
<td>Jenway 6035</td>
<td>England</td>
<td>2010</td>
</tr>
<tr>
<td>Turbidimeter</td>
<td>DHG 9101-2A</td>
<td>Searchtech UK</td>
<td>2010</td>
</tr>
<tr>
<td>Scanning Electron Microscope (SEM)</td>
<td>APEX 3020</td>
<td>England</td>
<td>2010</td>
</tr>
<tr>
<td>Digital microprocessor pH meter</td>
<td>Hanna pH</td>
<td>England</td>
<td>2010</td>
</tr>
</tbody>
</table>

Table 2: Reagents used

<table>
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<th>Reagents Name</th>
<th>Grade</th>
<th>Minimum Assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Thiosulphate</td>
<td>Analytical grade</td>
<td>98%w/w</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>100% distilled</td>
<td>100% distilled</td>
</tr>
<tr>
<td>Elemental Copper</td>
<td>Analytical grade</td>
<td>95%w/w</td>
</tr>
<tr>
<td>Elemental Manganese</td>
<td>Analytical grade</td>
<td>95%w/w</td>
</tr>
<tr>
<td>Methylene Blue</td>
<td>Analytical grade</td>
<td>99%w/w</td>
</tr>
<tr>
<td>Iodine Solution</td>
<td>Analytical grade</td>
<td>99.5%w/w</td>
</tr>
<tr>
<td>Zinc Chloride</td>
<td>Analytical grade</td>
<td>97%w/w</td>
</tr>
</tbody>
</table>

Table 3: Materials used

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yam Peel</td>
<td>Yam by product</td>
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<tr>
<td>Sample Bottles</td>
<td>Marcaty Bottles</td>
</tr>
<tr>
<td>Funnels</td>
<td>Pyrex</td>
</tr>
<tr>
<td>Beakers</td>
<td>Pyrex</td>
</tr>
<tr>
<td>Reagent Bottles</td>
<td>Pyrex</td>
</tr>
<tr>
<td>Whatman Filter Paper</td>
<td>150mm diameter</td>
</tr>
</tbody>
</table>

2.2. Collection/Preparation of Adsorbent

Yam peels was collected from various homes and from Toseton Kitchen, a restaurant located at Benin-Lagos expressway. The peels were thoroughly washed with distilled water, dried and pulverized. Carbonization was done using the method recommended by (Ekpete et al. 2011) with slight
modification as follows. A predetermined weight of the pulverized sample was placed in a muffle furnace which allows limited supply of air at a temperature of 350°C for 30-60 minutes. The carbonized samples were then activated using the method recommended by (Ekpete et al. 2011) with slight modification as follows: 25g of the charred sample was soaked in 250ml of 5.5M ZnCl₂ solution. The mixture was thoroughly mixed until it formed a paste. The paste was then transferred to an evaporating dish which was placed in a furnace and heated at 200°C for thirty minutes. This was allowed to cool and washed with distilled water to remove the residue salt, oven dried at 105°C for one hour, grind using mortar and pestle and sieved with 0.6µm sieve. The activated carbon was then characterized for its particle sizes, moisture content, ash content, volatile matter, Methylene Blue number, (Badmus et al 2007). The raw Yam Peels followed the same process as that of the activated Yam Peel, except it wasn’t carbonized.

2.3. Performance of Activated Carbon

Some of the parameters used to characterize the performance of the activated carbon includes:

2.3.1. Determination of pH

The standard test method for determination of activated carbon pH given in (ASTM, D3838-80) was used. 1.0g of activated carbon was weighed and transferred into a beaker 50ml of distilled water was measured and added and stirred for two hours. The samples were allowed to stabilize before the pH was measured using a digital pH meter (Hanna pH 210 model). (Ekpete O.A, Horsfall M, Tarawou)

2.3.2. Determination of Iodine Number

In the determination of the Iodine Number, 10ml of 5% by weight HCl was added to 1g of activated carbon and was allowed to boil for 30 seconds. After the solution was cooled to room temperature, 100ml of 0.1N iodine solution was added. The content was shaken vigorously and filtered 25ml of the filtrate was titrated against 0.1N Sodium Thiosulphate using starch as indicator. The iodine number was defined as the quantity of iodine adsorbed in (mg/g carbon) as residual iodine concentration (ASTM, D4607-94).

2.3.3. Methylene Blue Number

The methylene blue number is defined as the maximum amount of dye adsorbed on 1.0g of adsorbent. In this method, 1g of activated carbon was placed in contact with 10.0ml of 25mg/l. Methylene blue solution for 24 hours at room temperature followed by intermittent shaking the solution was thereafter filtered using Whatman Number one filter paper and an aliquot solution was taken for analysis. The remaining concentration of Methylene blue was analyzed using an Atomic Adsorption Spectrophotometer. The amount of Methylene blue adsorbed was calculated using the mass balance equation:

\[ q = \frac{V}{m} [C_o - C_e] \]  

(1)

Where, q defines the metal uptake [mg/g], C₀ and C are the initial and equilibrium metal ion concentration in the wastewater [mg/l] respectively, V is the water sample volume (ml) and M is the mass of adsorbent used (g) (Cleiton et al 2011)

2.3.4. Moisture Content Determination

Thermal drying method was used in the determination of moisture content of the samples 1.0g of the dried activated carbon was weighed and placed in washed, dried and weighed crucible. The crucible was placed in an oven and dried at 105°C to constant weight for 1 hour. The percentage moisture content (%MC) was computed as follows (Rengaraj et al 2002):

\[ \text{Moisture Content (\%)} = \frac{\text{loss of weight on drying (g)}}{\text{initial weight of sample (g)}} \times 100 \]  

(2)
2.3.5. Surface Area, Micropore Volume and Total Pore Volume Estimation

The surface area, micropore volume and total pore volume of the activated carbon were estimated using the iodine and Methylene blue number. The iodine and Methylene blue numbers were determined using standard methods as described in 2.3.2 and 2.3.3 respectively. Data obtained were then analyzed using standard software (SCAC- Structural Characterization of Activated Carbon).

2.4. Preparation of Waste Water (Aqueous Solutions)

The metal stock solution was prepared by dissolving elemental copper of analytical grade in distilled water. The stock solution was diluted in distilled water to obtain concentrations ranging from 5 to 60mg/l.

2.5. Investigation of Adsorption Parameters

2.5.1. Effect of Adsorbent Dosage

This is one of the parameters that strongly affect the sorption phenomenon in the dose of the adsorbents. This may be due to the increase in availability of surface active sites resulting from the increased dose of the adsorbent (Saceed et al, 2005). Effect of adsorbent dose was investigated by varying weight of Activated Yam Peal (AYP) ranging from 0, 2, 4, 6, 8, 10 and 12g which were contacted with 50ml of the wastewater for an equilibrium adsorption time of 2 hours at a fixed adsorption temperature of 30°C.

2.5.2. Effect of Contact Time

The kinetic studies were performed to determine the adsorption rates of the adsorbent and the minimum contact time for adsorption. 12g of the adsorbent was contacted with 100ml of solution in each sample bottle at adsorption temperature of 34°C. The content was stirred using a magnetic stirrer for different increment of time ranging from 0, 20, 40, 60, 80, 100 and 120 minutes. Samples were collected at the different time intervals, filtered through Whatman No – 1 filter paper, and an aliquot solution was taken for analysis to determine the equilibrium concentration and the overall effects of contact time on the adsorption process.

2.6. Adsorption Efficiency

The impact of adsorption process was studied by monitoring the effects of adsorption on conductivity, dissolved oxygen, and amount of metal ion removed.

Conductivity/dissolved oxygen level were monitored before and after adsorption to evaluate the impact of adsorption process. The amount of heavy metal ions removed during the series of batch investigation was determined using the mass balance equation given by (Raghuvanshi et al 2004):

\[ q = \frac{v}{m} [C_o - C_e] \]  

(3)

Where, \( q \) defines the metal uptake [mg/g], \( C_o \) and \( C \) are the initial and equilibrium metal ion concentration in the wastewater [mg/l] respectively, \( V \) is the water sample volume (ml) and \( M \) is the mass of adsorbent used [g].

The efficiency of metal ion removal (%) was calculated using the following mass balance equation of the form (Badmus et al 2007):

\[ \text{Removal Efficiency} \% = \left( \frac{C_o - C_e}{C_o} \times 100 \right) \]  

(4)

Where \( C_o \) and \( C_e \) are the metal ion concentrations (mg/l) in the water sample before and after treatment respectively.
2.7. Adsorption Isotherm Studies

The adsorption isotherm indicates how the adsorbent molecules distribute themselves between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state to give a relationship between the amount of adsorbate removed and the amount remaining (Dawodu et al, 2012). The experimental isotherm data set obtained were fitted with Langmuir and Freundlich adsorption isotherm models to ascertain the equilibrium relationship between the amount of metal ion removed and the amount still left in solution. The applicability of the isotherm equations was compared by judging the correlation coefficient, \( r^2 \) (Ho, 2004)

2.7.1. Freundlich Isotherm Model

The general form of this isotherm is given as:

\[
q = k_f C \frac{1}{n}
\]

Where, \( q \) = Amount adsorbed (g), \( K \) = Freundlich capacity constant, \( C \) = Equilibrium concentration (ppm), \( 1/n \) =Freundlich intensity parameter.

A linear form of this expression is given as \([\log (q) = \log (K_r) + 1/n \log (C)]\) and values of \( K \) and \( n \) were calculated from the intercept and slope of the plot of \([\log (q) \text{ against } \log (C)]\) (Qadeer, 2004).

2.7.2. Langmuir Isotherm Model

Activation energy of the adsorption process was determined using Svant Arrhenius equation of the form:

\[
K = A e^{-\frac{E}{RT}}
\]

Where, \( K \) is the rate constant of the adsorption process, \( A \) is the frequency factor, \( R \) is the molar gas constant, \( T \) is the thermodynamic temperature and \( E \) is the value of the activation energy of the adsorption process

The linearized form of the equation is given as:

\[
\ln K = \ln A - \frac{E}{RT}
\]

A linear plot of \((\ln K_{ad})\) against \(1/T\) gives an intercept that is equal to \(\ln A\) and a slope that is equal to \(E/R\) from where the activation energy of the adsorption process can be determined (Raghuvaran et al 2004).

2.8. Adsorption Rate Constant

The rate constant of adsorption (\( K_{ad} \)) measures the time domain for the adsorption process, it is the time dependent study of adsorption process. The first order is constant for the adsorption of metal ion. The granular activated carbon was studied using the Lagergren equation (Ho, 2004)

\[
\log [q_e-q] = \log q_e - \frac{K_{ad}1}{2303} t
\]

Where \( (q_e \text{ and } q) \) = the amount of a specific metal ion adsorbed at equilibrium and at a time \( t \) respectively and \( K_{ad} \) = the rate constant for the adsorption of a specific metal ion.

2.9. Adsorption Kinetic Studies

Pseudo-first order, pseudo-second order and elovich kinetic model were applied in this research study to describe the reaction – controlled mechanism for the sorption of Cu and Mn ions.

2.9.1. Pseudo First Order Kinetic Model

The pseudo first- order rate expression of Lagergren based on the solid capacity is expressed as follows:
\[
\frac{dq}{dt} = K_t(q_e - q_t)
\]  
(9)

Where, \(q_e\) and \(q_t\) are the adsorption capacity at equilibrium and at time \(t\), respectively (mg/g). \(K_t\) is the rate constant of pseudo first-order adsorption (Langergren et al. 1898). After integration and applying boundary conditions \(t = 0\) to \(t = t\) and \(q_t = 0\) to \(q_t = q_t\), the integrated form of equation (7) becomes:

\[
\log [q_e - q_t] = \log [q_e] - \frac{K_{ad}t}{2.303}
\]  
(10)

Where, \(q_e\) and \(q_t\) = amount adsorbed at equilibrium and at time \((t)\) respectively, mathematically:

\[
\log [q_e - q_t] = \log q_e - \frac{K_{ad}t}{2.303}
\]  
(11)

Where, \(2.303\) [slope] = \(K_{ad}\)

The linear plots of \(\log [q_e - q_t]\) versus time \((t)\) showed the appropriateness of the above equation and subsequently the first order nature of the adsorption process involved (Langergren et al. 1898).

2.9.2. Pseudo second – order kinetic model

The pseudo-second order kinetic rate equation is expressed as:

\[
\frac{dq}{dx} = K_2 (q_e - q_t)^2
\]  
(12)

Where; \(K_2\)=the rate constant of pseudo – second order adsorption \((\text{g} \cdot \text{mg}^{-1} \cdot \text{min}^{-1})\)

For the boundary condition, \(t = 0\) to \(t = t\) and \(q_t = 0\), to \(q_t = q_t\), the integrated form of the above equation becomes:

\[
\frac{1}{q_e - q_t} = \frac{1}{q_e} + Kt
\]  
(13)

Which was the integrated rate law for a pseudo second order reaction, the above equation was rearranged to obtain the equation below:

\[
q_t = -\frac{1}{1 + \frac{t}{K_2q_e^2}}
\]  
(14)

This has a linear form;

\[
\frac{t}{q_t} = -\frac{1}{K_2q_e^2} + \frac{1}{q_e}(t)
\]  
(15)

If the initial sorption rate is \(h = Kq_e^2\), Then equation (12) and (13) becomes:

\[
q_t = \frac{t}{\frac{h}{q_e} + q_e}
\]  
(16)

The plot of \(\frac{t}{q_t}\) against \((t)\) gave a linear relationship from which \(q_t\) and \(K_2\) was determined from the slope and intercept of the plot (Ho, 2006).

3.0. Results and Discussions

3.1. Characterization of Activated Yam Peel (AYP)

Results from the characterization of AYP is presented in Table 4. It was observed that the pH of AYP was 6.8 which indicates an acidic condition. The moisture content was 9.8% which indicates dry yam peel. The surface area of 412m²/g was obtained after analysis of the data of the methylene blue value and iodine number of the AYP, using standard software (SCAC- Structural Characterization of Activated Carbon). Also, the total pore volume and micropore volume as presented in the table were 0.21±0.02mg/g and 0.13±0.02ml/g respectively. This indicates that AYP is a good adsorbent for metal ion removal.
Table 4 Physical Properties of Adsorbent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash Content (%)</td>
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</tr>
<tr>
<td>Moisture Content (%)</td>
<td>9.8</td>
</tr>
<tr>
<td>Total Pore Volume (mg/g)</td>
<td>0.21±0.02</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>456</td>
</tr>
<tr>
<td>Surface Area (m²/g)</td>
<td>412±45</td>
</tr>
<tr>
<td>Volatile Matter</td>
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</tr>
<tr>
<td>Mean Particle Size (mm)</td>
<td>0.106</td>
</tr>
<tr>
<td>pH</td>
<td>6.8</td>
</tr>
<tr>
<td>Methylene Blue Number</td>
<td>18</td>
</tr>
<tr>
<td>Micropore Volume (ml/g)</td>
<td>0.13±0.02</td>
</tr>
</tbody>
</table>

3.2. Adsorption Studies

3.2.1. Effects of Adsorbent Dose

Figures 1 and 2 illustrates the effect of adsorbent dosage on sorption efficiency for Cu(II) ions an Mn(II) ions. It was evident that the amount of metal uptake increases from 264mg/g to 1980.00mg/g for 0.2g and 1.2g respectively for Cu Using Activated Yam Peels and also the efficiency of the removal increases as the adsorbent dosages of both Cu and Mn increase. While an efficiency for Cu at a peak of 39.62% for Activated Yam Peel, the Raw Yam Peel gave an efficiency of 15.76%. Also for Mn, an efficiency of 29.60% was gotten for the Activated Yam Peels while the efficiency for Raw Yam peels was 14.75%.

3.2.2. Effects of Contact Time

The effects of time for the adsorption of Mn(II) and Cu(II) ions were studied between 20 and 120 minutes and the results obtained are as illustrated in figures 3 and 4. The maximum adsorption capacity observed at beforehand for any of the metals may be due to large number of vacant sites available, which later slowed down and may be attributed to exhaustion of remaining surface sites and repulsive force between the adsorbent and metal ions and possibility of impurities intervening in the solutions, thereby causing variations.

![Figure 1: Effect of Dosage on the Efficiency of Cu(II) removal onto Raw and Activated Yam Peels](image1)

Figure 1: Effect of Dosage on the Efficiency of Cu(II) removal onto Raw and Activated Yam Peels

![Figure 2: Effect of Dosage on the Efficiency of Mn(II) removal onto Raw and Activated Yam Peels](image2)

Figure 2: Effect of Dosage on the Efficiency of Mn(II) removal onto Raw and Activated Yam Peels
Figure 3: Effect of Contact time on the Efficiency of Cu(II) removal onto Raw and Activated Yam Peels

Figure 4: Effect of Contact time on the Efficiency of Mn(II) removal onto Raw and Activated Yam Peels

3.3. Adsorption Isotherm

Adsorption isotherm models are relevant in adsorption studies since they can be employed to determine the relationship between the adsorbent – adsorbate interaction in other to establish the potential of the adsorbent materials. To visualize the adsorbent – adsorbate relationship, experimental data obtained from the batch adsorption studies were analyzed using the empirical Langmuir and Freundlich isotherm models. Results obtained are presented in figures: 5, 6, 7, 8, 9, 10, 11 and 12 respectively.

Figure 5: Linearized Langmuir Isotherm for Cu adsorption onto Raw Yam Peels
Figure 6: Linearized Langmuir Isotherm for Cu(II) adsorption onto Activated Yam Peel

Figure 7: Linearized Langmuir Isotherm for Mn(II) adsorption onto Raw Yam Peels

Figure 8: Linearized Langmuir Isotherm for Mn(II) adsorption onto Activated Yam Peels

Figure 9: Linearized Freundlich Isotherm for Cu(II) adsorption onto Raw Yam Peels
From the results of Figure 5 and 6, an appreciable coefficient of determination (R²), appreciable difference was observed between the computed values or the coefficient of determination (R²). For Figure 5; R² was observed to be 0.680 while for Figure 6; R² was 0.758. The difference in the R² values can be attributed to the effect of activation on the performance of the yam peels as absorbent for copper ion removal. It shows therefore that activated yam peels possess better affinity for copper compared to raw yam peels. The higher affinity of activated yam peels towards copper removal was again established in the Freundlich isotherm plot as observed in Figure 9 and Figure 10 respectively. In Figure 9, computed R² value was observed to be 0.564 raw yam peels while for Figure 10 computed R² value was observed to be 0.871 for activated yam peels.
An overview of Figures 5, 6, 9, 10 revealed that Freundlich isotherm model had the highest value of $R^2$ in terms of Copper ion removal. The implication is that Freundlich isotherm model best explained the absorption of copper onto yam peels. Hence, in the task of predicting the absorption capacity of yam peels for copper ion removal, Freundlich isotherm model ranked better than Langmuir. The suitability of Freundlich isotherm model in predicting the absorption capacity of yam peels was further established in the absorption of Mg$^{2+}$ ions onto raw and activated yam peels as observed in Figure 11 and Figure 12 respectively. From the results of Figures 11 and 12, the computed $R^2$ value were observed to be 0.685 for yam peels and 0.736 for activated yam peels.

Comparative analysis of Figures 6, 7, 8, 9, 10, 11, and 12 revealed that activated yam peel performed better than the raw yam peels in terms of Cu$^{2+}$ and Mg$^{2+}$ ions removal. In addition, raw yam peels showed higher potential for Mg$^{2+}$ ion removal as observed in Figure 11 while activated yam peels has better potential for Cu$^{2+}$ ion removal as observed in Figure 10.

3.4 Kinetic Studies

Thus the adsorption of Cu(II) and Mn(II) onto raw and activated yam peel was best described by the Pseudo Second Order Kinetic model being that the value of $R^2$ is closer to one as illustrated in Figures 13, 14, 15, 16, 17 and 18.
Figure 15: Pseudo-second order kinetics plot of Cu(II) adsorption onto Raw Yam Peels

Figure 16: Pseudo-second order kinetics plot of Cu(II) onto Activated Yam Peels

Figure 17: Pseudo-second order kinetics plot of Mn(II) onto Raw Yam Peels
To understand the kinetic behavior and establish the reaction mechanism during the fixation of Cu²⁺ and Mg²⁺ ions onto the active sites of the raw and activated yam peels, absorption data obtained during the batch absorption studies were analyzed using selected reaction kinetic were model such as pseudo first order postulated by Lagargreen and Hoard McKay pseudo second order kinetic model as presented in Figures 13, 14, 15, 16 and 18 respectively.

Analysis of figures 13, 14, 15 and 16 respectively the absorption of Cu²⁺ ion onto raw and activated yam peels reveals that the adsorption of Cu²⁺ onto yam peels follows a pseudo-second order kinetic model with computed r² values of 0.991 for raw yam peels and 0.834 for activated yam peels. The implication is that, the rate limiting step for the absorption of Cu²⁺ onto yam peels is chemical reaction (chemisorptions) for which the reaction mechanism follows a pseudo second order kinetics.

For the absorption of Mg²⁺ onto raw and activated yam peels, as observed in Figures 17 and 18, it was also revealed that the controlling step for absorption process is the chemical reaction and the reaction mechanism follows the pseudo second order kinetic.

4.0. Conclusion

From the overall analysis of the results obtained, this study indicates that:

i) Yam peels which are cost effective and relatively easy can serve as better alternative to imported and highly expensive commercial activated carbon for Cu²⁺ and Mg²⁻ ion removal. The adsorptions of these metals were found to be dose and time dependent. The Optimum Conditions for the removal of these metals are initial Concentrations of 50mg/l and mass of 1.0 g this is where the efficiency is highest.

ii) Activated yam peels are better candidates for metal ion removal compared to raw yam peels hence there is need to always activate the absorbent before use.

iii) Freundlich isotherm model was the best model that explained the absorption of Cu²⁺ and Mg²⁺ ions onto raw and activated yam peels should be employed to determine the absorption capacity of yam peels as absorbent for wastewater treatment.

iv) The rate limiting step for the absorption of Cu²⁺ and Mg²⁺ onto raw and activated yam peel is chemical reaction (chemisorption) and the reaction mechanism follows the pseudo second order kinetic model.

References


Flood Vulnerability Mapping of Lagos Island and Eti-Osa Local Government Areas Using a Multi-Criteria Decision Making Approach

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ABSTRACT

This study discusses the assessment and analysis of areas vulnerable to flooding in Eti-Osa and Lagos Island Local Government areas of Lagos state, using Geographic Information System (GIS), LIDAR and spatial modelling techniques. These areas require quality assessment of their level of vulnerability to floods, in order to take adequate measures and develop programs that will help prevent the impacts of flooding. A set of indicators influencing flooding, which are elevation, slope, flow accumulation and land use, were identified and used in the study. A vulnerability scale of (1–3) was developed, where 1 represents ‘low’, 2 represents ‘moderate’ and 3 represents ‘high’. The indicators identified were reclassified in the vulnerability scale. The flood vulnerability maps, in three different case scenarios, were created using the weighted overlay of the reclassified indicators identified. The weights used are determined by a Pairwise comparison method (Analytical Hierarchical Approach (AHP)). The mapping method was implemented in ArcGIS environment. The vulnerability mapping results show that for a normal case scenario, 27.15% of the area have high vulnerability, 49.79% have moderate vulnerability and 23.06% have low vulnerability. However, for a worst-case scenario, 60.01% have high vulnerability, 37.71% have moderate vulnerability and 2.28% have low vulnerability. Buildings at risk and the extent of areas at risk were determined and relevant recommendations were made.

Keywords: Flooding, Mapping, Multi-criteria, GIS, Vulnerability assessment.

1.0. Introduction

Flood is one of the most devastating natural hazards that occur in our world. The occurrence of floods has claimed so many lives and has been of great concern to man. Flooding, which is a natural occurring phenomenon, has also led to the destruction of properties in the flood prone parts of the world, leading to major economic damages in such places. Although, flood hazard is natural, human modification and alteration of nature’s right of way can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas (Eludoyin et al., 2010). Over time some causes of flooding in most urban areas have been due to increase in population, blockage of channels as a result of bad waste disposal as well as human activities at flood plains. But in addition to having a knowledge of these causes, a precise location of areas that are vulnerable to flooding as well as their assessments is of great importance in preparing for and managing flood disasters.

Flood vulnerability mapping is considered to be the key component of the preparedness phase of any flood disaster management. It is carried out long before the occurrence of the flood events. This makes it an indispensable activity in the process of managing flood events because the flood vulnerability maps will depict the precise location of areas that are at risk of flood hazards. These areas depicted by the maps could be a natural environment, notable properties or simply a place where people live. With a precise knowledge of the spatial location of areas vulnerable to flood, activities such as early warning, flood forecasting, can be carried out to help prevent its occurrence or minimize its effects after such occurrences. This is now followed by a response and mitigation process that includes the assessment of damages that have occurred after such a flood event. These steps in managing flood disaster makes flood vulnerability mapping and assessment of great need in the preservation of the environment.
Vulnerability mapping can allow for improved communication about risks and what is threatened (Edwards et al., 2007). Hence, Spatial Information on areas vulnerable to flood in Lagos State, especially in the flood prone areas like the study area considered in this research project, (Eti-Osa and Lagos Island Local Government areas), is not adequately available and this information is required for the determination of the potential loss of lives and even physical infrastructures as well as the effect such losses will have on the lives of the people present. The provision of such spatial information in the form of maps is a key measure that should be taken in the reduction and possible prevention of the negative effects of flooding.

In some parts of Nigeria, various attempts and tools have been employed in the mapping of flood vulnerable areas. Ishaya et al., (2009) made use of Remote Sensing and GIS techniques in flood management with the goal of mapping areas vulnerable to flood hazard in Gwagwalada urban area. The data obtained were simply Topographic Map and Landsat TM image of 1991 and 2001 respectively. They were processed, scanned, digitized, interpolated, classified and overlaid using ILWIS GIS software modules to generate classified Land use/land cover map, Digital Terrain Map and Flood vulnerability map of the study area. The results obtained were vulnerability maps of the study area and a vulnerability assessment showing that areas lying along the banks of River Usama are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the town. Much of the area is built up and this gives rise to high vulnerability to flash flood hazard.

In the course of creating a small island Flood Vulnerability tool for Mauritius, Streefland (2013), paid close attention to local communities present in the study area. The aim of the research was to provide a tool that is simple and transparent in order to enable its use by third parties, such as decision and policy makers. In the study, a literature survey was conducted on indicators influencing flood vulnerability. These indicators were Slope, elevation, drainage density, land use and soil were identified. A vulnerability scale of 1 to 5 was developed, where 1 = extremely low flood vulnerability and 5 = extremely high flood vulnerability. The identified indicators were reclassified into the vulnerability scale. The flood vulnerability map was created through weighted overlay of the reclassified indicators. The weights were determined through a literature survey and pairwise comparison. The result showed that 52% of Mauritius is moderately vulnerable to floods, 28% of Mauritius has high flood vulnerability, 18% has low flood vulnerability, and both extremely high and extremely low flood vulnerability account for 1%. According to the study, the results provided can be used to assist decision makers on hazard mitigation, and compare different islands on the basis of their flood vulnerability. GIS applications in flood risk mapping range from storing and managing hydrological data to generating flood inundation and hazard maps to assist flood risk management (Evans et al., 2007).

The aim of this work is to map areas in Eti-Osa and Lagos Island Local Government areas of Lagos state that are vulnerable to flood, using GIS, LIDAR technology and advanced spatial analyses of features present in the areas. LIDAR (DEM), GIS and various input data indicators were used in the production and analyses of the level of vulnerability to flooding of features present in the study areas. It involved the use of ‘weighted overlay’ GIS tool to produce the vulnerability maps. The weights used in the cause of the weighted overlay process were determined using a Pairwise comparison method developed by Saaty (1970, 2008). It covers the production of flood vulnerability maps showing the precise locations of physical infrastructures and features that are at risk. It also involves typical vulnerability analyses that reveal the effect flooding has on the land uses.

1.1. The Study Area

The study area, Eti-Osa and Lagos Island local government areas (shown in Figure 1) are dynamic in nature. They are adjoining Local government areas both sharing boundaries on the North with Lagos Lagoon, which is the largest coastal lagoon in western Africa. Eti-Osa L.G.A. directly shares its boundary on the south with the Atlantic Ocean. Lagos Island Local Government area in Lagos is a densely-populated area in Lagos State. It has a land area of approximately 4.996 square kilometres. It is located within Latitude 6° 26’ 34” N and Longitude 3° 24’ 30” E on the left and Latitude 6° 27’ 38” N and Longitude 3° 22’ 42” E on the right. Lagos Island L.G.A. can be described as a place with a variety of land uses. It’s a notable commercial area but also has a mixture of residential and institutional land uses.
On the other hand, Eti-Osa Local Government area of Lagos state, Nigeria is located within Latitude 6° 26' 34'' N and Longitude 3° 24' 30'' E on the left and Latitude 6° 29' 04'' N and Longitude 3° 39' 09'' E on the right. It covers a land area of approximately 174.066 square kilometres and it is an area that consists of very high commercial activity in Lagos State.

1.2. The Pairwise Comparison Method of Weight Determination

The Analytic Hierarchy Process (AHP), introduced by Saaty (1980), is an effective tool that can be used to deal with making decisions that are complex in nature. It helps the decision maker to set priorities that will help in making the best decisions. Hence, what is required is to reduce the complex decision to a pairwise comparison, synthesize the results and make the best decision out of it. What AHP does is to consider a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. It generates a weight for each evaluation criterion according to the decision maker. This means that the higher the weight, the more important the corresponding criterion. Pairwise comparison on the other hand is a method that is used to compare indicators to one another based on their importance in a particular phenomenon or context of decision making. This makes it an indispensable part of a complete AHP decision making method. Pairwise comparison has been used in various aspects from individual to collective decision making. According to Saaty (2008), in order to make a decision in an organised way to generate priorities we need to decompose the decision into the following steps:

i. Define the problem and determine the kind of knowledge sought.
ii. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels.
iii. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it. In order to measure the relative importance between two criteria, a numerical scale from 1 to 9, suggested by Saaty (2008) should be used. This is represented in Table 1.
iv. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority.
v. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level is obtained.

But in this work, since we are more interested in determining the vector of weights for the various criteria, Kunz (2010) in his presentation on Analytic Hierarchy process provided the following steps to carry out the determination of weights, as follows:

i. Develop a single pairwise comparison matrix for the criteria
ii. Multiply the values in each row to get the product
iii. Normalize the aforementioned product to get the appropriate ‘nth’ weight; r and
iv. Calculate and check for the Consistency ratio (CR)
Table 1: The Fundamental Scale of Absolute Numbers (Source: Saaty, 2008)

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Definition Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Weak or slight importance</td>
<td>Experience and Judgement slightly favour one activity over another</td>
</tr>
<tr>
<td></td>
<td>Moderate importance</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moderate plus importance</td>
<td>Experience and judgement strongly favour one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Strong importance</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Strong plus importance</td>
<td>An activity is favoured very strongly over another; it’s dominance demonstrated in practice</td>
</tr>
<tr>
<td>6</td>
<td>Very strong or demonstrated</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very, very strong importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>8</td>
<td>Extreme importance</td>
<td></td>
</tr>
</tbody>
</table>

The procedure above provides the same results (weights) as that provided by Saaty (1980). As a matter of fact, Kunz (2010) presentation made reference to Saaty’s work. The consistency ratio CR is used to tell how consistent the pairwise comparison is. If CR < 0.1, the consistency ratio (CR) is tolerable, and a reliable result may be expected. RI is the Random Index, i.e. the consistency index when the entries of P are completely random. The values of RI for small problems (n ≤ 10) are given in Table 2.

Table 2: Values of the Random Index RI for Small Problems

<table>
<thead>
<tr>
<th>n</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.0</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.51</td>
</tr>
</tbody>
</table>

2.0. Materials and Methods

2.1. Data Acquisition

The data acquisition process covered all the methods applied in acquiring data for the project and their sources, it involved all the various methods used in obtaining the raw data used for the mapping process and the subsequent analyses to be carried out. The data acquired and their sources for the study are as follows:

i. LIDAR data (DEM) acquired in the year 2008, in classified text file format, covering a total of 241 tiles (a tile is 1 square kilometre) from the Office of the Surveyor General of Lagos State.

ii. Shapefile (Vector Data) of buildings (general infrastructure) covering most part of the study area for the year 2009 was obtained from the office of the Surveyor General of Lagos State.

iii. Landuse map covering the entire study area for the year 2002 from the ministry of Physical Planning, Lagos State.

iv. Landuse map covering the western part (Banana Island inclusive) of the study area, for the year 2011.

v. Global Positioning System (GPS) coordinates of flood prone locations (a total of 62 locations) in the study area.

2.2. Data Processing

The data processing involved the following:

i. The GPS positions for all locations prone to flooding were acquired from the field and a database was created for them.

ii. LIDAR data processing was carried out using Surfer 10 and a further processing mosaicking of the LIDAR tiles was carried out using ArcGIS 10.1 software package. A LIDAR DEM of 5m resolution was generated.

iii. The land use map acquired was vectorised using AutoCAD 2012 software and a composite land use map of the study area was produced using ArcGIS 10.1
iv. A criteria selection process was carried out and they were selected based on their relevance to the study. These criteria are considered to be indicators or factors that influence flooding. Four factors or indicators were considered in this study and they are given as follows:
   a) Elevation  
   b) Slope  
   c) Flow accumulation  
   d) Land use

v. Thematic raster maps were produced for each of the indicators using the Reclassification method as provided in the ArcGIS environment.

vi. Weights were determined for the indicators using a pairwise comparison method as provided by the Analytical Hierarchical Processing (AHP). A detailed process of this is given as follows.

2.3. Determination of Weights for the Indicators Influencing Flooding

2.3.1. Developing a Single Pairwise Comparison Matrix for the Criteria

In order to develop the pairwise comparison matrix, each of the indicators were compared to each other and a particular intensity of importance (a scale of 1 to 9, as shown in Table 1), was given each comparison. When comparing an indicator with itself, the scale attached is one (1). Hence all values in the diagonal are given as 1. But in the case of making comparisons in this study, the elevation data is considered to be the most important and the land use the least important. This is due to the availability and correctness of the data acquired. Vertical indicators are compared to the horizontal indicators. A higher mark indicates the indicators importance compared to the other indicator. Hence, the comparison matrix [which is a four by four (4 x 4) matrix] is as given in Table 3.

<table>
<thead>
<tr>
<th>Flow Accumulation</th>
<th>Slope</th>
<th>Elevation</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>1</td>
<td>1/2</td>
<td>1/4</td>
</tr>
<tr>
<td>Slope</td>
<td>2</td>
<td>1</td>
<td>1/4</td>
</tr>
<tr>
<td>Elevation</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Land use</td>
<td>1/3</td>
<td>1/3</td>
<td>1/5</td>
</tr>
</tbody>
</table>

From the matrix in Table 3, we see the amount of importance attached to each row and column of the matrix of indicators. Taking a look at the comparison of the slope with the flow accumulation, a flow accumulation is dependent on the slope of the terrain, hence slope is twice more preferred or important compared to flow accumulation. That is why in row 2 columns 1, the comparison value given is ‘2’ and in row 1 column 2 the value is ‘½’. This same process was applied in attaching the intensity of importance value to each comparison and adjustments were made until an acceptable consistency ratio was obtained. The matrix translates into Table 4 (with the values in decimals).

<table>
<thead>
<tr>
<th>Flow Accumulation</th>
<th>Slope</th>
<th>Elevation</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>1.000</td>
<td>0.500</td>
<td>0.250</td>
</tr>
<tr>
<td>Slope</td>
<td>2.000</td>
<td>1.000</td>
<td>0.250</td>
</tr>
<tr>
<td>Elevation</td>
<td>4.000</td>
<td>4.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Land use</td>
<td>0.333</td>
<td>0.333</td>
<td>0.200</td>
</tr>
</tbody>
</table>

2.3.2 Multiplying the Values in Each Row Together and Calculating the ‘Nth Root’ of Same Product

The values on the row are multiplied together and the nth root of their product is determined. In this case n = 4. The tabulated calculation is given in Table 5.
From Table 5, the values of the 4th root were calculated and the summation of these values is given to be 5.266. Hence, in order to obtain the weights or priority vector, nth root obtained has to be normalized.

2.3.3. Normalizing the ‘4th’ Root of Products to get the Appropriate Weight

In order to normalize the 4th root, each value of the 4th root obtained, is divided by the summation of the values obtained for the 4th root product (5.266). The normalization results obtained gives us the criteria weights for each indicator. The summation of the obtained criteria weights must be equal to 1. The criteria weights are shown Table 6.

Table 6: Obtaining the Criteria weights

<table>
<thead>
<tr>
<th>Indicator/Factor</th>
<th>4th Root of Product</th>
<th>Criteria Weight (Priority Vector)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>0.783</td>
<td>0.149</td>
</tr>
<tr>
<td>Slope</td>
<td>1.107</td>
<td>0.210</td>
</tr>
<tr>
<td>Elevation</td>
<td>2.991</td>
<td>0.568</td>
</tr>
<tr>
<td>Landuse</td>
<td>0.386</td>
<td>0.073</td>
</tr>
<tr>
<td>Total</td>
<td>5.266</td>
<td>1.000</td>
</tr>
</tbody>
</table>

2.3.4. Calculating and Checking for the Consistency Ratio (CR)

Since the consistency ratio serves as a way of checking how consistent our pairwise comparison was, its calculation is compulsory. Hence, in order to calculate for it, the following steps were followed:

i. The pairwise comparison values in each column were added together and each added value was multiplied by the respective weight.

ii. Next the results from the multiplication were then added together (see Tables 7 and 8).

Table 7: Summation of Pairwise Comparison Values

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criteria weight (w)</th>
<th>SUM PW</th>
<th>(SUM PW) X (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>0.149</td>
<td>7.333</td>
<td>1.090</td>
</tr>
<tr>
<td>Slope</td>
<td>0.210</td>
<td>5.833</td>
<td>1.226</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.568</td>
<td>1.700</td>
<td>0.966</td>
</tr>
<tr>
<td>Landuse</td>
<td>0.073</td>
<td>12.000</td>
<td>0.879</td>
</tr>
<tr>
<td>Total</td>
<td>5.266</td>
<td>1.000</td>
<td>x = 4.161</td>
</tr>
</tbody>
</table>
Table 8: Multiplying Criteria Weights (W) by Summation of Pairwise Comparison Values (SUM PW)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Flow Accumulation</th>
<th>Slope</th>
<th>Elevation</th>
<th>Land Use</th>
<th>4th Root of Product</th>
<th>Criteria weight (Priority vector)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>1.000</td>
<td>0.500</td>
<td>0.250</td>
<td>3.000</td>
<td>0.783</td>
<td>0.149</td>
</tr>
<tr>
<td>Slope</td>
<td>2.000</td>
<td>1.000</td>
<td>0.250</td>
<td>3.000</td>
<td>1.107</td>
<td>0.210</td>
</tr>
<tr>
<td>Elevation</td>
<td>4.000</td>
<td>4.000</td>
<td>1.000</td>
<td>5.000</td>
<td>2.991</td>
<td>0.568</td>
</tr>
<tr>
<td>Land use</td>
<td>0.333</td>
<td>0.333</td>
<td>0.200</td>
<td>1.000</td>
<td>0.386</td>
<td>0.073</td>
</tr>
<tr>
<td>SUM PW</td>
<td>7.333</td>
<td>5.833</td>
<td>1.700</td>
<td>12.000</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

After this the Consistency Index (CI), which is required for the direct determination of the consistency ratio, was calculated using the Equation given by Saaty (1990) and Kunz (2010):

\[ CI = \frac{(x - n)}{n - 1} \tag{1} \]

(Where \( n = 4 \) (number of criteria) and value of \( x = 4.161 \))

\[ CI = \frac{(4.161 - 4.000)}{4.000 - 1} \]

\[ CI = \frac{0.161}{3.000} = 0.054 \]

The value of CI is given as 0.054 and as earlier presented, a perfectly consistent decision maker should always obtain CI=0, but small values of inconsistency may be tolerated. Hence, the consistency ratio CR, which is used to tell how consistent the pairwise comparisons are, is given by (Saaty, 1990; Kunz, 2010) as:

\[ CR = \frac{CI}{RI} \tag{2} \]

The values of Random Index (RI) for small problems (\( n \leq 10 \)) are shown in Table 2. For this particular problem, RI is 0.9. Hence, the consistency ratio is given as follows:

\[ CR = \frac{0.054}{0.9} = 0.059 \]

The consistency ratio (CR) obtained is given as 0.059, and this value is less than 0.1. This shows that our pairwise comparisons carried out and criteria weights obtained are consistent and accurate respectively, for the decision-making process of producing a flood vulnerability map. Converting the weights to percentage values, we have the percentage influence of each indicator. This is presented in Table 9.

Table 9: Determining Percentage Influence for Each Indicator

<table>
<thead>
<tr>
<th>Factor (Flood Indicator)</th>
<th>Criteria Weight</th>
<th>Percentage Influence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>0.149</td>
<td>14.9</td>
</tr>
<tr>
<td>Slope</td>
<td>0.210</td>
<td>21.0</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.568</td>
<td>56.8</td>
</tr>
<tr>
<td>Land use</td>
<td>0.073</td>
<td>7.3</td>
</tr>
<tr>
<td>Total</td>
<td>1.000</td>
<td>100</td>
</tr>
</tbody>
</table>

Approximating the percentage values (which is required for the weighted overlay process in ArcGIS 10.1), we have the final percentage influence for each indicator in Table 10.
Table 10: Percentage influence as attached to each indicator in this project

<table>
<thead>
<tr>
<th>Factors (Flood Indicator)</th>
<th>Percentage Influence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accumulation</td>
<td>15</td>
</tr>
<tr>
<td>Slope</td>
<td>21</td>
</tr>
<tr>
<td>Elevation</td>
<td>57</td>
</tr>
<tr>
<td>Landuse</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

After the determination of the weights, the weighted overlay tool in ArcGIS was used to produce a final flood vulnerability raster maps which were then converted to polygonal features for analyses purposes. The flood vulnerability map was created in three different scenarios. The difference in the scenarios was the alteration of the elevation ranges in each of the scenarios. The elevation ranges used are given in Table 11.

Table 11: Elevation Ranges Differentiation for all three case scenarios

<table>
<thead>
<tr>
<th>Normal Scenario (Elevation Range)</th>
<th>Moderate Scenario (Elevation Range)</th>
<th>Worst Scenario (Elevation Range)</th>
<th>Description</th>
<th>Scale</th>
</tr>
</thead>
</table>

3.0. Results and Discussion

3.1. Results

Flood vulnerability maps were produced after executing the GIS based tool (model). These maps were created in three case scenarios. They are represented in Figures 2, 3 and 4.

Figure 2: Flood Vulnerability Map (Normal Case Scenario)

Figure 3: Flood Vulnerability Map (Moderate Case Scenario)
3.2. Analysis of Flood Vulnerability Maps

Typical analyses were carried out on the flood vulnerability maps for the three case scenarios. The area covered by the various flood vulnerability classes, which are the low vulnerability, moderate vulnerability and high vulnerability for the three scenarios were calculated using the calculate geometry in the ArcGIS 10.1 environment. The results are presented in Tables 12, 13 and 14. Histograms of the flood vulnerability using the three case scenarios are presented in Figures 5, 6 and 7.

Table 12: Flood Vulnerability Analyses (Normal Case Scenario)

<table>
<thead>
<tr>
<th>Vulnerability Level</th>
<th>Area (Sq. Km)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>41.545</td>
<td>23.061%</td>
</tr>
<tr>
<td>Moderate</td>
<td>89.700</td>
<td>49.792%</td>
</tr>
<tr>
<td>High</td>
<td>48.904</td>
<td>27.146%</td>
</tr>
</tbody>
</table>

Table 13: Flood Vulnerability Analyses (Moderate Case Scenario)

<table>
<thead>
<tr>
<th>Vulnerability Level</th>
<th>Area (Sq. Km)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>14.003</td>
<td>7.773%</td>
</tr>
<tr>
<td>Moderate</td>
<td>76.027</td>
<td>42.202%</td>
</tr>
<tr>
<td>High</td>
<td>90.117</td>
<td>50.024%</td>
</tr>
</tbody>
</table>

Table 14: Flood Vulnerability Analyses (Worst Case Scenario)

<table>
<thead>
<tr>
<th>Vulnerability Level</th>
<th>Area (Sq. Km)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>4.099</td>
<td>2.275%</td>
</tr>
<tr>
<td>Moderate</td>
<td>67.938</td>
<td>37.712%</td>
</tr>
<tr>
<td>High</td>
<td>108.110</td>
<td>60.012%</td>
</tr>
</tbody>
</table>
From Figures 5, 6 and 7, we can see that there is an increase in the percentage of coverage of the high vulnerable areas. This poses a threat to the features present in the study area. With a percentage of 60.012% of the study area being vulnerable to flooding in the worst-case scenario, this poses a high threat to the people and lives present in the study area should a severe flooding situation occur. This will lead to a high physical and environmental impact on the infrastructure and people present in the environment.

3.3. Flood Vulnerability Assessment on the Building

Flood vulnerability assessments were carried out on the building features (structures provided), and this was to ascertain their level of vulnerability. Selections were made based on their locations on the flood vulnerable map, using the ‘Select by Location tool’. This provided a selection of all buildings that were vulnerable and their level of vulnerability were analysed based on the building use. The results provided are for the normal case scenario and they are presented in Tables 15, 16 and 17.
Table 15: Buildings with low flood vulnerability (Area in square meters)

<table>
<thead>
<tr>
<th>Building Use</th>
<th>Area (Sq. Meters)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Commerce</td>
<td>385611.464</td>
<td>6.199</td>
</tr>
<tr>
<td>Industrial</td>
<td>148321.923</td>
<td>2.385</td>
</tr>
<tr>
<td>Institutional</td>
<td>426519.431</td>
<td>6.857</td>
</tr>
<tr>
<td>Other Uses</td>
<td>1768.240</td>
<td>0.028</td>
</tr>
<tr>
<td>Recreational</td>
<td>100.065</td>
<td>0.002</td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>5257854.766</td>
<td>84.529</td>
</tr>
</tbody>
</table>

Table 16: Buildings with moderate flood vulnerability (Area in square meters)

<table>
<thead>
<tr>
<th>Building Use</th>
<th>Area (Sq. Metres)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Commerce</td>
<td>802891.3659</td>
<td>6.373</td>
</tr>
<tr>
<td>Industrial</td>
<td>50032.06801</td>
<td>0.397</td>
</tr>
<tr>
<td>Institutional</td>
<td>1421837.220</td>
<td>11.287</td>
</tr>
<tr>
<td>Other Uses</td>
<td>17858.86543</td>
<td>0.142</td>
</tr>
<tr>
<td>Recreational</td>
<td>39193.76022</td>
<td>0.311</td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>10265656.610</td>
<td>81.490</td>
</tr>
</tbody>
</table>

Table 17: Buildings with high flood vulnerability (Area in square meters)

<table>
<thead>
<tr>
<th>Building Use</th>
<th>Area (Sq. Meters)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Commerce</td>
<td>802891.366</td>
<td>6.373</td>
</tr>
<tr>
<td>Industrial</td>
<td>50032.068</td>
<td>0.397</td>
</tr>
<tr>
<td>Institutional</td>
<td>1421837.220</td>
<td>11.287</td>
</tr>
<tr>
<td>Other Uses</td>
<td>17858.865</td>
<td>0.142</td>
</tr>
<tr>
<td>Recreational</td>
<td>39193.760</td>
<td>0.311</td>
</tr>
<tr>
<td>Residential/Commercial</td>
<td>10265656.610</td>
<td>81.490</td>
</tr>
</tbody>
</table>

Table 15, Table 16 and Table 17 show that the residential/commercial buildings are the highest in vulnerability for all levels. This is due partly to the nature of the study area and the classification of the buildings based on the land use maps produced in this study. However, the results show that residential and commercial areas are mostly affected by flood. The vulnerability level to flood, for the institutional areas had an increase in percentage from the low to the moderate level of vulnerability.

4.0. Conclusions and Recommendations

4.1. Conclusion

The results and information generated from this study using LIDAR data, remote sensing techniques and GIS analyses have demonstrated that it is possible to effectively produce flood vulnerability maps at various levels (low, moderate and high vulnerability levels) as well make predictions as regards flooding in the study area. Desired analyses and inferences may also be carried out at whatever time they are required. After the production of the vulnerability maps and GIS analyses, the results provided serve to show the level of risk of flooding and the extents to which these areas and the people present in it are vulnerable. Major areas such as Dolphin Estate, Sura as well as Idumagbo, which are areas in Lagos Island, are highly at risk.

In conclusion, the use of remotely sensed data, flood modelling as well as Geospatial information system (GIS), has effectively demonstrated and initiated the aim of mapping areas that are vulnerable to flooding. These tools have been able to reveal areas at risk to flooding that need critical attention,
like the major areas in Lagos Island local government areas earlier mentioned, as well as other relevant information that will aid in a better monitoring and management of the study areas as regards to flooding, now and in the future. It is therefore compulsory that care must be taken though to ensure that the data gathered for such studies are accurate, so as to produce precise results, from which effective policies, laws and other regulations will be implemented.

5.1. Recommendations

The following recommendations are made:

i. The quality of data, maps produced as well as the modelling process carried out will be of great importance in the proper handling and management of flooding in Eti-Osa and Lagos Island.

ii. This project may be adopted and used as a source for planning and management in the study area and indeed in other administrative capacities.

iii. The development of good policy and proper planning with the results obtained from this study will go a long way in reducing flooding occurrences as well as help in the control and management of such occurrences in the study area.

iv. Proper data provision, updating and management for such studies should be carried out. This will ease the execution of such studies more frequently, thereby providing up to date information at various times.

v. Proper flood warning systems should be put in place for the study area for flood monitoring processes.

References


Van Western, C.J., and Hosfstee, F., (2000). The role of remote sensing and GIS in risk mapping and damage assessment for disasters in urban areas. Fernerkundung und Naturkatastrophen, pp. 442-450
Biodegradation Potentials of Bacterial Isolates from Auto-Mechanic Workshops in Oluku, Edo State, Nigeria

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ABSTRACT

The frequent discharge of used petroleum products from automobiles has become a major source of concern due to unguided discharge into the soil environment, hence the need for biodegradation of the products. Bacterial species were isolated from contaminated soil in mechanic workshops and screened for their hydrocarbon degradation potentials using standard microbiological procedures. Physicochemical properties of the contaminated soil were also analysed using standard techniques. The highest and lowest heterotrophic bacterial counts of $2.82 \pm 0.16 \times 10^8$ and $2.09 \pm 0.32 \times 10^8$ cfu/g were from the control soil and site 1 respectively. For hydrocarbon utilizing bacterial, Site 2 had the highest load of $8.33 \pm 2.55 \times 10^5$ while the control had the least $1.35 \pm 0.33 \times 10^4$ cfu/g. The bacterial isolates from the contaminated soil were found to be Corynebacterium kutsceri, Escherichia coli, Bacillus licheniformis, Bacillus subtilis, Bacillus megaterium, Klebsiella oxytoca, Staphylococcus aureus, Pseudomonas aeruginosa and Micrococcus luteus. The highest and lowest in the frequency of occurrence among the isolates were B. subtilis (27.5 %) and E. coli (1.4%) respectively. The screened hydrocarbon utilizing bacterial isolates were C. kutsceri, B. subtilis and P. aeruginosa. The ability to degrade crude oil revealed that bacterial consortium had the highest growth profile of $12.90 \times 10^5$ while the least was C. kutsceri with values of $8.20 \times 10^5$ cfu/g. The consortium bacteria had the highest percentage of hydrocarbon products degradation. The ability of the consortium bacteria to remove a high percentage of crude oil components makes it potentially useful for bioremediation of site highly contaminated with petroleum hydrocarbon.

Keywords: Bacteria, crude oil, mechanic workshops and contaminated soil

1.0. Introduction

With an over increasing world population, petroleum products are extensively used all over the globe that apparently have strong connection to environmental pollution due to hydrocarbon discharge (Bidoia et al., 2010). Petroleum spillage occurs from several causes such as, leakages from pipelines and storage tanks, waste disposal, blowout, accidental spills through transportation and uses (Obayori et al., 2014). Environmental pollution by petroleum products remain an unavoidable consequence of oil exploitation, transportation and distribution activities. Petroleum and its products toxicity on contaminated soil, depends on their concentration, composition, environmental factors and biological state of the organisms at the time of contamination (Eze et al., 2014).

The Nigerian environment is known for indiscriminate, nonchalant and highly unregulated petroleum products disposal (Odjegba and Sadiq, 2000), causing a decline in soil quality. Mechanic workshop often dispose-off used oil into open grounds, from where it finds its way into canals, drainages and underground water (Obayori et al., 2014). It may be of interest to note that small amount of petroleum hydrocarbon released into aquifers could results to concentrations of dissolved hydrocarbons which exceed regulatory limits (Spence et al., 2005). Also, exposure of petroleum hydrocarbons for a long time can cause liver or kidney disease, damage to bone marrow and high risk of cancer (Lloyd and Cackette, 2001). To overcome the environmental risk associated with petroleum and its products, research is now geared toward remediating the contaminated soil.

Oshoma et al., 2017

256
Indiscriminate discharge of used petroleum products from vehicles is a source of pollution in mechanic workshops and its environs. Hence, the need for a concerted effort in studying the feasibility of using oil degrading bacteria for remediation. Okon (2006) advocated for biological remediation of petroleum contaminated soil due to the negative consequences of physicochemical approaches. Bioremediation of petroleum by natural population of microorganisms is one of the effective mechanisms of reclaiming soil and aquifers. The clean-up of hydrocarbon by this approach is very attractive because it is easy to maintain, applicable over a large area, cost effective and destruction of the contaminant (Bento et al., 2005). A wide range of bacteria and fungi have been implicated to exhibit the ability to degrade or utilize hydrocarbon as substrates (Challian et al., 2004; Ekhave and Nkwelle, 2011).

Mechanic workshops used various petroleum products such as engine oil, diesel and kerosene on daily bases. The disposal of these products results in hardening or change in the texture of the soil, which has an effect on the microbiological and physicochemical quality of the contaminated soil. Hence, in view of the high number of mechanic workshops and their unguided disposal of used petroleum products into the environment, there lies the need to ameliorate the environmental risk associated with these products. Therefore, this investigation aims at assessing the potential of hydrocarbon degrading bacterial isolates from contaminated soil in mechanic workshops.

2.0. Materials and Methods

2.1. Study Area and Soil Sample Collection

The study areas were two auto mechanic workshops located at Site 1 and Site 2 within Ovia North East Local Government area, Edo State. Soil samples within these areas were collected into sterile polyethene bags using a soil auger at a depth of 0 – 15 cm. The samples were immediately transported to the laboratory for microbiological and physicochemical analysis.

2.2. Isolation and Enumeration of Bacteria

A 10 grams of contaminated soil sample was suspended in 90 ml of sterile distilled water in a conical flask. The soil suspension was thoroughly mixed and 10 fold serial dilution was carried out. Using pour plate technique, 0.1 ml from the dilutions were plated in duplicates on sterile Nutrient agar (NA), amended with Nystatin to discourage fungi growth, for total heterotrophic bacterial counts. The NA plates were incubated aerobically at 37 °C for 24 – 48 h. The number of viable cells in the samples were calculated from the colonies formed, inoculum size and dilution factor, then expressed as colony forming unit per gram (Cain et al., 2013).

2.3. Enumeration, Characterization and Identification of Hydrocarbon Utilizing Bacteria (HUB)

This involved cultivation of hydrocarbon degraders in minimal salt medium (with crude oil as carbon source). Minimal salt medium was prepared according to the composition formulated by Mills et al. (1978) as modified by Okpokwasili and Okorie (1988). One gram (1.0 g) of the oil contaminated soil sample was dissolved in test tubes containing 9 ml of sterile MSM and serially diluted (10-fold) using MSM as diluent. An aliquot (0.1 ml) of the dilutions was plated out in duplicate under aseptic condition using pour plate technique in the modified minimal salt agar (MSA) with 1 % crude oil as carbon source, incorporated with 0.5 ml Nystatin solution. The plates were incubated at 37 °C for 5 days.

After incubation, HUBs were enumerated, colonies of bacteria grown on the agar plates were counted, isolated, purified by streaking on NA plates and stored on NA slants for cultural characterization and identification. The bacterial isolates were characterised and identified on the basis of taxonomic schemes published in Bergey’s manual of Determinative Bacteriology (Holt et al., 1994). Bacterial isolates were characterised on the basis of their cultural, morphological and biochemical characteristics. The identified isolates were maintained on NA slants at 4 °C for further studies.
2.4. Screening of Isolated Bacterial for Utilization of Hydrocarbon

Degradation potential of HUB was screened according to the modified method of Hanson et al. (1993); Bidoia et al. (2010) using 2,6- dichlorophenol indophenol (DCPIP) as redox indicator. Minimal salt medium (MSM) (100 ml) was transferred into 250 mL Erlenmeyer flasks and sterilized at 121 °C for 15 min. After cooling, 1 % of blended crude oil, filter sterilized, was added and 0.55 w/v DCPIP as redox indicator. The bacterial isolates of 1 ml was inoculated, incubated at 28±2 °C for 144 h on a Gyrator Shaker at a speed of 180 rpm. One of the flask was uninoculated and served as the control. The flasks were monitored daily for colour change (from deep blue to colourless). Absorbance of all the assays was measured using UV visible Spectrophotometer (model 752), at an optical density of 600nm, to test for degradation ability of the isolates.

2.5. Biodegradation Potentials of Screened Isolation

The bacterial isolates which had scored the most reduced optical density during the screening test were used for degradation of crude oil. Time-course degradation of the crude oil was carried out in MSM according to the method of Mills et al. (1978) as modified by Okpokwasili and Okorie (1988). The medium was supplemented with 1 % crude oil and inoculated with overnight culture of isolates according to Ekhaiase and Nkwelle (2011) method. All the flasks were incubated at 28±2 °C in a Gyratory shaker at 150 rpm and monitored for a period of 15 days. The bacterial growth was monitored using pour plate technique on a nutrient agar plates. After incubation period, residual oil components concentrations were determined by Gas chromatography.

2.6. Physicochemical Parameter Determination of Soil Samples

Several physical and chemical properties of soil samples were evaluated. Soil sample pH was determined in 1:1 soil/water suspension ratio using pH meter (Jenway 3051) as described by Cowan and Steel (2004). The conductivity and sulphate content were determined according to the method of Onojake and Osuji (2012). Available phosphorous, nitrogen, exchangeable cations (Na+, K+, Ca2+ and Mg2+) and total hydrocarbon content (THC) were determined using the procedures stated by Akpoveta et al. (2011). The chloride content was determined using titrimetric procedure while total organic carbon (TOC) was by chronic acid titrimetric method of Eze et al. (2014). Heavy metal contents Fe2+, Mn2+, Pb2+, Zn2+ and Ni2+) were analysed by atomic absorption spectrophotometer (Alpha 4 AAS) after digestion of sample with nitric acid and distill water.

3.0. Results and Discussion

Degradation of petroleum components by microorganisms is possible due to the presence of enzymes secreted by them. The complex hydrocarbons can be degraded by those microorganisms which possess high enzymatic activities (Alexander, 1994). The heterotrophic bacterial (THB) counts showed that the soil (both contaminated and uncontaminated) contained bacteria. The highest and lowest bacterial load of 2.82 ± 0.16 ×10^8 and 2.09 ± 0.32 ×10^8 cfu/g was observed in the control and site 1 respectively. For the case of the hydrocarbon utilizing bacterial (HUB), site 2 had the highest load of 8.33 ± 2.55 ×10^5 while the control site had the lowest load of 1.35±0.33× 10^4 cfu/g (as seen in Table 1). Higher bacterial counts were observed in uncontaminated soil than the auto-mechanic workshop soil contaminated with petroleum products. Possible reason could be due to non-exposure of soil to petroleum products which did not distort the physicochemical and biological properties of this soil. The low bacterial counts in the mechanic workshops may be due to inability of some organisms to tolerate high concentration of the petroleum products in these environments. Same effect was observed in the report of Stephen et al. (2013).

The increase in HUB count from the mechanic workshop soil than the uncontaminated soil could be that these organisms have developed resistance effect against the hydrocarbon products found in the soil. It could also be a reflection of the soil microflora ability to strive and proliferate in these environments, despite the deliberate exposure of soil to varying dose of petroleum products (Selvakumar et al., 2014). The bacterial isolates from the contaminated soil were found to be...
**Corynebacterium kutsceri, Escherichia coli, Bacillus licheniformis, Bacillus subtilis, Bacillus megaterium, Klebsiella oxytoca, Staphylococcus aureus, Pseudomonas aeruginosa and Micrococcus luteus** as shown in Table 2. The highest in the frequency of occurrence among the isolates was *B. subtilis* (27.5 %) while *E. coli* had the lowest percentage occurrence of 1.4 %. The identified bacterial isolates have also been reported by various authors as the most predominant hydrocarbon degrading bacterial (Rahman *et al*., 2002; Selvakumar *et al*., 2014; Mbachu *et al* 2014). These bacterial identified had wide spread in the soil and can easily degrade hydrocarbon. The dominance of *B. subtilis* on the crude oil polluted soil may be due to the ability to produce spores which may shield them from the toxic effect of the hydrocarbon.

Table 1: Total Heterotrophic Bacterial (THB) and Hydrocarbon Utilizing Bacterial (HUB) Counts of Soil Samples Collected

<table>
<thead>
<tr>
<th>Area</th>
<th>THB (×10^8 cfu/g)</th>
<th>HUB (cfu/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>2.09 ± 0.32</td>
<td>4.07 ± 1.10 × 10^5</td>
</tr>
<tr>
<td>Site 2</td>
<td>2.33 ± 0.48</td>
<td>8.33 ± 2.55 ×10^5</td>
</tr>
<tr>
<td>Control</td>
<td>2.82 ± 0.16</td>
<td>1.35±0.33× 10^4</td>
</tr>
</tbody>
</table>

Table 2: Frequency of Occurrence (%) of HUB Isolates from the Soil Samples Collected from Mechanic Workshop

<table>
<thead>
<tr>
<th>Bacterial Isolates</th>
<th>% frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Corynebacterium kutsceri</em></td>
<td>7.2</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>1.4</td>
</tr>
<tr>
<td><em>Bacillus licheniformis</em></td>
<td>17.4</td>
</tr>
<tr>
<td><em>Bacillus subtilis</em></td>
<td>27.5</td>
</tr>
<tr>
<td><em>Bacillus megaterium</em></td>
<td>11.6</td>
</tr>
<tr>
<td><em>Klebsiella oxytoca</em></td>
<td>10.1</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>4.3</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>13.0</td>
</tr>
<tr>
<td><em>Micrococcus luteus</em></td>
<td>7.2</td>
</tr>
</tbody>
</table>

Redox indicator is a common means of measuring hydrocarbon utilizing bacteria in a contaminated environment (Bidoia *et al*., 2010). Screening of bacteria capable of utilizing crude oil as a sole carbon source is by the use of DCPIP. This a rapid and low cost procedure (Selvakumar *et al*., 2014). The ability of bacteria to utilize crude oil was ascertain by mainly colour change observation of DCPIP, where we have the quantified decolouration time indicating the best strain for crude oil degradation (Bidoia *et al*., 2014). The ability of bacterial isolates to utilize crude oil was screened as shown in Table 3. The isolates that decolourized DCPIP in the shortest time were used for the growth profile test. The isolates were found to *C. kutseri, B. subtilis* and *P. aeruginosa* with an OD values of 0.207, 0.140 and 0.187 respectively. All the bacterial isolates had the ability to grow on crude oil as their sole carbon source and energy when screened for crude oil utilization. Amazingly, same genera of bacterial have been implicated in hydrocarbon utilization, mostly Bacillus and Pseudomonas spp, by many authors (Oboh *et al*., 2010; Selvakumar *et al*., 2014; Sebiomo *et al*., 2011; Ekhaise and Nkwelle, 2011).
Table 3: Screening of Bacterial Isolates for Crude Oil Utilization Potentials

<table>
<thead>
<tr>
<th>Bacterial Isolates</th>
<th>Observed Colour Change</th>
<th>OD at 600 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corynebacterium kutsceri</td>
<td>Colourless after 96 h</td>
<td>0.207</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>Blue after 144 h</td>
<td>0.348</td>
</tr>
<tr>
<td>Bacillus licheniformis</td>
<td>Colourless after 120 h</td>
<td>0.212</td>
</tr>
<tr>
<td>Bacillus subtilis</td>
<td>Colourless after 48 h</td>
<td>0.140</td>
</tr>
<tr>
<td>Bacillus megaterium</td>
<td>Colourless after 96 h</td>
<td>0.280</td>
</tr>
<tr>
<td>Klebsiella oxytoca</td>
<td>Colourless after 96 h</td>
<td>0.220</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>Colourless after 120 h</td>
<td>0.290</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>Colourless after 48 h</td>
<td>0.187</td>
</tr>
<tr>
<td>Micrococcus luteus</td>
<td>Light blue after 144 h</td>
<td>0.513</td>
</tr>
</tbody>
</table>

Figure 1 shows growth profile of the bacterial isolates screened during the utilization of crude oil. Increase in growth over a period of 15 days showed the bacteria to utilize hydrocarbon as their sole carbon source. However, the highest growth profile on day 15 was found to be the consortium of the three bacteria, next was *B. subtilis* while the least was *C. kutsceri* with values of $12.90 \times 10^5$, $8.20 \times 10^5$ and $7.60 \times 10^5$cfu/g respectively. Eze et al. (2014) reported that soil environments contaminated with hydrocarbon are likely to contain microbial populations of diverse taxonomic characteristics capable of degrading the pollutant. Degradation of macromolecules in the contaminant to smaller molecules is influenced by range of useful enzymes expressed by the microorganisms that help in breaking down or decomposition of contaminant. The growth profile revealed no distinct lag phases exhibited by the bacterial isolates and their consortium. The increase in bacterial population of the crude oil degraders could be due to the fact that there is available nutrient supplied by the oil for their growth (Akpoveta et al., 2011). The crude oil served as sole carbon and energy sources to the bacteria.

The percentage removal of hydrocarbon components by the bacterial isolates is shown in Figure 2. The consortium of the three bacteria had the highest percentage hydrocarbon removal and the least was *C. kutsceri* with value 89.67 and 57.25% respectively. The utilization of hydrocarbon help the organism to increase in cell number with a concomitant decrease in hydrocarbon concentration during the incubation period (Sebiomo et al., 2011). This observation agreed with the work of Sebiomo et al. (2011) that the ability of microorganisms to grow in crude oil indicate effective hydrocarbon degradation potential. Worthy of note is that all the bacterial isolates were resident of the polluted environment hence, their biodegradation ability to the contaminants. For a complete removal of pollutant, biodegradation has been proven to be the best form. This potential should be improve in order to develop a faster means of clean-up of contaminated soil. The success of remediating polluted environment depends on microorganisms in close physical contact with the crude oil degrade. Therefore, to optimize biodegradation rate is to improve the growth rate of microflora that are indigenous to the soil. On a final analysis, the best way for successful removal/clean-up of pollutant is to increase the rate of biodegradation potentials of indigenous bacteria found in the contaminated soil. Based on the crude oil utilization capacity, the consortium is the most active degrader in the oil. This is suggestive of a synergistic relationship among individual members of the consortium that might have invariably boosted the degradative potential of the bacterial consortium (Ghazali et al., 2004).

While in this study, high percentage crude oil components were removed by the microorganisms,
insignificant value of 3% of the crude oil components was removed from the control medium. This could be influenced by physical factors such as run-off, flood and leaching, evaporation and photo-oxidation (Malik and Ahmed, 2011).

Figure 1: Total bacterial growth profile of the screened isolated and its consortium during the degradation of 1% crude oil.

Figure 2: Percentage removal of 1% crude oil components by bacterial isolates and its consortium after 15 days incubation. TAH, Total aliphatic hydrocarbon; PAH, Polycyclic aromatic hydrocarbon and TPH; Total petroleum hydrocarbon

The physicochemical properties of the soil samples showed varying values of the parameters analysed. The physicochemical parameters conducted on the oil polluted soil and oil free soil samples are shown in Table 4. The pH of the contaminated soil site 1 was more acidic than site 2 and control with values 6.143, 6.233 and 7.160 respectively. However, there was no statistical difference in pH (p > 0.05). The polluted sites had the highest electric conductivity, heavy metals and total organic carbon than the
control soil. pH of the contaminated soil was found to be acidic. The low pH may be due to increased degradation of crude oil by the organisms in the soil, resulting in accumulation of acidic metabolites (Ijah and Abioye, 2003). Phosphorus and sulphate were higher in the contaminated than the control soil. Phosphorus availability for microorganisms in the soil may be restricted by its tendency to precipitate in the presence of certain metals such as Ca$^{2+}$, Mg$^{2+}$ and Fe$^{2+}$. Increase in sulphate content can be attributed to the fact that there is continual replacement after being removed from soil (Eze et al., 2014). Nitrogen is an essential component of protein and nucleic acid. In most living being, nitrogen is taken up as assimilable nitrogen. Nitrogen can be lost from soil because some species of bacteria convert nitrate to gaseous nitrogen by using nitrate as a metabolic electron acceptor in place of oxygen (Nester et al., 2001). There was high level of electric conductivity in the polluted soils than the control soil, probably due to the presence of ions from the hydrocarbon introduced into the soil (Onojake and Osuyi, 2012). The high total organic carbon of the contaminated soil may be as a result of continuous released of the product into the soil. Same effect was found for THC, this could be a direct consequence of the unregulated discharged of petroleum products to the receiving soil.

Table 4: Physicochemical Properties of the Soil Samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.160 ± 0.071</td>
<td>6.143 ± 0.203</td>
<td>6.233 ± 0.493</td>
</tr>
<tr>
<td>Electric conductivity (uS/cm)</td>
<td>28.667 ± 2.136</td>
<td>84.400 ± 9.322</td>
<td>81.800 ± 10.652</td>
</tr>
<tr>
<td>Total organic carbon (%)</td>
<td>1.277 ± 0.177</td>
<td>3.047 ± 0.307</td>
<td>2.733 ± 0.421</td>
</tr>
<tr>
<td>Phosphorus (mg/kg)</td>
<td>1.953 ± 0.189</td>
<td>3.483 ± 0.142</td>
<td>5.303 ± 0.273</td>
</tr>
<tr>
<td>Total nitrogen (mg/kg)</td>
<td>0.677 ± 0.015</td>
<td>0.057 ± 0.009</td>
<td>0.040 ± 0.006</td>
</tr>
<tr>
<td>Total hydrocarbon content (mg/kg)</td>
<td>55.127 ± 1.213</td>
<td>202.530 ± 3.514</td>
<td>286.170 ± 2.892</td>
</tr>
<tr>
<td>Sulphate (mg/kg)</td>
<td>0.180 ± 0.46</td>
<td>0.323 ± 0.035</td>
<td>0.817 ± 0.084</td>
</tr>
<tr>
<td>Cation exchange capacity (mg/kg)</td>
<td>2.686 ± 0.283</td>
<td>7.569 ± 1.179</td>
<td>5.103 ± 0.076</td>
</tr>
<tr>
<td>Fe$^{2+}$, (mg/kg)</td>
<td>0.275 ± 0.157</td>
<td>10.750 ± 0.947</td>
<td>8.677 ± 0.667</td>
</tr>
<tr>
<td>Mn$^{2+}$ (mg/kg)</td>
<td>0.078 ± 0.003</td>
<td>3.093 ± 0.321</td>
<td>1.464 ± 0.154</td>
</tr>
<tr>
<td>Pb$^{2+}$, (mg/kg)</td>
<td>0.150 ± 0.057</td>
<td>0.647 ± 0.00</td>
<td>0.620 ± 0.113</td>
</tr>
<tr>
<td>Zn$^{2+}$ (mg/kg)</td>
<td>0.077 ± 0.019</td>
<td>0.763 ± 0.093</td>
<td>0.437 ± 0.047</td>
</tr>
<tr>
<td>Ni$^{2+}$, (mg/kg)</td>
<td>0</td>
<td>0.653 ± 0.101</td>
<td>0.350 ± 0.012</td>
</tr>
<tr>
<td>Cl$^{-}$ (mg/kg)</td>
<td>2.313 ± 0.193</td>
<td>7.787 ± 0.300</td>
<td>8.100 ± 1.489</td>
</tr>
<tr>
<td>Sand %</td>
<td>85.157 ± 2.079</td>
<td>73.763 ± 2.509</td>
<td>76.737 ± 2.039</td>
</tr>
<tr>
<td>Clay %</td>
<td>12.657 ± 0.315</td>
<td>23.070 ± 2.577</td>
<td>19.923 ± 1.390</td>
</tr>
<tr>
<td>Silt %</td>
<td>1.753 ± 0.122</td>
<td>3.167 ± 0.549</td>
<td>3.340 ± 0.655</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>7.893 ± 1.036</td>
<td>14.267 ± 1.943</td>
<td>17.633 ± 2.898</td>
</tr>
<tr>
<td>Bulk density (g/cm$^3$)</td>
<td>0.730 ± 0.026</td>
<td>0.903 ± 0.003</td>
<td>0.973 ± 0.012</td>
</tr>
</tbody>
</table>

References


Strength and Durability Performance of Slag Blended Cements in High Temperature Environments

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ABSTRACT

In this study, two slags of different chemical compositions were blended with a CEM I 52.5R-type Portland cement at 30% wt. replacement ratio. Various tests such as strength, water and chloride ion permeability test were carried out at a high temperature of 38°C. The performances of the slag blends were measured against that of a CEM I 42.5R-type Portland cement. The results obtained showed that the performances of the slag blends were better than that of the CEM I 42.5R cement. In comparing the performances of the slags, the blend prepared from slag 1 had higher strengths and better transport properties than that prepared from slag 2, and this was attributed to the higher basicity and alumina content of slag 1. The findings of the study suggest that in tropical/high temperature environments, the chemical composition of the slags play an important role in determining their performance.

Keywords: Tropical environment, GGBS, Compressive strength, Sorptivity, Chloride ingress

1.0. Introduction

Global production of Portland cement is over 4 billion tonnes per year. Consequently, approximately 6% of anthropogenic CO₂ emissions are associated with Portland cement (PC) production (Bye and Livesey, 2011). The drive to reduce this has led to a widespread use of supplementary cementitious materials (SCM) as partial replacement for PC. Ground granulated blast furnace slag (GGBS) is a type of SCM that is obtained as a by-product from the making of iron and steel. The molten iron slag from the blast furnace is quenched with water or steam to produce a glassy and granular material, which is grounded to a fine powder to produce GGBS (Moranville-Regourd, 2003). GGBS has almost the same fineness and specific surface area as PC (Hadj-sadok et al., 2011).

Currently, there is no reliable data regarding the annual production of iron and steel in Nigeria. In a report by (Akinwumi, 2012), it was estimated that about 3.5 to 4.5 million metric tonnes of steel was being produced per annum by the steel plants in Ajaokuta, Delta, Jos, Katsina and Osogbo. In another study by (Ohimain, 2013), it was also stated that about 1.3 million metric tonnes of iron was being produced by the Ajaokuta Steel Company. This implies that more than 0.40 million metric tons of slag could be available annually in Nigeria.

Several studies (Babu and Kumar, 2000; Barnett et al., 2006; Pavía and Condren, 2008; Lothenbach et al., 2011) have shown that using GGBS to partially replace PC in the making of concrete improves its properties. However, most of these studies were carried out in temperate environments. Only few studies, e.g. (Escalante et al., 2001; Ogirigbo and Black, 2016), have looked at how high temperatures affect the performance of slag blends. These studies showed that high temperatures accelerate the early hydration of slags, but the impact this will have on strength and transport properties was not sufficiently investigated. For a tropical environment like Nigeria, where temperatures vary from 26°C in the Southern parts to about 45°C in the Northern parts, it is imperative to study how high temperatures affect the performance of slag blended cements.
2.0. Materials and Methods

2.1. Materials

Two slag blends were prepared by mixing two slags of similar physical properties but different chemical composition (as seen in Table 1), with a CEM I 52.5R-type cement, at a replacement ratio (PC:GGBS) of 70:30. The strength and durability performance of the slag blends were compared against that of a CEM I 42.5R, which is a common type of cement used in Nigeria.

2.2. Details of Mixes and Curing Conditions

Three mixes were used for the study – a control mix (C) and two slag mixes designated as S1 and S2 respectively. Mortar samples were prepared from these mixes in accordance with (EN196-1:2005), and were used for all the tests. After mixing, the samples were poured into moulds and left to cure under air for a period of 20 – 24 hours. Thereafter, the samples were de-moulded and placed under water in curing tubs maintained at temperatures of 38°C, which is typical of a tropical environment.

Table 1: Properties of cementitious materials

<table>
<thead>
<tr>
<th>Property</th>
<th>S1</th>
<th>S2</th>
<th>CEM I 52.5R</th>
<th>CEM I 42.5R</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO (%)</td>
<td>38.24</td>
<td>37.90</td>
<td>62.38</td>
<td>63.16</td>
</tr>
<tr>
<td>SiO$_2$ (%)</td>
<td>36.58</td>
<td>40.14</td>
<td>19.10</td>
<td>19.71</td>
</tr>
<tr>
<td>Al$_2$O$_3$ (%)</td>
<td>12.23</td>
<td>7.77</td>
<td>5.35</td>
<td>5.08</td>
</tr>
<tr>
<td>Fe$_2$O$_3$ (%)</td>
<td>0.48</td>
<td>0.78</td>
<td>2.95</td>
<td>2.97</td>
</tr>
<tr>
<td>MgO (%)</td>
<td>8.55</td>
<td>9.51</td>
<td>2.37</td>
<td>2.19</td>
</tr>
<tr>
<td>Blaine (m$^2$/kg)</td>
<td>449</td>
<td>409</td>
<td>571</td>
<td>351</td>
</tr>
<tr>
<td>Particle size, d50 (µm)</td>
<td>11.0</td>
<td>11.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density (kg/m$^3$)</td>
<td>2940</td>
<td>2950</td>
<td>3180</td>
<td>3230</td>
</tr>
</tbody>
</table>

2.3. Test Methods

Unconfined compressive strength (UCS) was determined according to (EN196-1:2005). 40 x 40 x 160mm mortar prisms were cast and cured for periods of 1, 7, 28, 90 and 180 days.

Sorptivity was determined in triplicate according to the method used by (Tasdemir, 2003). 50mm mortar samples were used for the test. The samples were cured for 28 days, after which they were dried to constant mass in an oven at 50°C. After drying, the sides of the samples were coated with paraffin and weighed to obtain the initial mass before they were placed in a trough of water. The water level was kept at about 5mm from the base of the samples. The mass of the samples were recorded at predetermined times (1, 4, 9, 16, 25, 36, 49 and 64 mins). At each of these times, the mass of water absorbed by each specimen was calculated by subtracting the initial mass from the recorded mass, and from this the sorptivity coefficient (k) was determined using the following expression:

$$k = \frac{Q}{(A\sqrt{t})}$$

where:

$Q$ is the amount of water adsorbed in m$^3$

$t$ is the time in seconds

$A$ is the cross-sectional area of the specimen that was in contact with the water in m$^2$

$k$ is the sorptivity coefficient in m$^3$/m$^2$s$^{1/2}$.
Water absorption tests were carried out according to (BS1881-122:2011) using mortar samples. The mortar samples used were similar to those used for sorptivity test, in that they were prepared and cured in the same way. After curing, the samples were placed in an oven at 105°C for a period of 72 hrs. Thereafter, the samples were allowed to cool under air for about two hours, after which they were weighed and immersed completely in water for various periods of 10, 30, 60 and 120 mins. The mass of the samples were recorded at each of these times and the water absorbed \((W_a)\) as a percentage was obtained using the expression below.

\[
W_a = \frac{K(M_t - M_d)}{M_d} \times 100
\]  

where:

- \(M_d\) dry mass of the sample in grams
- \(M_t\) mass of the sample after time \(t\), in grams
- \(K\) correction factor for the shape of the samples, which is equal to 0.667 (BS1881-122:2011)
- \(W_a\) water absorbed in %

The depth of chloride ion penetration was determined using the silver nitrate colouration technique as used elsewhere (Otsuki et al., 1992; Güneyisi and Mermerdaş, 2007; Ogirigbo and Black, 2017). 50 mm mortar cubes were exposed to a 3% NaCl solution after an initial 28 days of wet curing. The samples were withdrawn periodically at 14, 28, 56 and 90 days during the 90-day soaking period to determine the depths of chloride ion penetration. The withdrawn samples were split in half and the surfaces of the freshly split samples were sprayed with a 0.1M silver nitrate solution. The presence of free chlorides is indicated by the formation of a white precipitate of silver chloride. Thus, by linear measurements from the edge of the specimen up to the colour change boundary, the depth of free chloride penetration was determined.

### 3.0. Results and Discussion

#### 3.1. Strength Performance

Figure 1 shows the unconfined compressive strength (UCS) development of all the mixes at 38°C. Within the first 28 days, all the mixes had gained more than 85% of their strength. This can be attributed to the influence of the high temperature curing, which is known to accelerate early hydration of cement, thereby leading to high early strengths (Brooks and Al-kaisi, 1990; Barnett et al., 2006). From the figure, it can be seen that the slag mixes had better strength performance than the plain CEM I 42.5R mix at all ages, unlike other studies at 20°C (Ogirigbo and Black, 2015) where early age strength development was found to be retarded with composite cements. The high temperatures here offset this slow strength development. This is because the hydration of slag in the presence of PC depends on the breakdown and dissolution of the glass slag structure by hydroxyl ions released during the hydration of PC (Pal et al., 2003), and this process is known to be accelerated at high temperatures (Escalante et al., 2001). In comparing both slags, the slag 1 mix was expected to perform better than the slag 2 mix due to its higher basicity (Ca/Si = 1.05, as compared to that of slag 2 - Ca/Si = 0.94). However, the difference in strength performance between the two slag mixes was only obvious at later ages, of 28 days and beyond. This suggests that in high temperature environments, the basicity of slags which is a function of their chemical composition is an important parameter that can influence their later strength performance.
3.2. Durability Performance

3.2.1. Water transport

The 28-day and 90-day sorptivity data are shown in Table 2, while the water absorption curves obtained by plotting the percentage of water absorbed (as determined by Equation 2) against time is shown in Figure 2. Increasing the curing duration from 28 to 90 days resulted in a decrease of about 20% and 10% in the sorptivities of the plain CEM I 42.5R mix and the slag mixes respectively. Similar drops were also observed in the water absorption data shown in Figure 2 and Table 3. This shows that prolonged curing improved the resistance to water penetration of all the mixes and agrees with the findings of (Güneyesi and Gesoğlu, 2008).

As observed in the compressive strength results, the slag mixes had better resistance to water penetration than the plain CEM I 42.5R mix. This implies that the pore structure of the slag mixes were more compact and refined than that of the plain cement mix, and explains why the slag mixes had better strength performance than the plain CEM I 42.5R mix.

As also observed in the compressive strength results, the water penetration resistance of the slag 1 mix was better than that of the slag 2 mix. This can also be attributed to the higher basicity of slag 1, which will enable it to contribute more to the formation of hydration products and to the densification of the pore structure (Ogirigbo and Black, 2016).

Table 2: Sorptivity of all the mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Sorptivity, k (m^2/m^3s^1/2) x 10^-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28 days</td>
</tr>
<tr>
<td>C</td>
<td>9.9 ± 0.07</td>
</tr>
<tr>
<td>S1</td>
<td>4.0 ± 0.07</td>
</tr>
<tr>
<td>S2</td>
<td>6.3 ± 0.04</td>
</tr>
</tbody>
</table>
Table 3: 30 mins water absorption for all the mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Water absorbed at 30 min (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28 days</td>
</tr>
<tr>
<td>C</td>
<td>2.3 ± 0.04</td>
</tr>
<tr>
<td>S1</td>
<td>1.3 ± 0.06</td>
</tr>
<tr>
<td>S2</td>
<td>1.8 ± 0.04</td>
</tr>
</tbody>
</table>

3.2.2. Chloride Ion Transport

The depth of chloride ion penetration measured for samples which had been cured for 28 days before exposure to a 3% NaCl is shown in Figure 3. The slag mixes were seen to have better resistance to chloride ion penetration than the plain CEM I 42.5R mix, especially at 90 days of exposure (see Figure 4). This can be attributed to two factors. The first, being the pore structure, which was seen from the results of the water penetration tests (Table 2 and Figure 2) to be more compact for the slag mixes than for the plain CEM I 42.5R mix. The second, being the chloride binding abilities of the mixes. Several studies (Dhir et al., 1996; Luo et al., 2003; Cheng et al., 2005; Thomas et al., 2012) have shown that slag blended cements have higher chloride binding capacities than plain cements. This implies that the slag mixes bound a greater proportion of the chloride ions that penetrated into the samples, leaving only few chlorides to remain in the pore solution as free chlorides. This high chloride binding ability exhibited by slags have been generally attributed to their higher alumina content (Dhir et al., 1996; Luo et al., 2003; Cheng et al., 2005; Thomas et al., 2012), which in this study (as shown in Table 1) can be seen to be much higher for the slags than for the plain cement.

As also observed in the previous results shown, the slag 1 mix showed better resistance to the penetration of chloride ions as compared to the slag 2 mix. The reason for this can be seen from Table 1, where the basicity and alumina content of slag 1 was significantly greater than that of slag 2.
4.0. Conclusions

This study investigated the strength and durability performance of slag blended cements in high temperature environments. In conclusion, the following points have been highlighted:

- All the mixes had gained more than 85% of their strength within the first 28 days. This was attributed to the influence of the high temperature curing, which accelerated the early hydration leading to high early strengths.
- The slag mixes had better strength performance than the plain cement mix at all ages. In comparing the strength performance of both slag mixes, slag 1 performed better than slag 2 and this was attributed to its higher basicity.
- For the transport properties studied (water and chloride penetration), the results obtained showed that curing for longer periods enhances the resistance to water penetration. The slag mixes showed better resistance to the penetration of water and chloride ions as compared to the plain cement. This was attributed to the more compact pore structure of the slag blends and their higher alumina contents.
- In comparing both slags, slag 1 showed better transport properties than slag 2 especially in terms of resistance to the penetration of chloride ions. This was attributed to the higher basicity and alumina content of slag 1.
Overall, the results from this study implies that in hot climates like the tropical regions, slag blended cements have better strength and transport properties than plain cements. Nigeria is fairly rich in slag and is situated in the tropics. Since high temperature enhances the performance of slags, it is recommended that slags are used as partial replacement materials for PC. Also, standards stipulate a minimum CaO/SiO₂ ratio for slags; for example, EN 197-1:2011 prescribes that for GGBS, the (CaO + MgO)/SiO₂ ratio by mass must exceed 1. The findings of this study show that these ratios would be more important for consideration in tropical environments.

Acknowledgements
The authors would like to thank Dr Leon Black of the school of Civil Engineering, University of Leeds, for his input in the research study; and also the Petroleum Technology Development Fund (PTDF) Nigeria, for providing the funding for the research work.

References


Application of Least Squares Estimation Techniques in 2D Conformal Coordinates Transformation from Local to National

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ABSTRACT

A two-dimensional conformal coordinate transformation is a similarity transformation which is also known as the four parameter transformation since it maintains scale relationships between the two coordinates system. This transformation type uses a mathematical model that establish a geometrical relationship between coordinates of points in different reference frames. It gained wider acceptance because of its capability to retain the shape of an area represented. This paper utilizes three control points; PT02, PT03 and PT04 to compute the transformation parameters and later all validated the derived coordinates of point PT04 known in the local system to national system using manual computation check. The second approach was to derive the transformation parameters using four control points. The result obtained was validated and found to agree with the derived national coordinates system for point PT07. Subsequently, all other points within the areas covered in the scope of work were transformed by writing script and running it in MATLAB software environment. The total area covered was 457.457 hectares.

Keywords: Kainji Dam, Conformal, Coordinate Transformation, DGPS

1.0. Introduction

This project was carried out around Kainji dam area of Nigeria aimed at transforming coordinates in the local coordinates system to national coordinates system. The survey of area covering about 457.457 hectares was undertaken for deformation monitoring purpose. Trimble DGPS R8 was deployed to acquire spatial data by taken measurements on control points PT02, PT03, PT04 and other points within the study area. The coordinates of these three control points were first defined in a local reference frame. The transformation process followed in this paper enables us to transform these local control points to Minna reference datum which is the Nigeria national reference frame system used for her mapping purposes.

Nigeria as a country is covered with first-order triangulation chains and traverse control networks. These networks were computed on the Nigerian geodetic datum which was established by astrogeodetic method with its origin located at station L40 opposite police secondary school. (It is a local geodetic datum termed “Minna B” datum because that which is applied in the west of the Republic of Cameroun is called “Minna A”). The Minna B datum is based on the Clarke 1880 ellipsoid with the following parameters; Semi-major axis, a = 6378249.145m; Flattening, f = 1/293.465. (Uzodinma and Ehigiator-Irughe, 2013). The L40 origin has the following adopted geodetic co-ordinates (Uzodinma and Ezenwere, 1993): Latitude φ = 09° 38′ 09″ N, Longitude λ = 06° 30′ 59″ E, and Height = 279.6m above the geoid.

Coordinate transformation from a local system is often encountered in Geomatics operations. There are cities and towns whose coordinate system are in local. There is need to transform the local coordinates system to the National. This can only be achieved if the minimum of two controls in the local system also has coordinates in the national system. Control points PT02, PT03 and PT04 are stations with both local coordinates system and national coordinates system, this enabled us to develop the mathematical
model for transforming other points whose coordinates are still in the local coordinate system. Trimble GNSS R8 receiver was used to define the coordinates of these three control stations in national coordinates system. Once these relationships is established, it is then possible to determine the transformation parameters needed for all other points to be transformed.

1.1. Study Area

The study area is as shown in figure 1; that is, the google earth satellite imagery for clearer view. The coordinates of Kainji dam is given as; 09°51′45″N and 04°36′48″E.

![Figure 1: Google map imagery of the study area. Source (Google Earth)](image)

1.2. Coordinates System

Coordinates systems may be in Local (assumed), National (NTM) and Universal (UTM). Whatever coordinates systems adopted, it is possible to transform between one system and another provided some points are known which are common to both systems. One of the methods of coordinates transformation is the conformal transformation treated in this paper.

1.3. Types of Transformation

Different types of transformation exist which are use based on the user’s choice and what they tend to achieve. Some of them are; affine, polynomial, projective, etc. Mikhail (1976), observed that the effect of a transformation on a 2D or 3D object will vary from a simple change of location and orientation (with no change in shape or size) to a uniform change in scale (no change in shape) and finally to changes of shape and size of different degrees of nonlinearity. One of the most common transformations in Geomatics applications, which shall be discussed in this paper, is the 2D conformal, its achievement procedures and due to its ability to preserve angles and shape of objects.

2.0. Materials/Method

2.1. Instrumentation

i. 1x Trimble Dual frequency GPS R8 ‘Base Station’ receiver.
ii. 2 x Trimble Dual Frequency GPS R8 ‘Rover’ receiver.
iii. Data Processing Computer.
2.2. Determination of Conformal Coordinate Transformation Parameters

2.2.1. Scaling

Scaling is one of the most important parameter to be considered in two-dimensional conformal coordinate transformation. It is usually determined by the application of the following mathematical model.

\[ S = \sqrt{\frac{(\Delta N)^2 + (\Delta E)^2}{(\Delta x)^2 + (\Delta y)^2}} \]  

Where \( \Delta N, \Delta E, \Delta x \) and \( \Delta Y \) are the changes in the nothing and easting coordinates of the control points in the national and local systems respectively.

2.2.2. Rotation

In order to make points \((x_A, y_A)\) in a local system coincide or correspond with points \((E_A, N_A)\) in a standard system rotation is required. This can be achieved by using the relation.

Rotation, \( \theta = \alpha + \beta \) where;

\[ \alpha = \tan^{-1}\left(\frac{x_B - x_A}{y_B - y_A}\right) \]  

\[ \beta = \tan^{-1}\left(\frac{E_B - E_A}{N_B - N_A}\right) \]  

2.3. Translations in \( E \) and \( N \)

The third step for a successful transformation is to compute \( T_E \) and \( T_N \) of coordinates using equations (4a) to (4d);

\[ T_E = E_A - E'_A \]  

\[ T_N = N_A - N'_A \]  

Similarly,

\[ T_E = E_B - E'_B \]  

\[ T_N = N_B - N'_B \]  

2.4. Formulation of the mathematical model

In order to develop the mathematical model needed for transformation, consider Figure 2.

\[ \text{Figure 2: Sketch of the relationship} \]

From the sketch shown in Figure 2, the following equations can be formulated.
\begin{align}
E_i &= r \cos \phi \cos \theta - r \sin \phi \sin \theta \\
N_i &= r \cos \phi \cos \theta - r \sin \phi \sin \theta
\end{align} \tag{5}

Substitute equation (5) into equations (6) we have;
\begin{align}
E_i &= X_i \cos \theta - Y_i \sin \theta \\
N_i &= Y_i \sin \theta + X_i \cos \theta
\end{align} \tag{6}

By applying scale factor to equation (6) we have;
\begin{align}
E_a &= SX_a \cos \theta - SY_a \sin \theta \\
N_a &= SY_a \sin \theta + SX_a \cos \theta
\end{align} \tag{7}

Where;
- \(E_a\): is the easting coordinate in the national system at point ‘a’
- \(N_a\): is the northing coordinate in the national system at point ‘a’
- \(X_a\): is the easting coordinate in the local system at point ‘a’
- \(Y_a\): is the easting coordinate in the local system at point ‘a’
- \(\theta\): rotational angle

![Diagram](image)

Figure 3: Representing the relationship

\[
\sin \theta = \frac{b}{a}, a = S \cdot \sin \theta, b = S \cdot \cos \theta
\]

\begin{align}
E_A &= X_A \cos \theta - Y_A \sin \theta + T_E \\
N_A &= Y_A \sin \theta + X_A \cos \theta + T_N
\end{align} \tag{8a, 8b}

\begin{align}
E_A &= aX_A - bY_A + T_E \\
N_A &= aY_A + bX_A + T_N
\end{align} \tag{9a, 9b}

Adding residuals to equations (9a) and (9b) the observation equation can be written as shown in equations (10a) and (10b);
\begin{align}
E_A + V_E &= aX_A - bY_A + T_E \\
N_A + V_N &= aY_A + bX_A + T_N
\end{align} \tag{10a, 10b}

Three control points are sufficient to successfully carry out the transformation. The solution to determine the transformation parameters can be formulated into a matrix algebra.

2.4.1 Developing the designed matrix for observation equation model using three control points

The designed matrices will be in the form;
\[
AX = L + V
\] \tag{11}
The solutions of ‘X’ using MATLAB gave the following values for the transformation parameters $a$, $b$, $T_E$ and $T_N$.

By substituting the values of ‘A’ and ‘L’ into equation (12) the solution of ‘X’ were determined as follows:

$$X = \begin{bmatrix} 0.6788 \\ 0.7346 \\ 242428.034 \\ 646410.026 \end{bmatrix}$$

Where; $a = (0.6788)$, $b = (0.7346)$, $T_E = (242428.034)$, $T_N = (646410.026)$. 

### 3.0. Results and Discussion

Table 1, shows the coordinate data whose values are known in both local and national system used in the transformation process. Thus, in the local system, coordinates of three points were known but in national system only two points were known whilst the third point to be determine by transformation. But the minimum requirement is at least two points in the local system. The solution from equation (12) can be manipulated using MATLAB. The data from the two control stations are formulated as follows.

**Table 1: Input data**

<table>
<thead>
<tr>
<th>Point</th>
<th>Local Coordinates</th>
<th>National Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting (m)</td>
<td>Northing (m)</td>
</tr>
<tr>
<td>PT02</td>
<td>1563.3413</td>
<td>320.9306</td>
</tr>
<tr>
<td>PT03</td>
<td>2000.0069</td>
<td>0.0074</td>
</tr>
<tr>
<td>PT04</td>
<td>2672.5435</td>
<td>118.5967</td>
</tr>
</tbody>
</table>

$$A = \begin{bmatrix} 1563.3413 & -320.9306 & 1.000 & 0.000 \\ 320.9306 & 1563.413 & 0.000 & 1.000 \\ 2000.0069 & -0.0074 & 1.000 & 0.000 \\ 0.0074 & 2000.0069 & 0.000 & 1.000 \\ 2672.544 & -118.597 & 1.000 & 0.000 \\ 118.597 & 2672.544 & 0.000 & 1.000 \end{bmatrix}, \quad L = \begin{bmatrix} a \\ b \\ T_E \\ T_N \end{bmatrix}, \quad X = \begin{bmatrix} X_a \\ X_b \\ X_c \\ X_d \end{bmatrix}$$

Where:

$A = \text{Vector of adjusted parameters}$, $X = \text{vector of unknown parameters}$, $L = \text{vector of observed parameters}$ and $V = \text{residual error}$.

This system can be solved using un-weighted least squares method in matrix form as in equation (12). Least squares emphasized that the sum of squares of the residual errors must be minimum.

$$X = (A^T A)^{-1} A^T L$$

(12)
Figure 3, depicts the screen shot of the MATLAB R2012a interface showing the written scripts, command window and the workspace.

![Screen shot of the MATLAB R2012a interface.](image)

From equation (13), making ‘V’ the subject of the formula,

\[ V = AX - L \]  \hspace{1cm} (13)

The solution of ‘V’ the vector of residual is given as follows;

\[
V = \begin{bmatrix}
1563.3413 & -320.9306 & 1.000 & 0.000 \\
320.9306 & 1563.413 & 0.000 & 1.000 \\
2000.0069 & -0.0074 & 1.000 & 0.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
\end{bmatrix}
\begin{bmatrix}
0.6788 \\
0.7346 \\
(242428.034) \\
(646410.026) \\
\end{bmatrix}
- \begin{bmatrix}
243253.013 \\
647775.697 \\
243784.914 \\
647876.607 \\
244154.112 \\
648452.897 \\
\end{bmatrix}
\]

From least squares adjustment, sum of squares of the residuals should be minimum. Therefore, the solution of the squares of the residuals gave;

\[ \sum_{i=1}^{n} V_i^2 = 2.098e^{-7} m \]
The solution to the normal equation ‘N’ is given by equation (14) while the solution to the inverse of the normal equation ‘N\(^{-1}\)’ for the model is given by equation (15);

\[
N = (A^T A)
\]

(14)

\[
N = \begin{bmatrix}
1563.3413 & -320.9306 & 1.000 & 0.000 \\
320.9306 & 1563.413 & 0.000 & 1.000 \\
2000.0069 & -0.0074 & 1.000 & 0.000 \\
0.0074 & 2000.0069 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000
\end{bmatrix}^T
\]

\[
N^{-1} = (A^T A)^{-1}
\]

(15)

\[
N^{-1} = \begin{bmatrix}
13703616.469 & 0 & 6235.892 & 439.535 \\
0 & 13703616.469 & -439.535 & 6235.892 \\
6235.892 & -439.535 & 3 & 0 \\
439.535 & 6235.892 & 0 & 3
\end{bmatrix}
\]

The standard deviation for the model which shows the accuracy can be computed as follows;

\[
\sigma_0^2 = \frac{V^T V}{r}
\]

(16)

Where:

“r” is the redundancy, that is, the number of equations minus the number of unknowns. In the case of 3 pairs of points with 6 equations and 4 unknown transformation parameters, the redundancy is (6-4) = 2. The solution to standard deviation of unit weight is shown below.
\[ \sigma_0^2 = 1.6715 e^{-07} \]

The covariance matrix for the transformation parameters when converting from local coordinates to national coordinates can be computed using the relations;

\[
C_{(E,N)} = \sigma_0^2 (A^T A)^{-1} = \sigma_0^2 N^{-1} \tag{17}
\]

Where;

\[ \sigma_0 \] = the standard deviation.

\[(A^T A)^{-1} = \text{Normal coefficient matrix.}\]

\[
C_{(E,N)} = 1.6715 \times 10^{-07} \times \begin{bmatrix}
1563.3413 & -320.9306 & 1.000 & 0.000 \\
320.9306 & 1563.413 & 0.000 & 1.000 \\
2000.0069 & -0.0074 & 1.000 & 0.000 \\
0.0074 & 2000.0069 & 0.000 & 1.000 \\
118.597 & -118.597 & 1.000 & 0.000 \\
2672.544 & 2672.544 & 0.000 & 1.000
\end{bmatrix}
\]

The solution of variance co-variance matrix is given as follows with variances at the diagonal and co-variances at other corners;

\[
C_{(E,N)} = \begin{bmatrix}
2.4685e^{-13} & -4.4243e^{-30} & -5.1311e^{-10} & -3.6167e^{-11} \\
-4.4243e^{-30} & 2.4685e^{-13} & 3.6167e^{-11} & -5.1311e^{-10} \\
-5.1311e^{-10} & 3.6167e^{-11} & 1.1276e^{-06} & 0 \\
-3.6167e^{-11} & -5.1311e^{-10} & 0 & 1.1276e^{-06}
\end{bmatrix}
\]

The standard deviation of the model is computed by taken the square root of the variances which gave the following values respectively.

\[
\sigma_a = \sqrt{2.4685e^{-13}} = 4.96e^{-07} \text{ m}
\]

\[
\sigma_b = \sqrt{2.4685e^{-13}} = 4.96e^{-07} \text{ m}
\]

\[
\sigma_{Te} = \sqrt{1.1276e^{-06}} = 1.06e^{-07} \text{ m}
\]

\[
\sigma_{Ts} = \sqrt{1.1276e^{-06}} = 1.06e^{-07} \text{ m}
\]

Validation of the model with three control points was verified using equations (18a) and (18b) in which we are able to compute the coordinates of point (PT07). Which we have represented in this case by subscript 'c' in the national system.

\[
E_c = a(\text{derived})E_c^{\text{local}} - b(\text{derived})N_c^{\text{local}} + T_e(\text{derived}) \tag{18a}
\]

\[
N_c = b(\text{derived})E_c^{\text{local}} + a(\text{derived})N_c^{\text{local}} + T_n(\text{derived}) \tag{18b}
\]

The solutions are as presented below;

\[
E_c = (0.6788 \times 2672.5435) - (0.7346 \times 118.5967) + (242428 \times 0.034) \\
N_c = (0.6788 \times 118.5967) + (0.7346 \times 2672.5435) + (646410 \times 0.026)
\]
The derived national coordinates for PT04 which was represented by question mark in table 1 is as shown below;

\[
E_c = 244154.1124m \\
N_c = 648452.8972m \\
\delta E_c = 0.983m \\
\delta N_c = 0.042m
\]

3.1. Designed matrix for observation equation model using four control points

Table 2 shows the case of having four coordinate data in the local system with three known point in the national, point (PT07) needed to be determined in the national system through transformation.

<table>
<thead>
<tr>
<th>Point</th>
<th>Local Coordinates</th>
<th>National Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting (m)</td>
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</tr>
<tr>
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</tr>
<tr>
<td>PT03</td>
<td>2000.0069</td>
<td>0.0074</td>
</tr>
<tr>
<td>PT04</td>
<td>2672.5435</td>
<td>118.5967</td>
</tr>
<tr>
<td>PT07</td>
<td>1624.6415</td>
<td>843.4996</td>
</tr>
</tbody>
</table>

The designed matrices will be in the form;

\[
AX = L + V \quad (19)
\]

The design matrix for four control points will follow the same procedure as before but the principle will be adopted if one needed to transform many points simultaneously. Just by adding one more control point (PT07) to the first three and repeating the processes from equations (12) to (18). The following results were obtained. Recall from equation (12) that we have the solution for matrix X but we differentiate this by introducing subscript 1 here;

\[
X_1 = \left( A^\top A \right)^{-1} A^\top L \quad (12^*)
\]

Putting our parameters for three control stations in matrix form and applying equation (12*) and then solving with MATLAB. But it is important to note that the ‘A’ matrix is no longer square. There are 6 rows and 4 columns, therefore, the matrix cannot simply be inverted. Substituting our parameters again give the following resulting for matrix ‘X1’.
\[
A = \begin{bmatrix}
1563.341 & -320.930 & 1.000 & 0.000 \\
320.931 & 1563.413 & 0.000 & 1.000 \\
200.007 & -0.007 & 1.000 & 0.000 \\
0.007 & 200.007 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
1624.642 & -843.499 & 1.000 & 0.000 \\
843.449 & 1624.642 & 0.000 & 1.000
\end{bmatrix}
\]
\[
L = \begin{bmatrix}
243253.013 \\
647775.697 \\
243784.914 \\
647878.607 \\
244154.112 \\
648452.897 \\
242910.886 \\
648175.241
\end{bmatrix}
\]
\[
X_i = \begin{bmatrix}
a \\ b \\ T_E \\ T_N
\end{bmatrix}
\]

The solutions of ‘\(X_i\)’, using MATLAB gave the following values for the transformation parameters \(a\), \(b\), \(T_E\) and \(T_N\). Which is still the same as the one obtained with two control points.

\[
X_i = \begin{bmatrix}
1563.341 & -320.930 & 1.000 & 0.000 \\
320.931 & 1563.413 & 0.000 & 1.000 \\
200.007 & -0.007 & 1.000 & 0.000 \\
0.007 & 200.007 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
1624.642 & -843.499 & 1.000 & 0.000 \\
843.449 & 1624.642 & 0.000 & 1.000
\end{bmatrix}^T
\]

The solution to matrix ‘\(X_i\)’ is the same as we have in matrix ‘\(X\)’, for \(a\), \(b\), \(T_E\) and \(T_N\) respectively.

\[
X_i = \begin{bmatrix}
0.6788 \\
0.7346 \\
242428.034 \\
646410.026
\end{bmatrix}
\]

Where; \(a = (0.6788)\), \(b = (0.7346)\), \(T_E = (242428.034)\), \(T_N = (646410.026)\).

From equation (13), making ‘\(V\)’ the subject of the formula.

\[
V = AX_i - L
\]
The solution of ‘V’ is given as follows;

\[
V = \begin{bmatrix}
1563.341 & -320.930 & 1.000 & 0.000 \\
320.931 & 1563.413 & 0.000 & 1.000 \\
200.007 & -0.007 & 1.000 & 0.000 \\
0.007 & 200.007 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
1624.642 & -843.499 & 1.000 & 0.000 \\
843.449 & 1624.642 & 0.000 & 1.000
\end{bmatrix}
\begin{bmatrix}
243253.013 \\
647775.697 \\
243784.914 \\
647878.607 \\
244154.112 \\
648452.897 \\
242910.886 \\
648175.241
\end{bmatrix}
\]

From least squares adjustment, sum of squares of the residuals should be minimum. The solution of the squares of the residuals gave;

\[
\sum_i^N V_i^2 = 0.00000103
\]

The solution to the normal equation ‘N’ and the inverse of the normal equation ‘N\(^{-1}\)’ for the model is given by (14\(^{*}\)) and (15\(^{*}\)) respectively;

\[
N = (A^T A)
\]

(14\(^{*}\))

\[
N^{-1} = (A^T A)^{-1}
\]

(15\(^{*}\))
\[
N^{-1} = \begin{bmatrix}
1563.341 & -320.930 & 1.000 & 0.000 \\
320.931 & 1563.413 & 0.000 & 1.000 \\
200.007 & -0.007 & 1.000 & 0.000 \\
0.007 & 200.007 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
1624.642 & -843.499 & 1.000 & 0.000 \\
843.449 & 1624.642 & 0.000 & 1.000
\end{bmatrix}
\begin{bmatrix}
1563.341 & -320.930 & 1.000 & 0.000 \\
320.931 & 1563.413 & 0.000 & 1.000 \\
200.007 & -0.007 & 1.000 & 0.000 \\
0.007 & 200.007 & 0.000 & 1.000 \\
2672.544 & -118.597 & 1.000 & 0.000 \\
118.597 & 2672.544 & 0.000 & 1.000 \\
1624.642 & -843.499 & 1.000 & 0.000 \\
843.449 & 1624.642 & 0.000 & 1.000
\end{bmatrix}^{-1}
\]

The standard deviation for the model which shows the accuracy can be computed as follows;

\[
\sigma_0^2 = \frac{V^TV}{r}
\]

(16*)

Where “r” is the redundancy, that is, the number of equations minus the number of unknowns. In the case of 4 pairs of points with 8 equations and 4 unknown transformation parameters, the redundancy is (8-4) = 4. The solution to standard deviation of unit weight is shown below.

\[
\sigma_0^2 = \frac{1}{4} \begin{bmatrix}
9.1702e^{-04} & 8.1558e^{-05} & -2.0187e^{-04} & 3.4292e^{-04} \\
8.1558e^{-05} & 9.1702e^{-04} & -2.0187e^{-04} & 3.4292e^{-04} \\
-2.0187e^{-04} & -2.0187e^{-04} & 9.1702e^{-04} & 8.1558e^{-05} \\
3.4292e^{-04} & 3.4292e^{-04} & 8.1558e^{-05} & 9.1702e^{-04}
\end{bmatrix}
\]

\[
\sigma_0^2 = \frac{4.8306e^{-07}}{4}
\]

The covariance matrix for the transformation parameters when converting from local coordinates to standard coordinates can be computed using the relations;

\[
C_{(E,N)} = \sigma_0^2 (A^T A)^{-1} = \sigma_0^2 N^{-1}
\]

(17*)

Where;

\[
\sigma_0^2 = \text{the standard deviation.}
\]

\[
(A^T A)^{-1} = \text{Normal coefficient matrix.}
\]
The solution of variance co-variance matrix is given as follows with variances at the diagonal and co-variances at other corners:

\[
C_{(x,y)} = \begin{bmatrix}
4.0389e^{-13} & 2.5573e^{-29} & -7.9369e^{-10} & -1.2955e^{-10} \\
2.5573e^{-29} & 4.0389e^{-13} & 1.2955e^{-10} & -1.8077e^{-05} \\
-7.9369e^{-10} & 1.2955e^{-10} & 1.7220e^{-06} & 0 \\
-1.2955e^{-10} & -7.9369e^{-10} & 0 & 1.7220e^{-06}
\end{bmatrix}
\]

The standard deviation of the model is computed by taken the square root of the variances which gave the following values respectively.

\[
\begin{align*}
\sigma_a &= \sqrt{4.0389e^{-13}} = 0.003m \\
\sigma_b &= \sqrt{4.0389e^{-13}} = 0.003m \\
\sigma_{T_x} &= \sqrt{1.7220e^{-06}} = 0.065m \\
\sigma_{T_y} &= \sqrt{1.7220e^{-06}} = 0.065m
\end{align*}
\]

Validation of the model with four control points was verified using equations (18a*) and (18b*) in which we are able to compute the coordinates of point (PT07). Which we have represented in this case by ‘d’ in the national system.

\[
\begin{align*}
E_d &= a(derived)E_d - b(derived)N_d + T_E(derived) \quad (18a^*) \\
N_d &= a(derived)N_d + b(derived)E_d + T_N(derived) \quad (18b^*)
\end{align*}
\]

The solutions are as presented below;

\[
\begin{align*}
E_d &= (0.6788 \times 1624.6415) - (0.7346 \times 843.4996) + (242428.031) \\
N_d &= (0.6788 \times 843.4996) + (0.7346 \times 1624.6415) + (646410.026) \\
E_d &= 242911.132m \\
N_d &= 648176.200m
\end{align*}
\]

The derived national coordinates for PT07 which was represented by question mark in table 2 is as shown below;

\[
\begin{align*}
E_d &= 242910.207m \\
N_d &= 648176.544m \\
\delta E_d &= 0.925m \\
\delta N_d &= 0.344m
\end{align*}
\]
4.0. Summary and Conclusion

This project carried out for deformation monitoring of the dam was carefully executed and two-dimensional conformal coordinate transformation was demonstrated using three control points whose value are known in both local and national coordinates systems over a small area. After which four control points were used to demonstrate how subsequent points were transformed in the area. In conclusion, this transformation procedure proved to be very useful where coordinates in local are needed in national values. The easting and northing of third point (PT04) and fourth point (PT07) were computed and presented in order to validate the correctness of the conformal coordinate transformation parameters derived using three and four control points respectively. The same transformation parameter values where obtained using three and four control points, this suggest that each additional point will not alter the values of transformation parameters. Using the method of least squares to transform several points is the best especially when there are several points to be transformed simultaneously. In general, the overall parameters derived are;

- **(i) Scale** = 1.0003, calculated using \( \tan^{-1}\left(\frac{b}{a}\right) \)
- **(ii) Rotation** = 47°15’57.56”, calculated using \( \left[\frac{a}{\cos\theta}\right] \) or \( \left[\frac{b}{\sin\theta}\right] \)
- **(iii) a** = 0.6788
- **(iv) b** = 0.7346
- **(v) Translation (\( T_E \))** = 242428.031
- **(vi) Translation (\( T_N \))** = 646410.026

Parameters (iii) – (vi) above are the solution of matrix (X).

The following recommendations arise from the results of this study:

- Geomatics and Civil Engineers can get rid of the problem of moving from one coordinate system to another especially when working in an area where local coordinate of at least two points are available and the national coordinate of same points are known. Then is possible to get the national coordinates of the same points and all other points over a given area for instance on a construction sites.
- With the procedure carefully followed, two-dimensional coordinate transformation can be easily performed and this paper has demonstrated that effectively.

References


Densification of (GNSS) Control Points for Cadastral and Mapping Purposes

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ABSTRACT

GNSS control densification is a continuous exercise in the field of Geomatics. This form the basis upon which other Geomatics and Engineering activities geared toward development are referenced. This paper employed the use of Hi-Target GPS to extend and establish controls at the confines of the study area in static mode while topographical survey was carried out using real-time kinematics method. Network adjustment, for the newly established control stations were carried out while the master station was held fixed. Data analysis and production of plans were done using softwares like Hi-Target V30, Carlson Civil Suite 2017 etc. The result of perimeter computation for the study area gave a total of 93.614 hectare

Keywords: Densification, Control Stations, GNSS Network, Cadastral, Mapping

1.0. Introduction

This paper discussed the concepts, instrumentation, office procedure, field work and software used in establishing control points located at a vast palm plantation farm at Igue-Iheyia/Isioho in Ovia North-East Local Government Area of Edo State. Control extension is very important for surveying and mapping of any engineering project. GNSS is a versatile, accurate, quick, better, time-saving and economical way of establishing control points. The distance between the base station (UN_GPS_100) and the GPS_01 is 5399.578m.

1.1 The concept of Static and Kinematics Modes in GNSS

Gunter (2003), observed that various techniques have been developed in recent years that exploit the capability of GPS to provide precise coordinates after a very short observation time, or even while the receiver (including the antenna) is moving along a trajectory. Gunter (2003), stated that rapid methods require the resolution of ambiguities in order to exploit the high accuracy potential of GPS phase measurements. Otherwise the noise level of real valued solutions for the short observation times would be too high. One prerequisite the Global Positioning System (GPS) for the rapid solution of ambiguities is that the distant-dependent errors be small. Hence, the rapid methods only work well for short distances (up to several kilometres) between the participating stations. For longer ranges, it is necessary to model the distance dependent errors, e.g. in active reference networks.

Different possibilities exist for subdividing the rapid methods of GPS. The scheme used here is into three categories stated as follows;

i. Rapid static methods,
ii. Semi-kinematic (stop and go) methods, and
iii. Real kinematic methods.

It was noted by Seeber (2003), that the rationale behind this subdivision is whether the receiver is taking measurements while it is in motion, and the coordinates of the trajectory can be determined (kinematic
mode), or whether the receiver is switched off during transportation, and coordinates can only be
determined when the antenna is stationary (static mode). A third mode is in between these possibilities,
in that the receiver has to maintain lock during the times of transportation, but coordinates are not
usually derived for the trajectory (semi kinematic mode).

A further distinction between static and kinematic surveying can be seen with respect to accuracy issues
(Kleusberg, 1990). In static GPS surveying, most random measurement errors are absorbed in the
residuals after adjustment, while in kinematic surveying, most random measurement errors are absorbed
in the coordinates. This is why the accuracy potential of static GPS cannot be reached completely with
pure kinematic methods (Seeber, 2003). As the GPS signal finally arrives at the earth’s surface, it may
be reflected by local obstructions before it gets to the receiver’s antenna. This is called multi-path error
as the signal is reaching the antenna in single line path as well as delayed path.

Sources of errors in GNSS surveying include but not limited to: (i) the multipath effect is caused by
reflection of satellite signals (radio waves) on objects. For GPS signals this effect mainly appears in the
neighbourhood of large buildings or other elevations. The reflected signal takes more time to reach the
receiver than the direct signal. The resulting error typically lies in the range of a few meters. (ii)
Atmospheric Effects, the GPS signals have to travel through charged particles and water vapour in the
atmosphere that delays its transmission. Since the atmosphere varies at different places and at different
times, it is not possible to accurately compensate for the delays that occur. While radio signals travel
with the velocity of light in the outer space, their propagation in the ionosphere and troposphere is
slower. In the ionosphere (consisting of layers) in a height of 80 – 400 km a large number of electrons
and positive charged ions are formed by the ionizing force of the sun. The layers refract the
electromagnetic waves from the satellites, resulting in an elongated runtime of the signals. Since the
Electromagnetic waves emit in form of a sphere, therefore, Inverse square law is employed and the
waves are slowed down inversely proportional to the square of their frequency ($1/f^2$) while passing the
ionosphere. The reasons for the refraction in troposphere are different concentrations of water vapors,
caused by different weather conditions. The error caused that way is smaller than the ionosphere error,
but cannot be eliminated by calculation. It can only be approximated by a general calculation model.
(iii) Receiver Error, since the receivers are also not perfect, they can introduce their own errors which
usually occur from their clocks or internal noise. Despite the synchronization of the receiver clock with
the satellite time during the position determination, the remaining inaccuracy of the time still leads to
an error of about 2 m in the position determination. Rounding and calculation errors of the receiver sum
up approximately to 1 m (CED, 2012).

1.2. Reconnaissance and Monumentation

This deals with gathering of information that is required to carry out a successful field operations. The
choice of control point used as master station was made. This first order GNSS control established is
located at University of Benin Ugbowo Campus close to Civil Engineering laboratory with the
following inscription (UN_GPS_100). Field reconnaissance was then performed in the study area to
ascertain how the ground conditions were as well as locating suitable points for the proposed new
controls. Seven controls were established around the study area defining the boundaries which were
later coordinated.

1.3. Study Area

The study area is at Igue-Iheya/Isiohor in Ovia North-East Local Government Area of Edo State,
Nigeria. Its geographic location lie between Latitude: 6°25′33.24″N, Longitude: 5°34′16.03″E and
Latitude 6°25′29.95″N, Longitude 5°35′33.25″E

1.4. GNSS Network Design and Observation

The GNSS observation started on the 3rd of April, 2017 and ended on the 7th of the same month. The
network was designed in such a way that four controls were established at the corners and three other
close to the middle of the project area. In each observation session a minimum of 45mins to 1hour was
used depending on the baseline length and satellite availability. Four Hi-Target V30/50 dual frequency
geodetic L1/L2 rover receiver with geodetic antennas were used to simultaneously track the satellites. Number of GNSS Baselines in the network were 18 while the number of adjusted points were 8.

**Figure 1:** Screen shot of Google Earth Landsat Imagery of the study area boundaries are marked with yellow place marks

**Figure 2:** Network design

1.5. **GNSS Field Survey Operation Procedures**

Boundaries were coordinated using GNSS static mode. This involves setting up the master at the control point (UN_GPS_100) at UNIBEN while the other three rovers were set up at stations whose positions are required. Time of observation lasted between 45 minutes to 1 hour. For detailing and topographic survey, Real time kinematic mode was used. This involves setting up the master at one of the newly coordinated station at the site, using radio signal, corrections were transmitted to the rovers.

2.0. **Materials/Method**

2.1. **Instrumentation**

i. 1 x Hi Target V30 Dual Frequency GNSS (Global Navigation Satellite System) ‘Base Station’ receiver.

ii. 2 x Hi Target Dual Frequency V30 GNSS (Global Navigation Satellite System) ‘Rover’ receiver.

iii. 1 x Data Processing Computer and Accessories.

2.2. **Pseudorange Observation Equations**

The principle involves measurement of distance or range to at least four Satellites whose X, Y and Z positions are known, in order to define the user’s $X_p$, $Y_p$ and $Z_p$ position. In its simplest form, the satellite
transmits signal on which the time of its departure \( (tD) \) from the satellite is modulated. The receiver in return notes the time of arrival \( (tA) \) of this time mark. The time taken from the transmitted signal to the receiver is given by, as \( (tA - tD) = \Delta t \) (called the delay time). The measured range \( R \) is obtained from equation 1(Geoffrey Blewitt, 2003).

\[
R_1 = (tA - tD) C = \Delta t C
\]

Where, \( c \) = the velocity of light.

\[
T = t + \tau
\]

\[
T^S = t^S + T^S
\]

The Receivers record data which are regular and are usually set at intervals say, every 2, 5, 10, 30 seconds, as defined by the receiver user and also a function of the task at hand. Receiver clock time \( T \), readings are used to identify when the measurement was made (Ehigiator – Irughe and Ehigiator, 2012). Therefore, the value of \( T \) at a measurement epoch is known exactly, and is written to the data file along with the observation, the unknown parameter is the true time of measurement. Therefore, the actual observation to satellites can be written thus:

\[
P^S = (T - T^S) C
\]

By substituting equating (2) into (3), we have

\[
\rho^S (t) = C((t + \tau) - (t^S + t^S))
\]

By re-arranging, equation (4) we have

\[
\rho^S (t) = C((t - t^S) + (\tau - t^S))C
\]

Where \( T \) is time when the transmitted signal was received at Receiver ground station, \( T^S \) is the satellite transmitted time, \( \rho \) is the range, \( C \), the speed of light is given as 299792458 m/s. The Pseudorange from Satellite to Receiver is thus given as (Blewitt, 2003).
\[ \rho^S(t, t^S) = \sqrt{\left( x^S(t^S) - x(t) \right)^2 + \left( y^S(t^S) - y(t) \right)^2 + \left( z^S(t^S) - z(t) \right)^2} \]  

(6)

The Navigation message allows us to compute the satellite position \((x^S, y^S, z^S)\) and the satellite clock bias \(\tau\). Therefore, we are left with 4 unknowns, the receiver position \((x, y, z)\) and the receiver clock bias \(\tau\). It is important to determine the satellite position at transmission time, \(t^S\). This is because the satellite range can change as much as 60 meters within 0.07 seconds from the time the signal was transmitted, to the time the signal was received. Starting with the receive time, \(t\), the transmit time can be computed by an iterative algorithm known as “the light time equation,” which can be written as follows \([\text{Blewitt}, 2003]\).

\[
\begin{align*}
t^S(0) &= t = (T - \tau) \\
t^S(1) &= t - \frac{\rho^S(t, t^S(0))}{C} \\
t^S(2) &= t - \frac{\rho^S(t, t^S(1))}{C}
\end{align*}
\]

(7)

The satellite position (and hence the range \(\rho^S(t, t^S)\)) is calculated at each step using the Keplerian-type elements from the Navigation Message. The algorithm is discontinued when there is convergent. Although more rapidly converging methods have been implemented, the above method is probably the easiest to understand. From equation (6) we can write a system of simplified observation equations from 4 satellites in view of the receiver. Using the above notation, we can write the pseudoranges equations for 4 satellites as \([\text{Ehigiator – Irughe and Ehigiator, 2012}]\);

\[
\begin{align*}
\rho^1 &= [(X_1 - X_p)^2 + (Y_1 - Y_p)^2 + (Z_1 - Z_p)^2]^{1/2} + c\tau - c\tau^1 \\
\rho^2 &= [(X_2 - X_p)^2 + (Y_2 - Y_p)^2 + (Z_2 - Z_p)^2]^{1/2} + c\tau - c\tau^2 \\
\rho^3 &= [(X_3 - X_p)^2 + (Y_3 - Y_p)^2 + (Z_3 - Z_p)^2]^{1/2} + c\tau - c\tau^3 \\
\rho^4 &= [(X_4 - X_p)^2 + (Y_4 - Y_p)^2 + (Z_4 - Z_p)^2]^{1/2} + c\tau - c\tau^4
\end{align*}
\]

(8)

Where \(X_n, Y_n, Z_n\) = the coordinates of satellites 1, 2, 3 and 4 \((n = 1 \text{ to } 4)\)  
\(X_p, Y_p, Z_p\) = the coordinates required for point \(p\)

2.3. Phase Differencing Modes

There are three types of phase differing modes in GNSS observation, these are; (1) Single, (2) Double and (3) Triple respectively. For this project the mode employed is double differencing mode which shall be discussed as follow.

2.4. Double Differencing Mode

The double-difference mode is executed between a pair of receivers and pair of satellites as shown in Figure (3). It involves taking the difference of two single differences obtained from two satellites \(j\) and \(k\). The procedure eliminates the receiver clock bias as follows;

\[
\begin{align*}
\phi^j_{AB}(t) &= \frac{1}{\lambda} \rho^j_{AB}(t) + N^j_{AB} - f^j \delta^j_{AB}(t) \\
\phi^k_{AB}(t) &= \frac{1}{\lambda} \rho^k_{AB}(t) + N^k_{AB} - f^k \delta^k_{AB}(t)
\end{align*}
\]

(9)
Figure 4: The Double-Difference Technique.

Taking the differences between the two equations in (9) the receiver clock errors, \( f^j \delta_{AB}^j(t) \) and \( f^k \delta_{AB}^k(t) \) are eliminated thus;

\[
\phi_{ab}(t)-\phi_{ab}(t) = \frac{1}{\lambda} \left[ P_{ab}(t)-P_{ab}(t) \right] + \left[ N_{ab} - N_{ab}^k \right]
\]

Using the short hand notation as in the single-difference

\[
\phi_{ab}^{j,k}(t) = \frac{1}{\lambda} \rho_{ab}^{j,k}(t) + N_{ab}^{j,k}
\]

The result of this mode is the omission of the receiver clock offsets. The double-difference model for long baselines when there is a significant difference in the atmospheric effect between the two baselines ends can be expressed as:

\[
\phi_{ab}^{j,k}(t) = \frac{1}{\lambda} \rho_{ab}^{j,k}(t) + N_{ab}^{j,k} - \frac{1}{\lambda} \Delta_{ab}^{i,k} \text{Ion} (t) + \frac{1}{\lambda} \Delta_{ab}^{i,k} \text{Trop} (t)
\]

2.5. Linearised Model

For completeness, we summarize the linearisation procedure and the development of the least squares method specifically for the GPS point positioning problem. First, we assume we can write the actual observation to be the sum of a modelled observation, plus an error term;

\[
P_{\text{observed}} = P_{\text{model}} + \text{noise}
\]

\[
= P(x, y, z, \tau) + \nu
\]

The provisional parameter values is given as \((x_0, y_0, z_0, \tau_0)\), using Taylor’s theorem the computed model can be expanded thus by ignore second and higher order terms.

\[
P(x, y, z, \tau) = \left\{ \begin{array}{l}
P(x_0, y_0, z_0, \tau_0) + (x-x_0) \frac{\partial P}{\partial x} + (y-y_0) \frac{\partial P}{\partial y} + (z-z_0) \frac{\partial P}{\partial z} + (\tau-\tau_0) \frac{\partial P}{\partial \tau} \\
= P_{\text{computed}} + \frac{\partial P}{\partial x} \Delta x + \frac{\partial P}{\partial y} \Delta y + \frac{\partial P}{\partial z} \Delta z + \frac{\partial P}{\partial \tau} \Delta \tau
\end{array} \right\}
\]

The residual observation is the difference between the actual observation and the computed using the provisional parameter values i.e.

\[
\Delta P = P_{\text{observed}} - P_{\text{computed}} = \frac{\partial P}{\partial x} \Delta x + \frac{\partial P}{\partial y} \Delta y + \frac{\partial P}{\partial z} \Delta z + \frac{\partial P}{\partial \tau} \Delta \tau + \nu
\]
\[ \Delta P = \begin{bmatrix} \frac{\partial P}{\partial x} & \frac{\partial P}{\partial y} & \frac{\partial P}{\partial z} \\ \frac{\partial P}{\partial \tau} \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \\ \Delta \tau \end{bmatrix} + v \]  

(15)

The above equation is for one satellite, for n satellite, we can develop similar equation which is often written as:

\[ b = Ax + v \]  

(16)

The estimated residual is given as:

\[ v = b - Ax \]  

(17)

The “least squares” solution can be found by varying the value of ‘x’ until the following functional is minimized thus:

\[ J(X) = \sum_{j=1}^{m} v_j^2 = v^T v = (b - Ax)^T (b - Ax) \]  

(18)

The normal equation to the solution is given as:

\[ \hat{x} = (A^T A)^{-1} A^T b \]  

(19)

The design matrix A which is usually the partial derivatives of each observation with respect to each parameter derived from the provisional values assuming n = 4 and data m, which can be written as:

\[
A = \begin{bmatrix}
\frac{x_0 - x^1}{\rho} & \frac{y_0 - y^1}{\rho} & \frac{z_0 - z^1}{\rho} & c \\
\frac{x_0 - x^2}{\rho} & \frac{y_0 - y^2}{\rho} & \frac{z_0 - z^2}{\rho} & c \\
\frac{x_0 - x^m}{\rho} & \frac{y_0 - y^m}{\rho} & \frac{z_0 - z^m}{\rho} & c
\end{bmatrix}
\]  

(20)

2.6. Datum Transformation

The term Datum is used to describe the reference frame for geodetic computation which define the parameters regarding the relationship between the ellipsoid and the real earth (Geoid). The position of a point on the earth surface can be given either in terms of (φ, λ, h) or (X, Y, Z) coordinates systems. Whist every systems used have an origin and have a relationship for transformation to other systems. The transformation from (φ, λ, h) system to (X, Y, Z) system can be achieved using the following relationship.

\[
X = \left[ N + h \right] \cos \phi \cos \lambda \\
Y = \left[ N + h \right] \cos \phi \sin \lambda \\
Z = \left[ \frac{N(1 - e^2) + h}{1 - e^2} \sin \phi \right]
\]  

(21)

Where \( N \) is radius vector of the prime vertical, \( h \) is the point above ellipsoid, \( e \) is the eccentricity. \( N \) and \( e \) are given by:

\[
e^2 = 2f - f^2
\]

\[
N = \frac{a}{(1 - e^2 \sin^2 \phi)^{1/2}}
\]  

(22)

Where, \( a \), is the major axis of the earth and \( f \), is the flattening of the reference ellipsoid. For WGS84, \( a = 6,378,137 \text{m}, f = 1/298.257223563 = 0.003352810665. \)
The inverse formula for obtaining $\phi$, $\lambda$, $h$ from $X$, $Y$, $Z$ is

\[
\begin{align*}
\tan \lambda &= \frac{Y}{X} \\
\tan \phi &= \left( Z + e^2 N \sin \phi \right) / \left( X^2 + Y^2 \right)^{1/2} \\
h &= (N + H) = (X \sec \lambda \sec \phi) - N
\end{align*}
\]

(23)

Where, $N$ is the geoidal undulation, $H$ is the orthometric height.

Using equations (1), the coordinate of the reference station was transformed to its equivalent geodetic coordinates in (WGS84) and the result is as presented in Table 1. Table 1a shows, the coordinate of the master control station in terms of longitude, latitude and height in the world geodetic coordinate system. Table 1b shows, the coordinate of the master control station in terms of Cartesian coordinate world geodetic coordinate system.

**Table 1a:** Reference Points in WGS84 (BLH) coordinate

<table>
<thead>
<tr>
<th>Stn/ Name</th>
<th>Lat (m)</th>
<th>Std.Dev (mm)</th>
<th>Lon (m)</th>
<th>Std.Dev (mm)</th>
<th>H (m)</th>
<th>Std.Dev (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN_GPS_100</td>
<td>006:24:13.88500N</td>
<td>0.0</td>
<td>005:36:57.82950E</td>
<td>0.0</td>
<td>129.2223</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Table 1b:** Reference point in WGS 84 (NEU) coordinate

<table>
<thead>
<tr>
<th>Stn/ Name</th>
<th>X(m)</th>
<th>Y(m)</th>
<th>U(m)</th>
<th>Std.Dev_N (mm)</th>
<th>Std.Dev_E (mm)</th>
<th>Std.Dev_U (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN_GPS100</td>
<td>6308306.5178</td>
<td>620320.5452</td>
<td>706672.3149</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Table 2:** Adjusted Points in WGS84 (XYZ)

<table>
<thead>
<tr>
<th>Station From</th>
<th>Station To</th>
<th>X(m)</th>
<th>Y(m)</th>
<th>Z(m)</th>
<th>Std.Dev_X(mm)</th>
<th>Std.Dev_Y(mm)</th>
<th>Std.Dev_Z(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGUE_GPS_01</td>
<td>UB_GPS100</td>
<td>6308270.1677</td>
<td>617684.1797</td>
<td>709442.2558</td>
<td>221.4</td>
<td>165.5</td>
<td>104.0</td>
</tr>
<tr>
<td>IGUE_GPS_02</td>
<td>IGUE_GPS_03</td>
<td>6308311.1310</td>
<td>617705.4102</td>
<td>709007.9638</td>
<td>166.9</td>
<td>112.3</td>
<td>89.8</td>
</tr>
<tr>
<td>IGUE_GPS_03</td>
<td>IGUE_GPS_04</td>
<td>6308573.4899</td>
<td>615336.6332</td>
<td>708732.1312</td>
<td>117.0</td>
<td>75.1</td>
<td>61.3</td>
</tr>
<tr>
<td>IGUE_GPS_04</td>
<td>IGUE_GPS_05</td>
<td>6308534.4371</td>
<td>615349.9549</td>
<td>709096.0886</td>
<td>189.9</td>
<td>86.1</td>
<td>75.9</td>
</tr>
<tr>
<td>IGUE_GPS_05</td>
<td>IGUE_GPS_06</td>
<td>6308397.1361</td>
<td>616529.1721</td>
<td>709273.9753</td>
<td>142.5</td>
<td>59.2</td>
<td>65.9</td>
</tr>
<tr>
<td>IGUE_GPS_06</td>
<td>IGUE_GPS_07</td>
<td>6308445.3406</td>
<td>616467.4822</td>
<td>708871.8646</td>
<td>183.9</td>
<td>70.5</td>
<td>97.7</td>
</tr>
<tr>
<td>IGUE_GPS_07</td>
<td>IGUE_GPS_01</td>
<td>6308310.0199</td>
<td>617710.3923</td>
<td>709013.1154</td>
<td>206.5</td>
<td>77.3</td>
<td>107.8</td>
</tr>
<tr>
<td>IGUE_GPS_01</td>
<td>UB_GPS100</td>
<td>6308306.5178</td>
<td>620320.5452</td>
<td>706672.3149</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The adjusted points in Table 2 are the coordinates of the control point established with their corresponding standard deviations produced by the software after performing network adjustment.

2.7. GPS Data Downloading and Processing

The data was downloaded from the master and rover GPS into the computer and Hi-Target software was used to process the data which was then used in Auto CAD and ArcGIS to produce the plan and three-dimensional map of the project area.

2.8. Adjustments of Observations

The qualities to be obtained after field measurements and adjustment in a GNSS network involving both adjusted and unadjusted baseline vector components, their covariance and the final coordinates. We perform baseline adjustment using UB_GPS_100 as our master control point which was held fixed.
The Geodetic coordinates in (WGS 84) for GPS_01 for example can be derived by taking into account the baseline that connect it to the master control as presented in Table 3. To determine the Geodetic coordinates of other points, the baselines of observations must be considered in succession in the network. The Geodetic coordinates for (IGUE) GPS_01, the baseline is from UB_GPS_100. For (IGUE) GPS_02, the baseline is from (IGUE) GPS_01 and so on. This relationship can be presented for the first baseline as we have in equation (24);

\[
\begin{align*}
[UB \_GPS \_100]X &= X_{Igue \_gps \_01} + \Delta X_{Corrected} + Vx \\
[UB \_GPS \_100]Y &= Y_{Igue \_gps \_01} + \Delta Y_{Corrected} + Vy \\
[UB \_GPS \_100]Z &= Z_{Igue \_gps \_01} + \Delta Z_{Corrected} + Vz 
\end{align*}
\]

Using equation (24), other positions were determined with respect to their corresponding baselines. Our results are presented for other points in table 3. Equations 16, 17, 18, 19 and 20 played vital roles in the adjustment procedure.

**Table 3: Baseline Residuals**

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Uncorrected Baseline</th>
<th>Baseline Residual</th>
<th>Corrected Baseline</th>
<th>Northing</th>
<th>Easting</th>
<th>Ellip. Hgt</th>
</tr>
</thead>
<tbody>
<tr>
<td>From</td>
<td>To</td>
<td>( \Delta X )</td>
<td>( \Delta Y )</td>
<td>( \Delta Z )</td>
<td>( V_x )</td>
<td>( V_y )</td>
</tr>
<tr>
<td>UB_GPS100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>IGUE_GPS_01</td>
<td>UB_GPS100</td>
<td>38.22</td>
<td>-203.46</td>
<td>-278.94</td>
<td>0.0010</td>
<td>-0.0241</td>
</tr>
<tr>
<td>IGUE_GPS_02</td>
<td>IGUE_GPS_01</td>
<td>-46.96</td>
<td>-21.23</td>
<td>43.29</td>
<td>0.0071</td>
<td>0.0077</td>
</tr>
<tr>
<td>IGUE_GPS_03</td>
<td>IGUE_GPS_04</td>
<td>-262.35</td>
<td>294.11</td>
<td>275.83</td>
<td>0.0020</td>
<td>0.0019</td>
</tr>
<tr>
<td>IGUE_GPS_04</td>
<td>IGUE_GPS_05</td>
<td>39.05</td>
<td>-13.32</td>
<td>-303.95</td>
<td>-0.0011</td>
<td>-0.0094</td>
</tr>
<tr>
<td>IGUE_GPS_05</td>
<td>IGUE_GPS_06</td>
<td>177.30</td>
<td>-179.71</td>
<td>-377.88</td>
<td>0.0073</td>
<td>-0.0222</td>
</tr>
<tr>
<td>IGUE_GPS_06</td>
<td>IGUE_GPS_07</td>
<td>-48.20</td>
<td>61.68</td>
<td>402.11</td>
<td>0.0123</td>
<td>0.0013</td>
</tr>
<tr>
<td>IGUE_GPS_07</td>
<td>UB_GPS100</td>
<td>115.32</td>
<td>-124.91</td>
<td>-141.25</td>
<td>0.0102</td>
<td>-0.0253</td>
</tr>
</tbody>
</table>

In Table 3, the station points, the master station in red held fixed, the vectors of corrected and uncorrected baselines also the coordinates of points including the eastings, northings and heights of each points.

**Table 4: Adjusted Points in Target System (NEU)**

<table>
<thead>
<tr>
<th>Station From</th>
<th>Station To</th>
<th>N (m)</th>
<th>E (m)</th>
<th>H (m)</th>
<th>Std.Dev._N (mm)</th>
<th>Std.Dev._E (mm)</th>
<th>Std.Dev._U (mm)</th>
<th>Linear accuracy</th>
<th>Ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGUE_GPS_01</td>
<td>UB_GPS100</td>
<td>208909.8937</td>
<td>351637.2480</td>
<td>145.3475</td>
<td>101.6</td>
<td>147.0</td>
<td>234.7</td>
<td>1.885335049205</td>
<td>0.0008</td>
</tr>
<tr>
<td>IGUE_GPS_02</td>
<td>IGUE_GPS_03</td>
<td>208164.6133</td>
<td>351655.3113</td>
<td>139.3252</td>
<td>93.0</td>
<td>100.8</td>
<td>172.4</td>
<td>1.016102597830</td>
<td>0.0016</td>
</tr>
<tr>
<td>IGUE_GPS_03</td>
<td>IGUE_GPS_04</td>
<td>207882.0914</td>
<td>349273.0613</td>
<td>138.9583</td>
<td>58.1</td>
<td>69.7</td>
<td>121.9</td>
<td>1.150445402589</td>
<td>0.0015</td>
</tr>
<tr>
<td>IGUE_GPS_04</td>
<td>IGUE_GPS_05</td>
<td>208247.9054</td>
<td>349289.3478</td>
<td>142.3395</td>
<td>70.3</td>
<td>79.4</td>
<td>194.9</td>
<td>1.350600012717</td>
<td>0.0035</td>
</tr>
<tr>
<td>IGUE_GPS_05</td>
<td>IGUE_GPS_06</td>
<td>208429.6720</td>
<td>350475.8339</td>
<td>140.3413</td>
<td>63.7</td>
<td>59.8</td>
<td>143.3</td>
<td>1.313503054333</td>
<td>0.0013</td>
</tr>
<tr>
<td>IGUE_GPS_06</td>
<td>IGUE_GPS_07</td>
<td>208025.2899</td>
<td>350410.0048</td>
<td>137.0538</td>
<td>97.4</td>
<td>73.8</td>
<td>182.8</td>
<td>1.550811505019</td>
<td>0.0005</td>
</tr>
<tr>
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<td>IGUE_GPS_01</td>
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<td>351660.3665</td>
<td>139.2854</td>
<td>108.6</td>
<td>82.2</td>
<td>204.2</td>
<td>1.313870689567</td>
<td>0.0031</td>
</tr>
<tr>
<td>IGUE_GPS_01</td>
<td>UB_GPS100</td>
<td>205821.5360</td>
<td>354285.2030</td>
<td>127.6627</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 4 shows the stations, adjusted points and their standard deviations in the target system (national system) standard deviation of zeros indicate a control point that was fixed and is assumed to be error free. The accuracy in part per million was presented and the distances of each base line as well.
The formula to perform the Molodensky Abridge Model for transforming WGS84 to the equivalent Minna datum Geographical coordinates read thus:

$$\Delta \phi'' = \left[ -t_x \sin \phi \cos \lambda - t_y \sin \phi \lambda + t_z \cos \phi + (a \Delta f + f \Delta a) \sin 2\phi \left( M \sin \lambda \right) \right]$$ (25a)

$$\Delta \lambda'' = \left[ -t_x \sin \lambda + t_y \cos \lambda \right] \left( V \cos \phi \sin \lambda \right)$$ (25b)

$$\Delta \phi'' = \left[ -t_x \sin \phi \cos \lambda - t_y \sin \phi \lambda + t_z \cos \phi + (a \Delta f + f \Delta a) \sin 2\phi \left( M \sin \lambda \right) \right]$$ (25c)

$$V(\phi) = \frac{a_L}{1 - e^2 2 \left( 1 - e^2 \sin^2 \phi \right) \left( 1 - e^2 \sin^2 \phi \right)^2}$$ (26)

Where:
- $t_x, t_y, t_z$: are the translations between both datums (in geocentric coordinates);
- $\phi, \lambda, h$: geodetic co-ordinates of the local geodetic system ellipsoid;
- $\Delta \phi, \Delta \lambda, \Delta h$: corrections to transform local datum co-ordinates to WGS84 $\phi, \lambda, h$;
- $\Delta X, \Delta Y, \Delta Z$: corrections to transform local datum co-ordinates to WGS84 $X, Y, Z$;
- $\Delta a, \Delta f$: (WGS84 minus local) semi-major axis and flattening respectively;
- $a$: semi-major axis of the local geodetic system ellipsoid;
- $f$: flattening of the local geodetic system ellipsoid;
- $V(\phi)$: radius of curvature in the meridian;
- $M(\phi)$: radius of curvature in the prime vertical.

The datum shift parameters derived by Shell Petroleum Development Company (SPDC) are presented thus: Datum Shift Parameters from WGS84 to Minna Datum Geographical coordinates are:

- $t_x = \text{plus} 111.916$
- $t_y = \text{plus} 87.852$
- $t_z = \text{minus} 114.499$
- $a_L = 6378249.145$
- $f_L = 1/293.465$
- $\Delta f = \text{minus} 0.54750714$
- $\Delta a = 112.145$

The accuracy standard for each baseline can be derive from linear accuracy relationship given as:

$$1 \cdot \frac{\left( Vx^2 + Vy^2 + Vz^2 \right)^{1/2}}{l_{ac}}$$ (27)

$Vx, Vy$ and $Vz$ are as presented in table (4) and $l_{ac}$ is the baseline length.

Dividing equation (27) by 1,000,000 gives the accuracy in part per million (ppm).

### 3.0. Analysis of Results and Plan Production

Adjustment of data made it possible for further use in a GIS software environment. AutoCAD enables the plan of the project area to be plotted and is as presented in the following Figures 5a and 5b. Figure 5a shows the contour which depict the difference in height as one traverse from one point to the other within the project site. This is usually useful for engineers in project design. Figure 5b depict the modelling of surface water flow on the project site assuming water is allowed to freely flow on the project site. This will be of value should there be a need to control or monitor erosion on the site.
Due to the fact that no satellites under horizon are available, GPS receivers can only receive signals from satellites above ground. This results in a poor geometry for fixing the height component in GPS measurements. In contrast, the horizontal components are fixed by satellites from different azimuths of the sky. It is therefore the VDOP value is higher than the HDOP value and the accuracy of vertical component is often less precise than horizontal one by 2 to 3 times or even more depending on the satellite geometry (Choi et al, 2007). The height (H) used in producing the plan in figure 5c was presented in table 3 alongside the coordinate of points in the horizontal (X, Y) plane. At confidence level of 10.00σ, significance level for tau test: 1.00% and ratio of standard error of unit weight: 61.7841.

The accuracy of the heights are not as good as that of the horizontal due to Satellite Constellation: Tropospheric Delay, Phase Centre Variation (PCV) and Offset: Multipath, Geoid-ellipsoid Separation Accuracy etc. as can be observed from table 4 considering the standard deviation in E,N and H. EGM 2008 was used to obtain the orthometric heights within the project area.

The heights used as anchor points in determining relative heights of other points within the network used to model water flow direction in figure 3 was presented in table 4 and the accuracy of each station was computed using the baseline residual values substituted in equation 27 provided earlier.

4.0. Conclusion and Recommendation

GNSS controls were successfully established at Igue-Iheya/Isiohor palm plantation farm, these controls can serve as bases for future surveying and mapping exercise around the area. (GNSS) method of densifying control is a versatile, accurate, quick, better, time-saving and economical way of establishing control points. It is therefore recommended that surveyors and mapping agencies should key into the enormous advantages of DGPS in establishing control stations through this high precision technique for mapping within an area where controls are not readily available.

Although, one master (base) control point have been used in this work, for best practices it is good to use two or three control points. Time of occupation should be considered based on base line length, this
will minimize error propagation within the network and further increase the reliability and accuracy level.

References


A Comparison of Monte Carlo Simulation and Discounted Cash Flow Investment Appraisal Techniques Using an Office Building in Akure, Nigeria

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ABSTRACT

Every rational investor aimed to secure an optimum return from an investment at certain level of risk. However, the factors that affect the realization of the expected return are not known with certainty. Therefore, the reliability of a single point estimate for investment decision is debatable particularly when the likelihood of realizing the expected return is crucial to the investor. This study aimed at examining a better method of analysing the uncertainty in property investment rather than the use of the single point estimate formula. We collected a set of historic data from a multi-tenanted office complex in Akure to carry out the investment analysis using Monte Carlo simulation and Discounted Cash Flow Technique. The results from the study were compared and revealed that the single point estimate accounted for a huge level of risk as probability of realizing the expected return is unknown. The Monte Carlo simulation offers a more robust opportunity for a measured investment decisions by providing a probability of realizing different level of the expected returns. The study concludes that it is difficult to make a smart investment decision on a single point estimate. It therefore recommends the use of Monte Carlo simulation for property investment analysis for a more realistic return.

Keywords: Monte Carlo, Nigeria, Simulation, Single-point estimate, Probabilistic

1.0. Introduction

Investment generally denotes the giving up of capital sum in expectation of future return or stream of income (Martin, 2010). A rational investor therefore considers the total cost of the investment with the return, minding the time, size, value and the flow of the expected return from the investment (Babawale, 2007). Real estate investment analysis often involves the use of the traditional deterministic approach. This approach does not take cognizance of the uncertainties surrounding the cash flows (Hoesli, et al., 2005). It only assumes a theoretical certainty in estimating the investment analysis variables. In this, investment analysts usually adopt the single point estimation for the analysis (Kelliher and Mahoney, 2000; French and Gabrielli, 2004). The exact state of each of these variables in the future is often uncertain at the time the investment decision is made, and a future change in any of these variables could culminate in a misleading analysis.

There is therefore a need for proper account for future uncertainty in investment analysis, real estate investment inclusive. An accurate management of the effect of uncertainty in real estate investment enhances the credibility and reputation of the analyst and the utility of the analysis and method/technique (French and Gabrielli, 2004). Therefore, it is necessary for investment analysts to ensure that the method used for real estate investment analysis gives allowance for future uncertainties that could arise in the projected investment variables. This could be done by generating a stochastic process for the variables which the deterministic approach is incapable, hence a need for a probabilistic approach (Balogh et al., 2013).

Monte Carlo simulation is a form of probabilistic investment analysis which gives an opportunity for stochastic process for the investment variables unlike the close-form formulas of the single point estimates. This is able to give an opportunity for developing large scenarios to accommodate several...
future possibilities (Baroni et al., 2006). Uncertainties in real estate portfolio are most times beyond the control of the investor and there is rationally an urge into searching for probable effects of these uncertainties in order to take viable decision on the investment. Both cash inflows and cash outflows are parts of the elements that constitute risk and uncertainty to the investors and therefore require adequate consideration in the investment analysis (Suhonen, 2014).

Monte Carlo simulation generates several scenarios that could possibly arise in the future around the single point estimation. It starts from the extreme worse case scenarios to the extreme good situation, and for each of these scenarios, the chosen single point investment analysis model is applied (Baroni et al 2006). The results from the Monte Carlo simulation analysis could then be statistically analysed to have a basis for the comparison with the single point estimation and then used to give advice to the investor on what could probably happen in the future and the chances of occurrence of the implications of changes in the various investment variables.

1.1. Single-point estimate approach of real estate investment analysis

The single point estimate considers the determination of what is possible to be the estimates of the variable input and appraised the investment on this, using closed-form formulas (Dupuy, 2003). One of the popular methods of using the single point estimate for real estate investment analysis is the Discounted Cash Flow (DCF) approach (Suhonen, 2014). This refers to an income valuation, where there is an application of a particular discount rate to investment cash flow for a given number of years, discounted to the present value (Damodaran, 2002). The DCF works on the premise of calculating the present value of expected future income for each year of the cash flow period. It also gives consideration for the residual value at the end of the holding period (Fetibegovic and Nilsson, 2011). The DCF does not give account to variability of the parameters due to risk and uncertainty. It only runs with the estimated variable and computes the appraisal singly (Dupuy, 2003; Suhonen, 2014). According to Kelliher and Mahoney (2000), the DCF technique makes use of the future cash flow, timing of the future cashflows, the discount rate.

The Discounted Cash Flow is defined as:

$$ PV = \sum \frac{C_t}{(1+r)^t} - I_0, $$

where $PV = \text{present (market) value}; C_t = \text{forecasted incremental cash flow after corporate taxes} - \text{strictly speaking the mean of the distribution of possible } C_t \text{ values}, t = \text{project life (Ct includes any salvage value)} \text{ and } r = \text{the opportunity cost of capital defined as the equilibrium expected rate of return on securities equivalent in risk in the project being valued.}$

Suhonen (2014) compared the Monte Carlo simulation with the DCF in supporting retail real estate investment decision. The results of the study showed that the traditional DCF is an investment appraisal method which gives only a single point valuation. Babawale (2007) examined four conventional single point estimates techniques; the payback period, the risk adjusted rate, discounted cash flow and sensitivity analysis and explained that these traditional valuation methods suffer from numerous limitations and criticisms, but, in particular, they all suffer at least from the same inherent limitations: they do not appropriately take the risk into account and they are highly sensitive to changes in parameters that constitute risk (Amedee-Manesme, et al., 2011). The use of Discounted Cash Flow (DCF) in real estate investment analysis has been discussed in several literatures; their applications, advantages and shortcomings, especially in not being able to account for uncertainty (Hoesli et al, 2006; Ojo, 2006; Babawale, 2007 and Amedee-Manesme et al, 2011). However, most of these literatures that examined the shortcomings of the single point estimate were mostly foreign to Nigeria. The results of Babawale (2007) which is Nigerian also needs to be updated and examined on another property investment opportunity, and in this study, the office building is considered.

1.2. Monte Carlo Simulation of real estate investment appraisal

Uncertainty is a common phenomenon in real estate investment. It is not absolutely certain that the expected future income from real estate investment would be as realized. Uncertainty refers to anything that is not known about the outcome of a venture as at the time of investment decision. The uncertainty surrounding the use of the single point estimate in the traditional DCF investment analysis process
comes from possible incorrect estimation of the input figures in the analysis. It could be possible to have a prediction of the probable values, but the possibility of variation is unavoidable (French and Gabrielli, 2004). Therefore, investment analysts develop models which could account for the uncertainties that surround the variables used in the investment analysis. One of these methods is the use of Monte Carlo simulation technique, which assigns probabilities to the input variables of the DCF model (Adair, 1996).

Monte Carlo Simulation has been used in finance to simulate iterations for the prices of derivatives and to predict future prices of stock (Hoesli et al., 2006). In real estate investment analysis, Pyhrr (1973) created a simulation model for the measurement of the risk associated with the investment. The study compared the use of the traditional DCF with Simulation analysis of the investment. Unlike the DCF method, Pyhrr (1973) found that the Simulation was able to accommodate the risk associated with the investment. Much of the later studies on the topic are based on this initial research of Pyhrr (1973).

Hoesli et al (2006) used Monte Carlo simulation to predict property values with the use of adjusted present value method and discovered that central values of the simulations are in most cases slightly less than the hedonic values. The confidence intervals are found to be most sensitive to the long-term equilibrium interest rate being used and to the expected growth rate of the terminal value. Most importantly, Hoesli et al (2006) also found that the use of Monte Carlo simulation has been found to be a useful tool for improving long-term investment decision making.

Amedee-Manesme et al, (2011) also combined the Monte-Carlo simulations and options for the management of risk of real estate portfolios. The study used Monte Carlo approach to simulate the probabilities surrounding the market prices and rental values. It revealed that the Monte Carlo simulation could distribute the probability of the cash flows over the period of the investment. The findings of Amedee-Manesme et al (2011) is in consonance with Baroni et al (2005) where Monte Carlo Simulation was used to simulate the rental value and the price of the investment. Baroni et al (2005) was also able to simulate the terminal value rather than the usual traditional method which is dependent on hazardous infinite growth rate.

Jayaraman’s (2013) review of Monte Carlo methods in real estate investment analysis explained that the technique was able to account for the uncertainty introduced into the analysis by the different parameters in consideration. The study found that the technique of Monte Carlo simulation could be adapted to the various traditional models of real estate investment analysis like the Discounted Cash Flow (DCF) and the Adjusted Present Value (APV) to properly account for uncertainties in real estate investment analysis. The study also revealed that the uncertainty is modeled in the Monte Carlo approach as a probabilistic differential equation which is simulated through the technique. Keith (2014) incorporated uncertainty into real estate investment analysis. The study made use of the probabilistic technique of Monte Carlo simulation to incorporate the uncertainties and the various options in real estate investment decisions. It was found from the work that the Monte Carlo simulation was able to provide different results rather than the single results from the deterministic models. This was found to be able to give the real estate investment analysts different angles of addressing real estate valuations problems.

In Nigeria, Babawale (2007) also worked on risk analysis in property investment using Monte Carlo Simulation Technique. The study carried out the analysis of a 55-room hotel development using the conventional method and then compared with the results from the Monte Carlo simulation technique. The study discovered that the Monte Carlo simulation technique offers possibilities of overcoming some of the weaknesses of the conventional methods as highlighted in the previous researches on the subject matter.

Observation shows that the application of Monte Carlo simulation in real estate investment analysis is fairly limited due to its demand for mathematical and statistical understanding (Hoesli et al, 2006). This has limited its application in real estate investment analysis in the developing nations of the world, Nigeria inclusive. However, the availability of different statistical software packages and technologies gives a good platform for carrying out Monte Carlo Simulation and in this study, the use of Microsoft Excel, which Nigerian investment analysts are more familiar with, is adopted for the simulation analysis.
This paper therefore applies the Monte Carlo simulation technique for real estate investment analysis using Microsoft Excel package which is more readily available to Nigerian real estate analysts. This is done with a view to validating the outcome of previous similar researches which were mostly from the developed countries of the world in a Nigeria city and with a particular reference to an office building unlike Babawale (2007) which was also in Nigeria but considered a hotel building at Lagos. This paper therefore aims at using the Monte Carlo simulation technique to analyze an office complex investment in Akure and comparing the results with a deterministic approach. This is done with a view to advising local real estate investment analysts on the best method to employ when dealing with the uncertainties.

2.0. Materials and Methods

2.1. Research design

This study adopted a purposive technique to collect data from some professionals in the built environment. These data are non-probabilistic in nature and are gotten from the respondents based on the probability of pessimism, optimism and the most possible. These data collected are then analyzed using both the Discounted Cash Flow (DCF) and the Monte Carlo Simulation.

2.2. Target population

The professionals in the built industry, especially the Estate Surveyors and Valuers, the Quantity Surveyors, the real estate developers were administered both close and open-ended questionnaire.

2.3. Study area and Case study property

Akure is the capital and the most populated city in Ondo State, South west Nigeria, characterised by the presence of notable commercial, financial and educational institutions being the state capital and the main administrative center of the state. The property market, even though nascent, is growing at a very high rate due to an increasing rate of immigration.

The case study property considered in this paper is the Nigerian Agricultural Cooperation and Rural Development Bank (NACRDB) building, an office complex, in Alagbaka commercial area, of Akure and is occupied by corporate offices. The property is a two-storey building, situated in a Central Business District (CBD) of the city, which makes it a good location for office building investment. It is one of the major purpose-built office properties in the location, where the historical records needed for this analysis could be easily gotten and used as a good sample for such investment in Alagbaka, Akure.

2.4. The data for the analysis

The data collected from the professionals was on the basis of the maximum, minimum and the best estimate values were derived from the average of the maximum and minimum values (see Table 1). For the simulation analysis, 1500 iterations were generated on Microsoft Excel package.

Table 1: Table showing the data

<table>
<thead>
<tr>
<th>Data required</th>
<th>Source</th>
<th>Number of Professionals considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>The unit cost of construction</td>
<td>Quantity surveying firms</td>
<td>Ten (10)</td>
</tr>
<tr>
<td>Rent per meter square</td>
<td>Estate Surveyors and Valuers (Both the firm in charge of the management of the building and the firms occupying the building)</td>
<td>Six (1); The managing firm and Five other estate surveying firms located on the building</td>
</tr>
<tr>
<td>Unit cost of repair and maintenance</td>
<td>Quantity surveyor and the managing Estate surveyors and Valuers</td>
<td>Ten (10) Quantity Surveying firms and the managing Estate surveying firm</td>
</tr>
<tr>
<td>Yield on the investment</td>
<td>Estate Surveyors and Valuers</td>
<td>Six (6) estate surveying firms</td>
</tr>
<tr>
<td>Year of investment</td>
<td>Estate Surveyors and Valuers</td>
<td>Six estate surveying firms</td>
</tr>
<tr>
<td>Year of review</td>
<td>Estate Surveyors and Valuers</td>
<td>Six estate surveying firms</td>
</tr>
</tbody>
</table>
2.5. Methods of Data Analysis

The descriptive statistics analysis was employed in this study. The descriptive statistics tools are; Mean, Standard deviation, Skewness and Kurtosis in analyzing the simulated results. The analysis of the single point estimate viability was done using the Discounted Cash Flow approach; DCF is defined as follows:

\[ PV = \sum \frac{C_t}{(1+r)^t} I_0, \]

where \( PV = \) present (market) value; \( C_t = \) forecasted incremental cash flow; \( t = \) project life; \( r = \) the opportunity cost of capital defined as the equilibrium expected rate of return on securities equivalent in risk in the project being valued. \( I_0 = \) initial capital outlay. NPV equals PV less the cash outlay required (initial investment).

2.5.1. Monte Carlo simulation model

Monte Carlo simulation model is given by:

\[ \Pr \left[ \frac{1}{N} \sum N \varepsilon - \mu < 3\sigma/\sqrt{N} \right] \approx 99.8\%, \]

where \( N \) is the number of iterations, \( \varepsilon \) is the error term and is denoted by \( 3\sigma/\sqrt{N} \), \( \sigma \) is the standard deviation (Wayne, 2004). To determine the required sample for simulation, the following model was used:

\[ N = \left( \frac{3\sigma}{\varepsilon} \right)^2, \]

where \( N \) is the number of iterations, \( \sigma \) is the standard deviation, \( \varepsilon \) is the total error. In Microsoft Excel, \( \sigma = \text{STDEV}(\text{MINIMUM:MAXIMUM}), \text{while, } \varepsilon = \frac{\text{AVERAGE}(\text{MINIMUM:MAXIMUM})}{1500}. \)

![Flow chart of the Monte Carlo Simulation process](image)

Figure 1: Flow chart of the Monte Carlo Simulation process

3.0. Results and Discussion

The minimum and maximum values were gotten from the responses of the respondents to the questionnaire as shown in Table 2. The rent per square meter in the building is within the range of \( N 5,000 \) and \( N 8,000 \) per annum depending on the floor. The cost of repair and maintenance and other ancillary cost during tenancy is in the range of \( N 83.333 \) and \( N 111.111 \). The cost of construction per meter square is in the range of \( N 65,000 \) and \( N 70,000 \). The average of the responses of the respondents on each of these data was used as the most probable estimate. The data obtained from the estate surveying and valuation firms indicate that rent review of such property is done on 10% upward review (inflation rate induced), which also reflects in the review of the cost of repair and maintenance. The discount rate is in the range of 5% - 15% as gotten from the Estate Surveying and Valuation firms and empirically substantiated in Udoekanem et al, (2014).
Table 2: The Data for the Investment Analysis

<table>
<thead>
<tr>
<th>S/N</th>
<th>Data</th>
<th>Source of data</th>
<th>Most possible maximum value</th>
<th>Most possible minimum value</th>
<th>Most probable (best estimates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rent per meter square</td>
<td>Estate surveyors and valuers</td>
<td>₦8,000</td>
<td>₦5,000</td>
<td>₦6,500</td>
</tr>
<tr>
<td>2.</td>
<td>Cost of construction per square meter</td>
<td>Quantity surveyors</td>
<td>₦70,000</td>
<td>₦65,000</td>
<td>₦66,000</td>
</tr>
<tr>
<td>3.</td>
<td>Cost of maintenance and repair per square meter</td>
<td>Quantity surveyor and estate surveyors and valuers</td>
<td>₦111.111</td>
<td>₦83.333</td>
<td>₦90</td>
</tr>
<tr>
<td>4.</td>
<td>Discount rate on commercial property</td>
<td>Estate Surveyors and Valuers</td>
<td>15%</td>
<td>5%</td>
<td>12.5%</td>
</tr>
<tr>
<td>5.</td>
<td>Year of the investment</td>
<td>Real estate investors; estate surveyors and valuers</td>
<td></td>
<td></td>
<td>20 YEARS</td>
</tr>
<tr>
<td>6.</td>
<td>Growth rate every 4 years (inflation rate induced), applicable to the repair and maintenance cost</td>
<td>Estate Surveyors and Valuers</td>
<td>11%</td>
<td>9%</td>
<td>10%</td>
</tr>
<tr>
<td>7.</td>
<td>Year of review</td>
<td></td>
<td></td>
<td></td>
<td>Every 4 Years</td>
</tr>
<tr>
<td>8.</td>
<td>Inflation rate as at the time of analysis</td>
<td>CBN publication</td>
<td>11%</td>
<td>9%</td>
<td>10%</td>
</tr>
</tbody>
</table>

3.1. Appraising the Investment Using DCF Single Point Estimate

The terminal value of the investment was derived by directly capitalizing the cash inflow for the next year after the investment period has been exhausted, for the remaining 79 years permissible according to the Land Use Act, 1978.

The capitalization rate is given as:

\[ \frac{1-PV}{i} \tag{5} \]

where,

\[ PV = \frac{1}{A} \tag{6} \]

Cash inflow for the next year after the investment period has been exhausted = ₦10,323.369. The capitalization rate/discount rate = 15%. The calculation from equation (5) gives 6.6666. This is then multiplied by the expected cash inflow for the year after the investment period has been exhausted; 6.6666 * 10,323.369 = ₦68,821.367. Therefore, the terminal value is = ₦68,821.367.

Table 3: Table showing the single point estimate of the investment

<table>
<thead>
<tr>
<th>Year</th>
<th>Rent/M²(₦)</th>
<th>Cost/M²(₦)</th>
<th>Net Rent/M²(₦)</th>
<th>PV N1@12.5%</th>
<th>DCF</th>
</tr>
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<tbody>
<tr>
<td>1-2</td>
<td>6500.00</td>
<td>90.000</td>
<td>6410.00</td>
<td>1.000000</td>
<td>6410.00</td>
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<td>6500.00</td>
<td>90.000</td>
<td>6410.00</td>
<td>0.790123</td>
<td>5064.691</td>
</tr>
<tr>
<td>5-6</td>
<td>7150.00</td>
<td>99.000</td>
<td>7051.00</td>
<td>0.624295</td>
<td>4401.905</td>
</tr>
<tr>
<td>7-8</td>
<td>7150.00</td>
<td>99.000</td>
<td>7051.00</td>
<td>0.493270</td>
<td>3478.048</td>
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<tr>
<td>9-10</td>
<td>7865.00</td>
<td>108.900</td>
<td>7756.100</td>
<td>0.389744</td>
<td>3022.896</td>
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<tr>
<td>11-12</td>
<td>7865.00</td>
<td>108.900</td>
<td>7756.100</td>
<td>0.307946</td>
<td>2388.461</td>
</tr>
<tr>
<td>13-14</td>
<td>8651.50</td>
<td>119.790</td>
<td>8531.710</td>
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<td>15-16</td>
<td>8651.50</td>
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<td>131.769</td>
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</tbody>
</table>

On a single point estimate, the cost of construction per square meter is ₦66,000, the terminal value at the end of 20 years, as calculated with the formula in equation (5) gives ₦68,821.367. Therefore, the NPV on the single point estimate is calculated as follows;
Using equation 2 and values of single point estimate from Table 3, the sum of the DCF is ₦33,855.417 (obtained from: $\text{PV} = \sum \frac{C_f}{(1+i)^t} + \text{Terminal Value} - I_0 = 31034.06 + 68,821.367 - 66,000 = ₦33,855.417$)

Therefore, from the single point estimate analysis, the investment is expected to be viable at ₦33,855.417. This indicates that the investment is viable based on the rent per square meter.

In reality, the chance of occurrence and other possible outcomes are not included in this estimation, hence a need for more robust method of analysis.

3.2. Appraising the Investment via Monte Carlo Simulation

Monte Carlo Simulation was adopted, the model in equation 2 was applied to carry out the analysis in Microsoft Excel. This was run to simulate 1500 scenarios that could occur within the range of input values given. The descriptive statistics which validate the reliability of the simulation are presented in Table 4.

Table 4: Summary of simulation viability results

<table>
<thead>
<tr>
<th>No. of iterations</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>17850.34</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>11414.23</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.680</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.574</td>
</tr>
<tr>
<td>Minimum</td>
<td>693.40</td>
</tr>
<tr>
<td>Maximum</td>
<td>49493.14</td>
</tr>
</tbody>
</table>

From Table 4, the Skewness shows that the distribution of the data is more to the positive, right side at 0.680 while the -0.574 value of the Kurtosis shows a relatively flattened top of the distribution of the data. The Skewness and Kurtosis still hold for the assumption of normality of the distribution of the Monte Carlo simulation results, as they are both not outside the range of -1.0 and +1.0. The value of the mean of the results of the viability from the simulation is 17850.34. This value is however higher than the highest possible viability of occurrence as shown in Table 2. The minimum viability value is 693.40 while the highest possible viability value is 49,493.14. This shows a huge variation in the viability of the investment that could occur if there is such change in the choice in the input variables by the analyst.

The Standard Deviation Value of 11414.23 shows a high amount of viability variation possible from the mean value of the viability of the investment.

Most of the simulation output was reported in the ₦5001 to ₦10000 range followed by the ₦10001-₦15000 range (See Table 5). The least return came in the ₦45001 to ₦50000 range, with 12 outcomes. The single point estimate gave a result of ₦33,855.417 that falls within the range of ₦30001-₦35000, with the probability of occurrence of 0.073 and the probability of not achieving at 0.832. However, from the simulated results, the range of the most probable chance of occurrence is ₦5000 to ₦10000, which is lower than the prediction from the single point estimate, a confirmation that the single point estimate can be misleading; this result corroborates the findings from Babawale (2007).

The advantage of the Monte Carlo simulation over the single point estimate is in the ability to give a better understanding of the various possible outcomes from the investment, using the iterated possibilities (See Figure 2 and Figure 3). This provides a better understanding of investment decision using the various possible estimates. If a single point estimate has been used for investment decision making, based on the high level of income from the investment, which is not impossible, say, on the NPV of ₦45001 to ₦50000 range, the probability of achieving this is however very low at 0.008 while the probability of not achieving high at 0.927, ditto all other higher NPV results. What is most probable is the result from the NPV of the range ₦5001 to ₦10,000 at 0.222. The standard deviation of ₦11414.23 shows the huge risk factor of ₦11414.23 if the decision on investment is based on a single point estimate.
Table 5: Results from the Simulation with the Frequency and Probability of their Achievement

<table>
<thead>
<tr>
<th>NPV Range(₦)</th>
<th>Frequency</th>
<th>Cumulative frequency of NPV</th>
<th>Percentage</th>
<th>Probability of achieving</th>
<th>Cumulative probability of achieving</th>
<th>Probability of not achieving</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5000</td>
<td>141</td>
<td>141</td>
<td>9.4</td>
<td>0.094</td>
<td>0.094</td>
<td>0.906</td>
</tr>
<tr>
<td>5001-10000</td>
<td>334</td>
<td>475</td>
<td>22.26</td>
<td>0.223</td>
<td>0.317</td>
<td>0.777</td>
</tr>
<tr>
<td>10001-15000</td>
<td>252</td>
<td>727</td>
<td>16.8</td>
<td>0.168</td>
<td>0.485</td>
<td>0.515</td>
</tr>
<tr>
<td>15001-20000</td>
<td>203</td>
<td>930</td>
<td>13.5</td>
<td>0.135</td>
<td>0.618</td>
<td>0.382</td>
</tr>
<tr>
<td>20001-25000</td>
<td>179</td>
<td>1109</td>
<td>11.93</td>
<td>0.119</td>
<td>0.739</td>
<td>0.261</td>
</tr>
<tr>
<td>25001-30000</td>
<td>130</td>
<td>1239</td>
<td>8.67</td>
<td>0.087</td>
<td>0.826</td>
<td>0.174</td>
</tr>
<tr>
<td>30001-35000</td>
<td>110</td>
<td>1349</td>
<td>7.33</td>
<td>0.073</td>
<td>0.899</td>
<td>0.101</td>
</tr>
<tr>
<td>35001-40000</td>
<td>93</td>
<td>1442</td>
<td>6.2</td>
<td>0.062</td>
<td>0.961</td>
<td>0.039</td>
</tr>
<tr>
<td>40001-45000</td>
<td>46</td>
<td>1488</td>
<td>3.07</td>
<td>0.031</td>
<td>0.992</td>
<td>0.008</td>
</tr>
<tr>
<td>45001-50000</td>
<td>12</td>
<td>1500</td>
<td>0.8</td>
<td>0.008</td>
<td>1</td>
<td>0.992</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1500</td>
<td>1500</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 2: Estimated Returns and Corresponding Chances of Occurrences

Figure 3: Graph of cumulative probability of achieving against the cumulative frequency of NPV
4.0. Conclusions

This study evaluates and compares the DCF and Monte Carlo simulation in investment appraisal. It applies primary data collected from an office complex. Analysis of the results from the DCF produced a single point estimate of the investment whose certainty is unknown. Using the same data, the Monte Carlo simulation analysis generated a range of results with known possibilities of occurrence. This implies that the result from the single point estimate could be misleading as the probability of realizing the estimate is unknown. The Monte Carlo simulation offers robust results with known possibilities. This gives the investors the opportunities to compare the probable outcomes from the several iterations. Subject to the level of risk preferred, the simulation allows the investor to choose a desired level of return from the investment.

The results of the analysis of this study have shown that the use of single point estimate in office building investment analysis is not capable of properly explaining the inherent uncertainties. However, the use of Monte Carlo Simulation was not only able to identify the uncertainties but also presents the chances of occurrence of the various outcomes of the investment decision.

It is shown from this study that property investment analysts in Nigeria should embrace the use of Monte Carlo Simulation in their analysis so as to facilitate a more efficient investment decision making by the investors through the various probabilities of outcomes that could be derived from Monte Carlo simulation results.

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Maintenance Practice and Occupant’s Satisfaction in Public Housing Estates: An Osogbo, Nigeria Perspective

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ABSTRACT

The paper appraises the maintenance practice and residents’ satisfaction of public housing estates in Osogbo, Nigeria with a view to encouraging best practices and adequate maintenance strategies in a proposition to preserving the existing housing stock and enhanced maintenance of public estates in the study area. One Hundred and Five (105) questionnaires were distributed among the residents of two (2) residential estates and 97 questionnaires were retrieved, representing 92.40%. Opinion of the Estate Surveyors and Valuers was also sought on the factors affecting maintenance in public housing estate. Analysis was carried out through the use of mean, severity index, cross-tabulation and Chi-Square test of association. It was discovered that there is no statistically significant relationship between maintenance practice and public services alongside infrastructures in the estates. Although, there is a significant relationship between occupants’ level of satisfaction with maintenance of public services and infrastructures; the Phi and Cramer's V tests revealed a very weak strength in the association. The paper therefore suggests an integrated maintenance approach for effective upkeep of public estates infrastructures and facilities.

Keywords: Estates, Maintenance Practice, Public Housing, Occupants, Satisfaction

1.0. Introduction

Housing is one of life’s basic necessities which encapsulates shelter, physical and mental health, economic and social wellbeing. However, Ibem and Amole (2010) observed that several Nigerians are still living in poor housing conditions. Hence, in a bid to provide quality housing in Nigeria, there have been government involvements at all levels. This has often occasioned the mass housing estates construction, provision of site and services and other infrastructures in urban centres for all income groups among others (Akindele et al., 2014). This form of housing provision has been construed as public housing, as it emphasizes the role of the government and its agencies in facilitating housing provision.

In spite of the efforts and increase funding by the government, the state of housing maintenance and repair is far from satisfactory (Nor'Aini et al., 2013). Jiboye (2004) had previously noted that public housing has been in a badly maintained condition in Nigeria. The culture of poor and lackadaisical attitude towards maintenance like an infection has eaten deep into the marrow of Nigeria. This is obvious from the way public houses are managed. Buildings are set up and anticipated to live their life span without a bit of maintenance strategy. The less satisfactory maintenance level in most public housing in the country has been attributed to lack of proper and adequate monitoring and the politically motivated bureaucracy of those responsible for the maintenance of facilities and infrastructures in public housing (Adejimi 1998). Little wonder why despite the theories and hypotheses postulated and propounded, maintenance problems remained adamantly unyielding and so unsolved.

Iyagba (2005) maintained that the general absence of maintenance culture in Nigeria as a nation is one of the greatest economic and social problems. According to Harding et al. (2007), successive governments are more interested in the provision of new housing units without recourse to regular
maintenance of the existing ones as a more sustainable way of reducing housing deficit. In addition, there is usually poor implementation of National Housing Policy, inadequate funding, lack of continuity of projects upon change in government, insecurity and neglect of such projects (Jiboye, 2008). Therefore, Anele (2010) opined that Nigeria will continue to waste scarce financial resources on building new infrastructure which cannot be sustained if urgent steps are not taken to embrace good maintenance culture.

In view of the forgoing, a number of studies have considered public housing. For instance, Adenuga et al. (2010) examined the need for effective maintenance practices in public buildings and reasons for neglect of maintenance responsibilities. Lack of maintenance culture, lack of maintenance knowledge, lack of emphasis on training, retraining and continuing education on effective maintenance by the establishment, indiscipline and ignorance on the part of users, absence of planned maintenance programme and reactive maintenance, complexity of design, non-involvement of maintenance team at design stage and inadequate funds for maintenance are found to be affecting maintenance of public building in Nigeria.

Similarly, Akindele et al, (2014) assessed the condition of housing, adequacy of housing facilities and residents’ perception of housing satisfaction with public estates in Osogbo, Nigeria. Using weighed mean values, it was found that there is a general deficiency in infrastructure development and almost all the estates considered in the study lack basic facilities. The study, however, did not consider maintenance of the estates and the strategy adopted, which is one of the drives for this study.

With this state of affair in mind, it is thoughtful to inquire into the satisfaction of the occupants of the Nigerian public housing estates. Residents’ satisfaction is the positive or negative emotion exhibited by occupants with respect to their housing. Residents’ satisfaction has yet been employed as a measure to examine the success of housing development projects. It has been a very significant tool to evaluate and improve the performance of government policies associated with housing. In that feedback and resident’s views collected with regard to housing projects could be fed back into the future design process for improvement (Mohammad and Mohamed, 2012).

2.0. Methodology

2.1. Study Area

Osogbo is situated on latitude 7° 46’ N and longitude 4° 34’ E of Greenwich Meridian. It assumed the rank of a State capital subsequent the establishment of Osun State in 1991. Its population, based on 2006 census was 156,694 and the total land area was about 2,875km². Over the years, the city has witnessed remarkable growth both spatially and in population. In recent times, the location of Osogbo as a state capital coupled with other developmental factors has led to the influx of people from other towns and villages. Despite the increasing provision and availability of some basic infrastructures, the level and condition of these facilities are still very insufficient as a result of the speedy rate of urbanization and population growth observed in the town. The quality of housing amenities and infrastructures is largely poor and falls below the probable standard. Considerably, adequate housing consolidates not only the national development but also determines the health, security, sanitation and socio-cultural and physical wellbeing of the populace. Development in Osogbo is observed as one moves from the interior towards the outskirts while most of the business neighbourhoods are mixed with residential districts.

2.2. Data collection Instrument

The data used for the analysis in this study are primary data and were collected using questionnaires. Eighteen questionnaires out of the 20 questionnaires distributed to the occupants of G.R.A Osogbo were retrieved representing 90%, while 79 out of the 85 questionnaires distributed to the occupants of the Federal housing Estate, Osogbo was retrieved, representing 92.94%. On a general note, 97 out of the 105 total administered questionnaires on the target population were retrieved representing 92.40%. Equally, 19 (86.36%) out of the 22 questionnaires distributed to the Estate Surveyors and Valuers was
retrieved. This suggests a great percentage of response, thus giving sound footing for further analysis. The questionnaire was designed using a Likert scale, where the options of the possible responses from the respondents were ranked. Likert scale Kristin according to (2004) consist of respondents responses to statements about the object, where responses fall into ordered categories.

To assess the condition of infrastructure and services in the Estates, a Likert scale that ranges from ‘1’ = Bad, ‘2’ = Average, ‘3’ = Good was used. For the condition of the infrastructure and services in the Estates, Mean Score above 1.50 are considered to be ‘Good’ while the Mean Score less than 1.50 are regarded as ‘Bad’. Also, a Likert scale ranged from “1” = very dissatisfied, “2”=dissatisfied, “3”=slightly satisfied, “4”=satisfied and “5”=very satisfied, was used to measure respondents’ level of satisfaction on various housing components. The overall satisfaction for each feature of residential satisfaction was analysed based on a mean score of 3.00 as positive indication of satisfaction, and values below 3.00 indicating dissatisfaction. While factors affecting maintenance in public housing estate was evaluated using severity index, further analysis was carried out using cross tabulation and Pearson's chi-square test (chi-square test of association) on statistical Package for Social Sciences (SPSS).

2.3. Method of Data Analysis

i. Weighted Mean Score
Weighted Mean score as explained by Abunab et al. (2016) was adopted to analyse the condition of infrastructure and services and the overall level of residents’ satisfaction.

For the condition of the infrastructure and services, the Weighted Mean Score is given as:

\[ WMS = \frac{3n_3 + 2n_2 + n_1}{n_3 + n_2 + n_1} \] (1)

Where \( n_3 \) = number of responses for “Good”, \( n_2 \) = number of responses for “Average”, \( n_1 \) = number of responses for “Bad”.

For the overall level of residents’ satisfaction, the Weighted Mean Score is given as Weighted Mean Score (WMS) is determined using Equation (2).

\[ WMS = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1}{n_5 + n_4 + n_3 + n_2 + n_1} \] (2)

Where \( n_5 \) = number of responses for “Very Satisfied”, \( n_4 \) = number of responses for “Satisfied”, \( n_3 \) = number of responses for “Slightly Satisfied”, \( n_2 \) = number of responses for “Dissatisfied”, \( n_1 \) = number of responses for “Very dissatisfied”.

ii. Chi-Square Test of Association
The Chi-Square test of association is used to discover if there is a relationship between two or more categorical variables measured at an ordinal or nominal scale. This test gives evidence of an association or no association (Pandis, 2016). This was used in this study to test the relationship between the observed and expected level of maintenance of public infrastructure in the estates. It was also used to test for the relationship between the observed and expected level of satisfaction of residents with the maintenance of public services and infrastructure.

Chi-square is given as:

\[ \chi^2 = \sum \left( \frac{(E_i - O_i)^2}{E_i} \right) \] (3)

Where,

The subscript “c” = the degrees of freedom
\( E_i \) = the Expected value; and
\( O \) = the Observed value.

iii. Severity Index
Mathematically, severity index according to Kadir et al (2005) is given as:
Severity Index \((SI) = \frac{\sum R_w W}{R_t} \) (4)

Where,
\(R_w\) = number of respondents;
\(W\) = weight or points assigned; and
\(R_t\) = total number of responses obtained from that variable. The scale depicting the degree of severity is interpreted as follows:

- S.I \(\leq 1.4\) implies not serious, not difficult or never felt its effect
- S.I = 1.5 – 3.4 implies moderately serious or difficult or felt its effect some of the time
- S.I = 2.5 – 4.4 implies usually serious, usually difficult or felt its effect many times
- S.I \(\geq 4.5\) implies very serious, very difficult or felt its effect most of the time.

3.0. Results and Discussion

The analysis of the data obtained through the questionnaire was carried out using descriptive analysis. Descriptive analysis featured the use of simple frequency distribution table, weighted mean score and Pearson’s chi-square test.

Table 1: Condition of infrastructures and facilities

<table>
<thead>
<tr>
<th>Infrastructures and facilities</th>
<th>Occupants of G.R.A</th>
<th>Occupants of Federal Housing Estate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Rank</td>
<td>Mean Rank</td>
</tr>
<tr>
<td>Water supply</td>
<td>2.78 1st</td>
<td>2.89 1st</td>
</tr>
<tr>
<td>Refuse Collection</td>
<td>1.78 13th</td>
<td>2.11 12th</td>
</tr>
<tr>
<td>Sewage Disposal System</td>
<td>2.39 8th</td>
<td>2.87 2nd</td>
</tr>
<tr>
<td>Drainage</td>
<td>2.17 9th</td>
<td>2.72 3rd</td>
</tr>
<tr>
<td>Road Network</td>
<td>2.17 9th</td>
<td>2.50 5th</td>
</tr>
<tr>
<td>Schools and educational centers</td>
<td>2.61 3rd</td>
<td>2.06 13th</td>
</tr>
<tr>
<td>Health facilities</td>
<td>2.56 5th</td>
<td>2.42 8th</td>
</tr>
<tr>
<td>Commercial center</td>
<td>1.83 12th</td>
<td>2.48 6th</td>
</tr>
<tr>
<td>Recreational centers</td>
<td>2.17 9th</td>
<td>2.39 9th</td>
</tr>
<tr>
<td>Firefighting equipment</td>
<td>2.56 5th</td>
<td>2.43 7th</td>
</tr>
<tr>
<td>Electricity</td>
<td>2.61 3rd</td>
<td>2.17 11th</td>
</tr>
<tr>
<td>Telecommunication infrastructure</td>
<td>2.44 7th</td>
<td>2.32 10th</td>
</tr>
<tr>
<td>Security services</td>
<td>2.67 2nd</td>
<td>2.53 4th</td>
</tr>
</tbody>
</table>

Table 1 shows the assessment of the condition of infrastructural facilities available in the estates. From the G.R.A., the condition of water supply with mean score of 2.78 and security services with a mean score of 2.67 is good and has been ranked 1st and 2nd respectively. The least / relatively in a fair state is refuse collection with a mean score of 1.78 and has been ranked 13th. The occupants of Federal Housing Estate also rated water supply to be in a very good condition with a mean score of 2.89 and ranked 1st, this is closely associated with the good condition of sewage disposal and drainage with the mean scores of 2.87 and 2.72, and ranked 2nd and 3rd respectively. However, all the infrastructures and facilities identified were found to be in at least an average condition, as their Mean Score were all above 1.5, this results show an improvement on the condition of infrastructure in the study area when compared with the results of Akindele et al, (2014) who had earlier found a poor condition of infrastructures in the study area. However, the condition of the school and educational ranked lowest. This is not unrelated to the poorly maintained physical condition of the infrastructures of the schools educational centres as at the time of the analysis of this study. Equally, Kehinde et al. (2015) found that public estates in the entire study area were poorly equipped with infrastructure.

Table 2: Level of Satisfaction with specific building components

<table>
<thead>
<tr>
<th>Specific Building Components</th>
<th>Occupants of G.R.A</th>
<th>Occupants of Federal Housing Estate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Rank</td>
<td>Mean Rank</td>
</tr>
<tr>
<td>Doors</td>
<td>3.83 4th</td>
<td>3.44 6th</td>
</tr>
<tr>
<td>Windows</td>
<td>3.50 6th</td>
<td>3.85 4th</td>
</tr>
<tr>
<td>Roof</td>
<td>4.00 2nd</td>
<td>4.03 2nd</td>
</tr>
<tr>
<td>Internal Wall</td>
<td>3.61 5th</td>
<td>4.18 1st</td>
</tr>
<tr>
<td>Beams and columns</td>
<td>4.00 2nd</td>
<td>3.75 5th</td>
</tr>
<tr>
<td>External walls</td>
<td>4.11 1st</td>
<td>3.99 3rd</td>
</tr>
<tr>
<td>Finishing</td>
<td>3.22 7th</td>
<td>2.81 7th</td>
</tr>
</tbody>
</table>
The level of satisfaction with some specific building components was also assessed and presented in Table 2. The results have been ranked accordingly for better understanding. G.R.A occupants were found to be satisfied with the ‘external walls’ with a mean score of 4.11, which ranked 1st while the occupants of Federal Housing considered the ‘Internal walls’ most satisfactory on their list with a mean score of 4.18 and was ranked 1st. ‘Finishing’ shows the lowest satisfaction at both Estates; showing that the level of satisfaction derived by the occupants of both Estates on the Finishing of the building is low. These results show that there are differences in the level of satisfaction of the resident on the identified building components in both estates. The level of satisfaction of the residents to the roof at both estates ranked second with a mean score that were above 2.5. This explains the uniqueness of different estates and the difference in the value of their land and landed properties. It could be from the law guiding the development of each estate or the ownership which control the type and nature of development.

Table 3: Level of Satisfaction with the available infrastructures and facilities in the Estates

<table>
<thead>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td>Security services</td>
<td>2.72</td>
<td>9th</td>
</tr>
</tbody>
</table>

The respondent’s level of satisfaction with the infrastructures is presented in Table 3. The occupants of G.R.A. are more satisfied with water which has the highest mean score of 4.22 and has been ranked 1st. This is closely followed by ‘sewage disposal’, ‘Road network and drainage’ with mean scores of 4.17 and 3.72 ranked 2nd and 3rd respectively. The least satisfied is recreational centre which is ranked 13th. On the other hand, occupants of the Federal Housing estate consented to the high level of satisfaction with security with a mean score of 3.94. This is closely followed by water supply and electricity with mean scores of 3.84 and 3.75, and ranked 2nd and 3rd respectively. The least satisfied are health and recreational which ranked 12th each. Nevertheless, there were difference in the satisfaction with infrastructure and facilities and their condition when compared Tables 1 and 3. One of the infrastructures and facilities had increase in their rank at the level of satisfaction while others had decrease in their level of satisfaction at both estates. Only water supply maintained the first position of it condition and the level of satisfaction derived from it by the resident at the G.R.A. At both estate, infrastructure such and facilities such a refuse collection, sewage disposal, and telecommunication infrastructure had an increase in their rank at the level of satisfaction, while the health facilities had a drop in rank at both estate. Infrastructures and facilities that had an increase in rank at the level of satisfaction derived from them as compared to their condition imply that though their condition are not as good as other infrastructure and facilities that are ranked higher, the resident derived more satisfaction from them. Also, the infrastructures that had a higher rank in their condition than their rank at the level of satisfaction, imply that it is possible that an infrastructure or facilities may be in a good condition, it does not translate to serving it purpose as expected. The Health facilities for instance could be in a better condition than Electricity at Federal Housing Estate, it however does not satisfy the desire of the resident as electricity does at the estate.
Table 4: Cross tabulation of the level of maintenance of public services and infrastructures in the Estates

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Level of Maintenance</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>Federal Housing Estate</td>
<td>18</td>
<td>44</td>
</tr>
<tr>
<td>% within Respondents</td>
<td>22.8%</td>
<td>55.7%</td>
</tr>
<tr>
<td>Government Reserved Area (GRA)</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>% within Respondents</td>
<td>11.1%</td>
<td>38.9%</td>
</tr>
</tbody>
</table>

Table 4 gives insight into the respondent’s opinion of the level of maintenance of public services and infrastructures at both estates. The result of the table shows that the majority of the respondent at the Federal Housing Estate believed that the estate is fairly managed at 55.7% while the majority of the respondent at the GRA responded that the level of maintenance of the estates is good. However, at both estates, poor level of maintenance has the least percentage of response. This implies that the maintenance of the estates are between fair and good.

Table 5: Chi-Square Tests of association of the maintenance of public services and infrastructures in the Estates

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Approx. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>6.193</td>
<td>2</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>5.728</td>
<td>2</td>
<td>0.057</td>
<td></td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>4.973</td>
<td>1</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5, shows that the critical value of chi-square $\chi^2 = 6.193$ is greater than the observed value of chi-square $p = 0.045$ ($p < 0.05$). This suggests that there is no statistically significant difference between the opinion of respondents of both estates on the maintenance of public services and infrastructures. Hence, it is evident that the level of maintenance of public services and infrastructures is not differ from one public estate to another. This may be corroboration of poor building maintenance habits earlier identified by Quayson and Akomah (2016) and Twumasi-Ampofo et al. (2017) as being prevalent in public buildings.

Table 6: Cross tabulation of the level of satisfaction with maintenance of public services and infrastructures

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Quality of the services and infrastructures</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>N S</td>
</tr>
<tr>
<td>Federal Housing Estate</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>% within Respondents</td>
<td>27.8%</td>
<td>11.4%</td>
</tr>
<tr>
<td>Government Reserved Area (GRA)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>% within Respondents</td>
<td>22.2%</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

Table 6 gives the clear understanding of the respondent’s opinion on the level of satisfaction with maintenance of public services and infrastructures. The level of maintenance in relation to the satisfactory nature of the quality of services and infrastructure shows that majority of the respondents are satisfied with the quality of services at 60.8% and 66.7% at the Federal Housing Estate and G.R.A respectively. However, 22.2% and 27.8% of the residents of G.R.A and Federal Housing Estate respectively are not satisfied with the quality of services and infrastructures provided in the estates. This clearly indicates the need for an efficient maintenance programme so as to improve the satisfaction of the occupants.
Table 7: Chi-Square Tests of association of the occupants’ level of satisfaction with maintenance of public services and infrastructures

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2 sided)</th>
<th>Approx. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>.257</td>
<td>2</td>
<td>0.879</td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>.264</td>
<td>2</td>
<td>0.877</td>
<td></td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>.253</td>
<td>1</td>
<td>0.615</td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>.051</td>
<td></td>
<td>0.879</td>
<td></td>
</tr>
<tr>
<td>Cramer's V</td>
<td>.051</td>
<td></td>
<td>0.879</td>
<td></td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7 shows that the critical value of chi-square $\chi^2 = 0.257$ which was lesser than the observed value of chi-square $p = 0.897$. This implies a statistically significant association in the opinion of the occupants of the Estates’ on the level of satisfaction with maintenance of public services and infrastructures. Nevertheless, the chi square test does not tell the strength of association. According to Malhotra (2009), strength of association is of interest when the association is statistically significant. The strength of association can be measured by phi correlation coefficient and Cramer’s V. The Cramer’s V value varies between 0 to +1. If it takes the value of 0, there is no association while +1 shows perfect positive association. A large value of V merely indicates a high degree of association, but does not indicate how the variables are associated. The strength of association through a Phi and Cramer's V test from the test revealed a very weak relationship (Phi = .051 and Cramer’s V = .051) between occupants’ and their level of satisfaction with maintenance of public services and infrastructures at both estates’. Kehinde (2015) et al. earlier established that public estates in Osogbo fell short of overall mean value measurement of residents’ satisfaction.

Table 8: Source of infrastructure and facilities Maintenance

<table>
<thead>
<tr>
<th>Source</th>
<th>Occupants of G.R.A Osogbo</th>
<th>Occupants of Federal Housing Estate Osogbo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Frequency</td>
</tr>
<tr>
<td>Development Levy</td>
<td>4</td>
<td>22.2</td>
</tr>
<tr>
<td>Joint Community Service</td>
<td>5</td>
<td>27.8</td>
</tr>
<tr>
<td>Through Government Efforts</td>
<td>5</td>
<td>27.8</td>
</tr>
<tr>
<td>Individual Efforts</td>
<td>3</td>
<td>16.7</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 8 assesses the body majorly responsible for the maintenance of the infrastructures and amenities in the neighbourhood. The result shows that 27.8% of the respondents at G.R.A. indicated that maintenance of the infrastructure is done through Joint Community Service while 48.1% of the respondents at Federal Housing Estate also revealed that the maintenance of the infrastructure is done through Joint Community Service. At G.R.A. and Federal Housing Estate respectively, 27.8% and 16.5% also confirm the involvement of the Osun State and its relative agencies in the maintenance of the infrastructures. The use of development levies was also identified by the study. On the other hand, some of the respondents also agreed to the combined role of residents association and the government agencies marked as ‘others’ for the maintenance of the estate services and infrastructures with the highest percentage at the Federal Housing estate representing 7.6% and 5.6% for G.R.A.
Table 9: Factors affecting Maintenance in Public Housing Estate

<table>
<thead>
<tr>
<th>Mean</th>
<th>Severity Index (SI)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of substandard of materials and building components</td>
<td>4.1</td>
<td>1st</td>
</tr>
<tr>
<td>Maintenance Culture</td>
<td>4.0</td>
<td>2nd</td>
</tr>
<tr>
<td>Availability of fund for maintenance of the building</td>
<td>4.0</td>
<td>3rd</td>
</tr>
<tr>
<td>Low concern to future maintenance</td>
<td>3.9</td>
<td>4th</td>
</tr>
<tr>
<td>Behaviour and attitude of occupants</td>
<td>3.9</td>
<td>4th</td>
</tr>
<tr>
<td>Lack of care/use of building components and services</td>
<td>3.8</td>
<td>6th</td>
</tr>
<tr>
<td>Lack of care/use of building components and services</td>
<td>3.8</td>
<td>6th</td>
</tr>
<tr>
<td>Clients attitude to maintenance</td>
<td>3.7</td>
<td>8th</td>
</tr>
<tr>
<td>Inadequate building maintenance standard and policy</td>
<td>3.7</td>
<td>9th</td>
</tr>
<tr>
<td>Workmanship during construction and maintenance</td>
<td>3.6</td>
<td>10th</td>
</tr>
<tr>
<td>Design affecting Resolution</td>
<td>3.5</td>
<td>11th</td>
</tr>
<tr>
<td>Improper selection of building material component and system</td>
<td>3.4</td>
<td>12th</td>
</tr>
<tr>
<td>Technological changes and fashion</td>
<td>3.4</td>
<td>13th</td>
</tr>
<tr>
<td>Availability of skilled maintenance personnel</td>
<td>3.3</td>
<td>14th</td>
</tr>
<tr>
<td>Ignorance about the basic properties of building materials and components</td>
<td>3.3</td>
<td>15th</td>
</tr>
<tr>
<td>Poor maintenance of maintenance group</td>
<td>3.2</td>
<td>16th</td>
</tr>
<tr>
<td>Non availability of replacement parts and components</td>
<td>3.1</td>
<td>17th</td>
</tr>
<tr>
<td>Use of new materials and components in building</td>
<td>3.1</td>
<td>18th</td>
</tr>
<tr>
<td>Lack of communication between maintenance contractors, clients and users</td>
<td>2.8</td>
<td>19th</td>
</tr>
<tr>
<td>Delay in occupancy after completion</td>
<td>2.5</td>
<td>20th</td>
</tr>
</tbody>
</table>

Table 9 analyses the respondents’ opinion on the factors affecting building maintenance in public estates. The various factors were assessed, presented with SI and ranked for better meaning and interpretation to the study. The most ranked factors are the ‘use of substandard of materials and building components’ ‘maintenance culture’ and ‘availability of fund for maintenance of the building’ with the SI score of 4.1, 4.0 and 4.0 respectively. These factors fall within 2.5 - 4.4 and implies that the factors are usually serious, usually difficult or its effect are felt many times. These factors and others that are highly ranked in this analysis corroborated the factors established in Adenuga et al., (2010) especially lack of maintenance culture, and low concern for future maintenance (absence of planned maintenance programme).

4.0. Conclusion

The study assessed the maintenance of public housing estates in Osogbo, Nigeria with a view to embracing best practices and adequate maintenance policies in an attempt to provide rational guide to make objective decision in preserving the present housing stock and further enhance maintenance of public estates in the study area. It has identified the various infrastructures available in the estates and analysed them in terms of their availability, condition and the relative satisfaction of the occupants with respect to the availability of the infrastructures. The level of satisfaction of the occupants to the general features of the buildings and infrastructures has also been considered. The analysis of this study show that though the condition of a facility or infrastructure may be better than other infrastructure, it might not be satisfactory in its level of utilization. Therefore, the provision of the facilities and infrastructure are not enough, the impact of their utilization is also to be given adequate attention. The results of this study therefore suggest that for maintenance of public infrastructure and facilities to be effective, there is the need for an integrated maintenance approach.

References


Residents’ Perception and Response to Development Control Activities in Nigerian Cities: The Case of Ibadan and Akure, South-West, Nigeria

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ABSTRACT

This study assessed residents’ perception and response to development control activities in Ibadan and Akure Nigeria. This was with a view to suggesting policy a response capable of enhancing orderly control of development in the cities and others with similar background. A local government was selected in each of the two cities. This is followed by the selection of two wards in each of the selected local governments across the two cities. In the four selected wards, every 20th residential building was sampled sequel to listing of buildings based on street numbering system and counting of buildings where houses were not numbered. For the study, 106 residents were sampled on whom questionnaires were administered. This sample comprised 55 respondents in Ibadan and 51 residents in Akure. Data analysis was done using descriptive statistics. Findings revealed that demolition exercise was the major source of awareness of development control activities across the two cities. However, there were differences in residents’ perception of roles of development control agencies in Ibadan and Akure. The study also found that majority of the residents across the two cities do not have survey plans neither do they prepare building plans before embarking on construction. This study established the divergent views on satisfaction with conduct of development control activities among residents of Ibadan and Akure. The study recommended that development control agencies in the two cities should cultivate a cordial relationship with the residents in order to motivate them to fulfil land administration requirements before embarking on construction exercises.

Keywords: Development control, physical planning, residents, urbanization, urban centres

1.0 Introduction

Urban centres throughout the world exhibit an incredible diversity of characteristics, economic, structure, levels of infrastructure, historical origins, patterns of growth and degree of formal planning (Amujiri, 2001; Agbola, 2007; UN-Habitat, 2009). The process of urbanization has become more rapid and massive, thus posing a challenge to a greater part of the world than ever before (Alabi, 2010; Fabiyi, 2006). Studies such as Bhata (2010), Oyelade, (2012), Adeyemi (2014) and UN-HABITAT (2016) have established that population upsurge in cities account for lateral expansion, structural growth of settlement and associated problems. Lateral growth occurs when the city expands in geographical boundaries. In essence, the issue of agglomeration of population into urban areas leads to the quest for more development on land to commensurate with the demographic structure.

The state of the physical environment particularly in the urban centres today is a major source of global concern (Kawu,, Ahmed, and Usman, 2012). Most land users in the developing world in their quest for development carried out their activities without recourse to planning agencies for planning approval and strict adherence to planning standards thereby contravening existing planning laws related to development (Oduwayne 2004; Olujimi and Fashuyi, 2004; Obabori, Obiwuevi and Olomu, 2007; Aluko, 2010). Physical development often has severe impacts on the environmental components such as land, water and air. The concern is greater in respect of developing nations like Nigeria. This justifies a need for proper physical planning in attaining sustained control and development of the environment. Urban planning involves organized legal activities that are directed towards spatial ordering of land uses in order to create a functional and healthy physical environment for living, working and recreating.
It provides a framework for building and managing the environment. One of the veritable ways of carrying out urban planning is development control. Adeyeye (2010) defined development control as a physical planning instrument which generally involves the regulation, restraining and keeping in order or checking material change to land. In another parlance it is a strong and effective tool of urban planning and management (Vivan, Kyom and Balasom, 2013). Development control is a way of checking and regulating development of land by planning authorities (Obabori et al, 2007). Development control policies are aimed to ensure coordination and compatibility of land uses to bring about improvement in the general welfare of a people (Sanusi, 2006).

The cumulative effect of the urbanization process is seen in the haphazard spatial development, the attendant problems of congestion, the inaccessibility to some activity areas, pollution, slum formation, rising costs of land, accessibility to urban land for land housing, incompatible use, flooding, overcrowding and congestion, housing famine, environmental chaos and other forms of environmental degradation (Kio-Lawanson, Duru, John and Eebee, 2016). Development control activities in Nigeria are domiciled in land administration agencies ranging from federal to local government levels. Till date, development control has been applied in Nigeria through series of Acts, Laws and Policies. These include the Land Use Act of 1978, Urban Development Policy of 1992, the Urban and Regional Planning Decree of 1998 as well as the Housing and Development Policy of 2002. Despite the existence of these laws and policies, development control problems still persist in the country.

The persistence of uncontrolled expansion of Nigerian cities has forced planners and stakeholders to accept that development control has failed (Agboola, 2007). The high rate of urbanization of physical environmental problems which characterized urban centres in Nigeria is an indication that development control mechanisms in the country have been ineffective. The effects of these problems are development of illegal structures in urban centres. Issues pertaining to development control activities have attracted the interest of researchers in Nigeria. Several studies have advocated for strengthening the effectiveness of the exercise through better enforcement of the law. These studies include Omisore and Akande (2004), Aribigbola (2008), Olotuah, (2010) and Ogundele et al (2011). Others studies that have examined the practice of development control activities in the country Oduwaye, (2004), Olujimi (2009), Ujoh and Ifatimehin, (2010), Kawu, Ahmed and Usman, (2012), Vivian, Kyom and Balasom (2013).

These researches have highlighted the concept, relevance and problems associated with development control in Nigeria. They have also examined the uses of various development control tools as well as development control mechanisms for producing conducive, aesthetically pleasing, functional, safe and more importantly healthy environment for all Nigerians. As relevant as these studies could be in ensuring the effectiveness of development control activities in Nigerian cities, a major setback is their little emphasis on the perception of the people on development control. The views of the residents, who are the major stakeholders in ensuring the success of the development control exercise, have been less considered in literature. It has been established that residents’ perception data can be used as a tool in proffering solution to different problems in different areas of human endeavour (Afon, Abolade and Okanlawon, 2006). In this era of participatory approach to urban issues, the need for residents’ perception in the quest for effective development control cannot be jettisoned.

Information from perception studies guides policy makers in adopting bottom-up approach, leading to decision making that will be acceptable to the people at a particular time. Understanding residents’ perception of development control activities will be a successful instrument to ensure full citizen involvement in the exercise. It can be used to know the attitude of residents to particular aspects of the programme. For the success of any physical planning activity information about peoples’ perception on physical development agencies are very imperative. This type of investigation is very imperative as the role of citizen participation in the success of development control activity cannot be underestimated. The thrust of this paper, therefore, is to examine residents’ perception of development control activities in Ibadan and Akure, Nigeria. In achieving this, the study examined the socio-economic characteristics of the residents and their opinion on the effectiveness of development control activities in the study area.
2.0. Materials and Methods

2.1. Study Area

The study area is Akure, the administrative capital of Ondo State. Akure became the state capital of Ondo State in 1976. The town is located within 7°15' North of the Equator and Longitude 5°05' East of the Greenwich Meridian. It is about 204km east of Ibadan, capital of Oyo state; 168 km west of Benin City, capital of Edo state; 311 km north-east of Lagos; and 323 km south-west of Abuja, the Federal Capital Territory of Nigeria. The city spreads over an area of about 15,500 km² in about 370m above the sea level (Owoeye and Adedeji, 2003) Its population figure of the city by the National Population Census of 1963 was just 71,106. With the influx of public servants into the town consequently upon state creation in 1976, the population rose to 239,124 and 360,268 in 1991 and 2006, respectively, with a projection of 476,159 in the year 2014 (Owoeye and Ibitoye, 2016). The increased relative political influence of Akure as a State capital since 1976, when Ondo State was created has been partly responsible for its rapid development. This is because, the decentralization exercise, which accompanied the policy that led to the creation of the State led to the creation of jobs, which attracted many people. The multifarious activities, performed by Akure, influence the desire to construct new roads and rehabilitate the old ones to take care of the envisaged new roles and status of the city.

Ibadan is currently the capital city of Oyo State; one of the 36 States of Nigeria. It is located approximately on latitude 7°22' and 7°40' North of the Equator and 3°53' and 4°10' East of the Greenwich Meridian. It is Nigeria’s second-largest urban agglomeration, with a population of about 3.3 million people (Oyelayo, 2014). It is centrally situated in the South-western sector of the country. Ibadan comprises of eleven local government areas. Administratively, Ibadan Metropolis consists of five local government areas; the inner city. These are Ibadan North, Ibadan North East, Ibadan North West, Ibadan South East and Ibadan South West. The peculiarity of these five areas is that they converge at a point, Mapo hill. The remaining six local government areas constitute the suburbs of the metropolis. Spatially, Ibadan sprawls over a radius of 12-15 km (Afon and Faniran, 2012; Fakere, Fadairo and Oriye, 2012). The city is facing serious environmental issues relating to its high rate of urbanisation accompanied by acute shortage of water supply and poor management of solid and liquid wastes (Oyelayo, 2014).

The basis for selection of the cities were to compare residents’ perception to development control activities between older generation city (capital cities as at independence of Nigeria) and cities named after independence of Nigeria.

2.2. Field Survey and Analysis Method

This study was based on a field survey through administration of questionnaire. The sampling procedure started with a focus on the two capital cities. One local government was selected in each of the capital cities. Two wards were selected in each of the local government area selected. A total of four political wards were selected for survey. In the two political wards selected in Ibadan, reconnaissance survey revealed that 1120 buildings while in the two political wards selected in Akure, there are 1020 residential buildings. One out of every 20th residential building identified was sampled sequel to listing of buildings based on street numbering system and counting of buildings where houses were not numbered in each of the cities. In each of the selected residential buildings, the target respondents were the household heads.

For the study, 106 residents were sampled on which questionnaires were administered. This sample comprised 55 respondents in Ibadan and 51 residents in Akure. One out of every twenty buildings was selected and questionnaire was administered on an adult residing in each of the selected buildings across the selected wards. Issues addressed in the questionnaire included socioeconomic attributes of the residents and those pertaining to residents’ perception and response to development control activities in their cities. The questionnaire was designed to seek the opinion of the residents on the level of
agreement/disagreement with functions of development control agencies on a 5-point Likert scale using 1 for strongly disagreed (SD), 2 for disagreed (DA), 3 for neutral (N), 4 for agreed (A) and 5 for strongly agreed (SA). Residents’ opinion on satisfaction/dissatisfaction with development control activities was rated on a 5-point Likert scale using 1 for strongly unsatisfied (SUS), 2 for unsatisfied (US), 3 for neutral (N), 4 for satisfied (S) and 5 for strongly satisfied (SS). Analysis of the data was done using cross tabulation and mean.

Mean index was used to analyse residents level of agreement with functions of development control agencies and satisfaction with development control activities in the study area. The analysis of the responses evolved ‘‘Residents’ Agreement Indexes’’ (RAI) and mean Residents’ Agreement Indexes’ (̅RAI). To obtain a RAI, a weighted value of 5,4,3,2 and 1 were respectively attached to rate each response (SA=5, A=4, N=3, DA=2 and SD=1) on any of the functions. The RAI for each item was obtained through the sum of the product of number of responses of each item and the respective weighted value attached to each rating. This is expressed mathematically as:

$$SWV = \sum_{i=1}^{5} X_iY_i$$  \hspace{1cm} (1)$$

where SWV = summation of weight value, $X_i$ = number of respondents to rating i, and $Y_i$ = the weight assigned a value (i = 1, 2, 3, 4, 5).

The RAI for each item on the scale was arrived at by dividing the Summation of Weighted Value (SWV) by the total number of respondents (N=55) and (N=51) for Ibadan and Akure respectively, mathematically expressed as:

$$\overline{RAI} = \frac{SWV}{N}$$  \hspace{1cm} (2)$$

The ̅RAI later was computed by summing the total number of RAI and dividing by the number of the identified functions of development control agencies (n = 15), mathematically expressed as:

$$\overline{RAI} = \frac{RAI}{n}$$  \hspace{1cm} (3)$$

Any RAI with actual value of the ̅RAI indicated a moderate level of agreement of functions of development control agencies by household heads. Values with positive deviations indicated high level of agreement while those with negative deviations indicated low level of agreement of the function of development control agencies by household heads. The ranks of the index values were likewise provided.

Deviation about the Mean Residents Agreement Index (RAI- ̅RAI) for each of the Residents Agreement Indexes was later computed. The deviations were only representative measures of dispersion that provided information on either agreement or disagreement with the functions of development control agencies as perceived by the residents. The variables with positive deviations had high level of agreement while those with negative deviations indicated low level of agreement. For more understanding of the dispersion of the distribution about the mean indexes, the standard deviation (SD) for each city was computed. The standard deviation measured the degree of spread or dispersion of the level of agreement with the functions of development control agencies within the same distribution. A small value of the standard deviation indicated that RAI clustered around the ̅RAI. In further establishing the above fact and also ascertaining the reliability of the ̅RAI based on the data distribution for each of the cities, the Coefficient of Variation (CV) for each city was computed.

Respondents’ satisfaction with the activities of development control agencies was measured through an index called Residents Severity Indexes RSI. The procedure of arriving at this indexes is similar to the one used to measure Residents Agreement Indexes (RAI).
3.0. Results and Discussion

3.1. Socioeconomic and Housing Attributes of Residents

In this study, findings were made on the socioeconomic and housing characteristics of residents that could influence their perception and response to development control activity. The variables discussed in this regard are gender, age, educational status, income, length of residence and type of building. These identified factors of perception in literature, and by extension, perception of development control exercise are discussed to provide descriptive information on the personal and social aspects of the respondents (Afon, 2011; Daramola 2015; Daramola and Olowoporoku, 2016; Odunsi, 2016; Olowoporoku, 2017a).

The frequency distribution of these variables across Ibadan and Akure is presented in Table 1. The study revealed that, in Ibadan, 41.8% of the respondents were male while 58.2% were female. In Akure, the male respondents comprised 64.7% of the total of 51 respondents while the remaining 35.3% were female. This gender distribution will afford the study to have perceptions based on gender differential. Also, majority of the respondents (70.9%) in Ibadan were between age of 20 and 60 years. The case was similar in Akure with 78.4% of the residents aged 20 to 60 years while 21.6% of the remainder were more than 60 years. These findings indicate that the residents were of age to give reliable information on development control activities. The mean ages in Ibadan and Akure were 53 years and 51 years respectively while the overall mean age was 49 years.

Table 1: Socio-economic and Housing Attributes of Residents

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Ibadan</th>
<th>Akure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23 (41.8%)</td>
<td>33 (64.7%)</td>
<td>56 (32.8%)</td>
</tr>
<tr>
<td>Female</td>
<td>32 (58.2%)</td>
<td>18 (35.3%)</td>
<td>50 (47.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 20</td>
<td>6 (10.9%)</td>
<td>0 (0.0%)</td>
<td>6 (5.7%)</td>
</tr>
<tr>
<td>20-40</td>
<td>39 (70.9%)</td>
<td>40 (78.4%)</td>
<td>79 (74.5%)</td>
</tr>
<tr>
<td>≥ 61</td>
<td>10 (18.2%)</td>
<td>11 (21.6%)</td>
<td>21 (19.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td><strong>Educational Attainment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>12 (21.8%)</td>
<td>14 (27.4%)</td>
<td>26 (24.5%)</td>
</tr>
<tr>
<td>Secondary</td>
<td>22 (40.9%)</td>
<td>6 (11.7%)</td>
<td>28 (26.4%)</td>
</tr>
<tr>
<td>Tertiary</td>
<td>21 (39.3%)</td>
<td>31 (60.9%)</td>
<td>52 (49.1%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td><strong>Average Monthly Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ N20,000</td>
<td>11 (20.9%)</td>
<td>4 (31.4%)</td>
<td>15 (20.8%)</td>
</tr>
<tr>
<td>N21,000 - N40,000</td>
<td>16 (31.3%)</td>
<td>13 (37.1%)</td>
<td>29 (40.2%)</td>
</tr>
<tr>
<td>≥ N41,000</td>
<td>10 (20.9%)</td>
<td>18 (51.4%)</td>
<td>28 (39.9%)</td>
</tr>
<tr>
<td>Total</td>
<td>*37 (100.0%)</td>
<td>*35 (100.0%)</td>
<td>*72 (100.0%)</td>
</tr>
<tr>
<td><strong>Number of Years Spent in the Study Area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤10 years</td>
<td>7 (12.7%)</td>
<td>10 (19.6%)</td>
<td>17 (16.0%)</td>
</tr>
<tr>
<td>11-20 years</td>
<td>40 (72.7%)</td>
<td>26 (51.0%)</td>
<td>66 (62.3%)</td>
</tr>
<tr>
<td>≥20 years</td>
<td>8 (14.6%)</td>
<td>15 (29.4%)</td>
<td>23 (21.7%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td><strong>Type of Residents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenants</td>
<td>19 (34.5%)</td>
<td>24 (47.1%)</td>
<td>43 (40.6%)</td>
</tr>
<tr>
<td>Landlords</td>
<td>36 (65.5%)</td>
<td>27 (52.9%)</td>
<td>63 (59.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
</tbody>
</table>

*This was less than the total number of respondents as some respondents refused to declare their monthly income.

As stated by Olofsson and Öhman, (2006) and Owoeye and Adelejì, (2003) that level of education influences awareness. Thus, residents’ level of educational attainments across the two cities could serve as the basis for assessment of the perception of the residents on the development control activities in the study area. Findings on residents’ educational qualifications in Ibadan revealed that 21.8%, 40.0% and 38.2% of the residents in the city had primary, secondary and tertiary education respectively while in Akure, findings revealed that 27.4% of the residents had primary education, 11.7% had secondary education while the remaining majority (60.9%) had tertiary education.
For easy analysis, the initial quantitative data on residents’ average monthly income were grouped into three: low, medium, and high. Income below ₦20,000 categorised as low income. The reason is that the minimum wage at the federal level in Nigeria is ₦18,000 while it ranges from ₦15,000 to ₦20,000 in the states of the federation (Afon, 2011; Daramola, 2015). The medium monthly income was categorised from ₦20,000 to ₦60,000 while residents earning above ₦60,000 were categorised as high income earners. Based on the categorisation, variation in income class existed across the two capital cities as presented in Table 1. Further findings on the average monthly income in Ibadan revealed the 29.7% of the respondents earned less than ₦20,000, 43.3% earned between ₦21,000- ₦60,000 while 27.0% earned above ₦61,000. The mean monthly income in Ibadan was ₦51,355. In Akure 11.4%, 37.1% and 51.4% of the respondents earned less than ₦20,000, between ₦21,000- ₦60,000, and above ₦61,000 respectively. The mean monthly income in Akure was ₦49,780.

Other identifiable parameters in relation to development control activities are number of years spent in the study area. Studies such as Brown and Raymond (2007) and Olowoporoku (2017b) postulated that environmental concern is a function of length of residence. This is because the longer the period people live in an area; the more they are likely to understand the problems associated with the environment. Findings revealed that majority (87.3%) had spent more than 10 years residing in the Ibadan while in Akure 80.4% of the respondents had spent more than 10 years in the city.

Investigation was also made into the type residents to know whether the house were owner-occupier or rented. The essence of this variable is that the ownership or otherwise of the house occupied by a resident can determine his knowledge about development control activities. In Ibadan, 65.5% of the residents sampled were owners of the houses they occupied while 34.5% rented their houses. In Akure, 47.1% of the sampled residents were tenants; the remaining 52.9% were landlords.

3.2. Residents’ Awareness of Development Control Activities

Findings were made into the source of awareness of development control activities in the study areas. This is as contained in Table 2. Residents were allowed to select more than one option as an individual can be aware through more than one source at a time. Investigation from Ibadan revealed that demolition exercise, building collapse and mass media were the three prominent sources of awareness and they accounted for 22.5%, 21.1% and 16.9% of the respondents respectively. Findings from Akure revealed that demolition exercise (21.5%), period of building collapse (20.0%) and contravention notices (16.1%) were the prevalent means of awareness of residents about development control activities in the city.

<table>
<thead>
<tr>
<th>Table 2: Residents Source of Awareness on Development Control Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sources</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Demolition exercise</td>
</tr>
<tr>
<td>Building collapse</td>
</tr>
<tr>
<td>Mass media</td>
</tr>
<tr>
<td>Contravention notices</td>
</tr>
<tr>
<td>Building approval process</td>
</tr>
<tr>
<td>Family/friends</td>
</tr>
<tr>
<td>Billboard/Posters</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*This was more than the total number of questionnaire because respondents selected more than one option

Table 3 shows residents’ view of the function of development control agencies. This is measured in the study by calculating Residents’ Agreement Indices (RAI). The RAI across the two cities are measured by mean and standard deviation. Computed average RAI for the Ibadan and Akure were 3.142 and 3.140 respectively.
Table 3: Residents’ Agreement Indices (RAI) with functions of Development Control Agencies in the Study Area

<table>
<thead>
<tr>
<th>Residents’ Agreement</th>
<th>Ibadan</th>
<th>Akure</th>
<th>Mean RSI</th>
<th>Standard Deviation (SD)</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granting of planning permit</td>
<td>4.304</td>
<td>3.198</td>
<td>3.218</td>
<td>2.817</td>
<td>2.871</td>
</tr>
<tr>
<td>Preparation of development plans</td>
<td>4.376</td>
<td>2.980</td>
<td>3.218</td>
<td>2.644</td>
<td>2.464</td>
</tr>
<tr>
<td>Formulation of physical development policies</td>
<td>3.360</td>
<td>3.446</td>
<td>3.360</td>
<td>3.097</td>
<td>3.079</td>
</tr>
<tr>
<td>Controlling of physical development activities</td>
<td>3.432</td>
<td>3.485</td>
<td>3.432</td>
<td>3.079</td>
<td>3.097</td>
</tr>
<tr>
<td>Preparation of residential layout</td>
<td>3.360</td>
<td>3.455</td>
<td>3.360</td>
<td>3.079</td>
<td>3.097</td>
</tr>
<tr>
<td>Selection of sites for different land uses</td>
<td>2.884</td>
<td>3.277</td>
<td>2.884</td>
<td>2.871</td>
<td>2.644</td>
</tr>
<tr>
<td>Opening up of roads</td>
<td>3.532</td>
<td>3.079</td>
<td>3.532</td>
<td>3.079</td>
<td>3.097</td>
</tr>
<tr>
<td>Granting of fence permit</td>
<td>3.218</td>
<td>2.871</td>
<td>3.218</td>
<td>2.871</td>
<td>2.644</td>
</tr>
<tr>
<td>Settlement of disputes on land ownership</td>
<td>3.218</td>
<td>2.644</td>
<td>3.218</td>
<td>2.644</td>
<td>2.464</td>
</tr>
<tr>
<td>Taking part in street naming</td>
<td>3.320</td>
<td>3.069</td>
<td>3.320</td>
<td>3.069</td>
<td>3.071</td>
</tr>
<tr>
<td>Settlement of dispute on land use development</td>
<td>2.852</td>
<td>3.168</td>
<td>2.852</td>
<td>3.168</td>
<td>3.028</td>
</tr>
<tr>
<td>Location of bus stops</td>
<td>2.954</td>
<td>3.455</td>
<td>2.954</td>
<td>3.455</td>
<td>3.156</td>
</tr>
<tr>
<td>Declaring city section special planning areas</td>
<td>2.742</td>
<td>2.644</td>
<td>2.742</td>
<td>2.644</td>
<td>2.464</td>
</tr>
<tr>
<td>Declaring some roads as one way traffic</td>
<td>2.964</td>
<td>3.069</td>
<td>2.964</td>
<td>3.069</td>
<td>3.071</td>
</tr>
</tbody>
</table>

The study revealed that residents in the Ibadan agreed that development control agencies grant planning permits as it ranked first. In Akure, there was a different opinion as residents ranked control physical development activities first among the role of development control agencies. The calculated highest means values in the Ibadan and Akure were 4.376 (preparation of development plans) and 3.485 (control of physical development activities) respectively.

Residents’ in the Ibadan disagreed that development control functions include declaring city section special planning areas as it ranked the lowest and rated 2.742. In Akure, residents disagreed that development control agencies’ function includes settlement of disputes on land ownership and declaring city section special planning areas. These received the lowest ratings Akure with computed means of 2.641. From the foregoing analysis in the table 3, it can be deduced that respondents in the two cities have different perception of the function of development control agencies. The standard deviation (SD) for Ibadan and Akure 0.243 and 0.269 respectively. The SD was very helpful in computing the CV for each of the towns which was 7.8% and 8.7% respectively. This implied that 92.2%, and 91.3% of the resident agreement indexes for Ibadan and Akure clustered around the mean resident agreement indexes that was computed for the respective towns. With the higher proportions of CVs of the dataset obtained from these towns, it could be inferred that the computed RAI’s were very much reliable.

Presented in Table 4 are responses of residents with satisfaction with the various development control activities. Computed average Resident Satisfaction Index (RSI) in Ibadan and Akure were 3.333 and 3.258. Findings revealed that residents in the Ibadan were satisfied with education and enlightenment programme and settlement of disputes and as both ranked first and second with a rating of 4.304 and 4.376 respectively in the city. Residents in the Akure were satisfied with period of granting approval to proposed plans and public involvement in decision making as they ranked them 3.609 and 3.594 respectively. Residents of Ibadan were dissatisfied with timely action on contravention and public involvement in decision making as they ranked lowest with mean values 2.742 and 2.852 respectively. In Akure the residents were unsatisfied with the timely action on contravention notice and politeness of development control officers as they rated 2.797 and 2.942 respectively.
Table 4: Residents’ Satisfaction Indices (RSI) with Development Control Activities

<table>
<thead>
<tr>
<th>Residents’ Satisfaction</th>
<th>Ibadan</th>
<th>Akure</th>
<th>Rank</th>
<th>Ibadan</th>
<th>Akure</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education and enlightenment programme</td>
<td>4.376</td>
<td>1.043</td>
<td>1st</td>
<td>3.203</td>
<td>-0.055</td>
<td>5th</td>
</tr>
<tr>
<td>Settlement of disputes</td>
<td>4.304</td>
<td>0.971</td>
<td>2nd</td>
<td>3.333</td>
<td>0.075</td>
<td>4th</td>
</tr>
<tr>
<td>Dissemination of planning information</td>
<td>3.532</td>
<td>0.199</td>
<td>3rd</td>
<td>3.159</td>
<td>-0.099</td>
<td>7th</td>
</tr>
<tr>
<td>Enforcement of development control regulations</td>
<td>3.390</td>
<td>0.057</td>
<td>4th</td>
<td>3.174</td>
<td>-0.084</td>
<td>6th</td>
</tr>
<tr>
<td>Politeness of development control officer to developers</td>
<td>2.964</td>
<td>-0.369</td>
<td>5th</td>
<td>2.942</td>
<td>-0.316</td>
<td>8th</td>
</tr>
<tr>
<td>Period of granting approval to proposed plans</td>
<td>2.954</td>
<td>-0.379</td>
<td>6th</td>
<td>3.609</td>
<td>0.351</td>
<td>1st</td>
</tr>
<tr>
<td>Timely detection of contravention</td>
<td>2.884</td>
<td>-0.449</td>
<td>7th</td>
<td>3.507</td>
<td>0.249</td>
<td>3rd</td>
</tr>
<tr>
<td>Public involvement in decision making</td>
<td>2.852</td>
<td>-0.481</td>
<td>8th</td>
<td>3.594</td>
<td>0.336</td>
<td>2nd</td>
</tr>
<tr>
<td>Timely action on contravention</td>
<td>2.742</td>
<td>-0.591</td>
<td>9th</td>
<td>2.797</td>
<td>-0.461</td>
<td>9th</td>
</tr>
</tbody>
</table>

From the foregoing analysis in the table 4, it can be deduced that in the residents in the two cities are at variance with satisfaction with development control activities across the two cities. The standard deviation (SD) for Ibadan and Akure 0.626 and 0.282 respectively. The SD was very helpful in computing the CV for each of the towns which were 18.7% and 8.7% respectively. This implied that 81.3%, and 91.3% of the resident agreement indexes for Ibadan and Akure clustered around the mean resident satisfaction indexes that were computed for the respective towns. With the higher proportions of CVs of the dataset obtained from these towns, it could be inferred that the computed RSI̅s were very much reliable.

3.4. Residents’ Response to Development Control Activities

Information on residents’ response to development control activities is as presented in Table 5. Starting with availability of survey plans, findings on Ibadan and Akure revealed that majority (67.3%) and (58.8%) of the residents do not have survey plans. Further findings were made into the reasons why resident do not have survey plans. In Ibadan 29.7% of the residents claimed the cost of survey plan was high while the majority (70.3%) claimed survey plan was not compulsory in the construction process. In Akure, 40.0% of the residents claimed high cost of obtaining survey plan was the reason for them not to obtain survey plans while 60% of the respondents’ claimed survey plan was not compulsory in the construction process.

Investigation was made to determine if residents prepared building plans before construction of buildings. In Ibadan, it was discovered the proportion of the residents that did not prepare building plans before construction were 76.4% while the remaining 23.6% prepared building plans before construction. In the Akure, 70.6% of the residents did not prepare building plans before construction of their buildings while 29.4% of the respondents prepared building plans before construction. On the reason for not preparing building plans before construction majority, 70.9% of the residents in Ibadan claimed preparing building plan was an additional cost to cost of construction while in Akure, 56.9% of the residents opined that building plans increase the cost of construction in the study area.

On approval of buildings before construction, in Ibadan 87.8% of the residents did not get approval before construction while in Akure 78.4% of the residents did not obtain approval before construction of their buildings. Findings on reasons for not taking approval before building houses in Ibadan revealed that 46.7% of the residents claimed planning approval was costly while 53.4% claimed that taking approval for building was time consuming. In Akure, 41.8% claimed planning approval is costly while 58.2% claimed planning approval is time consuming.

In Ibadan a little more than half (66.7%) collected approval through middlemen, 16.7% collected approval through architects while the remaining 16.7% collected approval through town planners. In
Akure, 36.4% of the residents collected approval through middlemen and 36.4% collected approval through town planners.

Table 5: Residents’ response to Development Control Activities

<table>
<thead>
<tr>
<th>Activities</th>
<th>Ibadan</th>
<th>Akure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (%)</td>
<td>Frequency (%)</td>
<td>Frequency (%)</td>
</tr>
<tr>
<td>Availability of Survey Plans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>18 (32.7%)</td>
<td>21 (41.2%)</td>
<td>39 (36.8%)</td>
</tr>
<tr>
<td>No</td>
<td>37 (67.3%)</td>
<td>30 (58.8%)</td>
<td>67 (63.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td>Reasons for No Survey Plans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High cost</td>
<td>11 (29.7%)</td>
<td>12 (40.0%)</td>
<td>23 (34.4%)</td>
</tr>
<tr>
<td>Not Compulsory</td>
<td>26 (70.3%)</td>
<td>18 (60.0%)</td>
<td>44 (65.6%)</td>
</tr>
<tr>
<td>Total</td>
<td>37 (100.0%)</td>
<td>30 (100.0%)</td>
<td>67 (100.0%)</td>
</tr>
<tr>
<td>Preparation of Building Plan Before Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13 (23.6%)</td>
<td>15 (29.4%)</td>
<td>28 (26.4%)</td>
</tr>
<tr>
<td>No</td>
<td>42 (76.4%)</td>
<td>36 (70.6%)</td>
<td>78 (73.6%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td>Reasons for Not Preparing Building Plan Before Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building cost Addition</td>
<td>39 (70.9%)</td>
<td>29 (56.9%)</td>
<td>68 (64.2%)</td>
</tr>
<tr>
<td>Not necessary</td>
<td>16 (29.1%)</td>
<td>22 (43.1%)</td>
<td>38 (35.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td>Obtainment of Approval Before Embarking on Any Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6 (12.2%)</td>
<td>11 (21.6%)</td>
<td>17 (16.0%)</td>
</tr>
<tr>
<td>No</td>
<td>49 (87.8%)</td>
<td>40 (78.4%)</td>
<td>89 (84.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>55 (100.0%)</td>
<td>51 (100.0%)</td>
<td>106 (100.0%)</td>
</tr>
<tr>
<td>Reason for Not Taking Approval</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning Approval Costly</td>
<td>42 (46.7%)</td>
<td>33 (41.8%)</td>
<td>75 (45.7%)</td>
</tr>
<tr>
<td>Time Consuming</td>
<td>48 (53.4%)</td>
<td>46 (58.2%)</td>
<td>94 (54.3%)</td>
</tr>
<tr>
<td>Total</td>
<td>90 (100.0%)</td>
<td>79 (100.0%)</td>
<td>169 (100.0%)</td>
</tr>
<tr>
<td>Means of Collection of Approval</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contract to Architect</td>
<td>1 (16.7%)</td>
<td>2 (18.1%)</td>
<td>2 (11.7%)</td>
</tr>
<tr>
<td>Contact to Town Planner</td>
<td>1 (16.7%)</td>
<td>4 (36.4%)</td>
<td>5 (29.4%)</td>
</tr>
<tr>
<td>By Oneself</td>
<td>0 (0.0%)</td>
<td>1 (9.1%)</td>
<td>1 (5.9%)</td>
</tr>
<tr>
<td>Middlemen</td>
<td>4 (66.7%)</td>
<td>4 (36.4%)</td>
<td>8 (47.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>6 (100.0%)</td>
<td>11 (100.0%)</td>
<td>17 (100.0%)</td>
</tr>
</tbody>
</table>

4.0. Conclusions

The importance of examining the residents’ perception on development control activities is based on the significance of the roles of residents in the success of any government enterprise. Also, the satisfaction that the residents derive from the activity will serve as a motivating factor for their participation in the programme. From the findings above, the following are observable. Generally, residents were aware of development control activities across the two cities. However, there were differences in residents’ perception of development control agencies and satisfaction with the development control activities, as a result of differences in the way development control agencies carry out their duties and residents’ socioeconomic characteristics.

Majority of the residents got aware of development control activities via building collapse and demolition exercise. The outcome of the study revealed that residents in Ibadan agreed that development control agencies are solely responsible for grant planning permits while residents in Akure agreed that the main duty of development control agencies are to regulate physical development activities. These identified activities are the core of development control agencies. The study established the divergent views on satisfaction with conduct of development control activities in the study area. In Ibadan, residents reflected their dissatisfaction with timely action on contraventions, while residents in Akure rated the politeness of development control officers to developers poorly. This low level of satisfaction towards the conduct of the activity can trigger residents’ apathy towards development control in the
study area. Based on these, the followings are recommended on development control activities in the study area.

There should be a reduction in the cost of procuring building permits also the bottlenecks involved in the process should be reduced in order to aid easy access to building permits. There should be proper awareness to the residents about the benefits of development control activities in the study area. The development control agencies should cultivate a cordial relationship with the residents so as not scare people from fulfilling their roles during the building approval period. Public campaign through the use of mass media and bill boards should be employed in order to spread the gospel of development control to residents of the two cities and other cities with similar background.

References


Degree in the Department of Urban And Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria.


Improving Roadway Operations and Safety for Large Truck Vehicles by Optimizing some Critical Geometric Design Parameters

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ABSTRACT

Large truck vehicles are constrained by their physical and operational attributes such as length, width, height and axle loading, which affect their performance on highway infrastructure. In recent times, car-truck and truck only crashes have increased due to the complex interactions of such vehicles on geometrically deficient roadway systems. By adjusting geometric design parameters in accordance with stipulated requirements across deficient roadway sections it is possible to estimate using crash rate index the degree of improvements observed. A total of 189.4 kilometers of three roadway lengths (Benin-Ore, Benin-Agbor and Benin-Sapele) were investigated for geometric design deficiencies across crash sections. Adjustments were made using AASHTO design specifications based on speed limit, terrain type and roadway functional class for three critical geometric design parameters namely: degree of horizontal curvature, vertical grade and roadway lane width. Comparison of parameter estimates before and after adjustments showed corresponding cumulative percentage improvements of 6.5%, 13% and 4.7% for Benin-Ore, Benin-Agbor and Benin-Sapele roadways respectively. This implies that adjustments to critical design parameters at deficient roadway sections can help in mitigating large truck crash rates and allow for better accommodation and operation of such truck vehicles on plied roadways.

Keywords: highway infrastructure, highway improvement, geometric design parameters, Nigerian highways, truck crash rates.

1.0. Introduction

The necessity of highway geometric design is to cater for the safe operation of vehicles of known configuration. When plied road sections are geometrically deficient, there is an increased likelihood that the safety of road users will be jeopardized. The AASHTO highway design manual (AASHTO, 2011) recognizes four (4) different classes of vehicles for which roadways may be designed for. These include: passenger cars, buses, trucks, and recreational vehicles. Large trucks otherwise referred to as long combination vehicles (LCVs) represent the most complex design vehicles due to their overall physical dimensions and operational attributes (Elefteriadou et al., 1997). Sections of existing roadway systems with small curb return radii at intersections and interchanges, steep vertical grades as well as narrow or reduced lane widths pose haulage difficulty and high crash susceptibility for large truck vehicles especially among traffic mix on significantly plied routes (Galadima et al., 2017).

Harkey et al. (1996) documented several operational characteristics of long combination vehicles, including their off-tracking tendency, stability, speed, acceleration, braking and stopping distance, believed to have impact on transportation safety as well as close relationship to geometric design.

The study was geared towards understanding how such large truck vehicles operate in order to better accommodate them through geometric design or regulate them through more stringent laws and better enforcement. The operational characteristics of these vehicles have an impact on transportation safety and relationship with geometric design features. The authors suggested the need for additional study in the following areas:
i. The operation of large truck vehicles on road sections with poor horizontal and vertical grades.
ii. The operation of LVCs on congested freeways and
iii. The operation of such vehicles on rural and urban roadway intersections.

These were suggested in order to foster geometric design improvements to critical parameters on freeway road systems facilitating significant traffic movement.

Miaou and Lum, (1993) developed a Poisson regression based model to evaluate the effects of highway geometric design on truck accident involvement rates on rural interstate highways in Utah and to quantify the uncertainties of the expected reductions in truck accident involvement from the improvements in highway geometric design. The analyses gave predictions for the number of truck accident reductions due to improvements in geometric design elements such as: horizontal curvature, vertical grade and paved inside shoulder width for roadway sections.

On many interstate roadway systems in Nigeria, these design elements are often deficient or inadequately designed for in accordance with standard design practices stipulated by AASHTO. Roadway shoulder widths for instance may be unavailable or inconsistent across road sections with average width sometimes spanning from 1.0 to 1.5m which falls short of the minimum truck design vehicle (WB-15) width of 2.6m. By investigating selected roadway systems it is intended to check via estimates the degree of improvements recorded in order to foster truck safety through adjustments to some geometrically deficient elements (degree of horizontal curvature, vertical grade and lane width) across sections. Due to lack of data availability and consistency, roadway shoulder width was not included as a critical parameter.

2.0. Methodology

2.1. Data Collection and Route Selection

The Federal Road Safety Commission (FRSC), Ikpoba Hill zonal division in Benin City, Edo State, furnished the primary crash data for the routes investigated. The focal point of this study was constrained to two and three lane (divided) access roadways with flow rates across sections averaging 3000 or above vehicles per day per lane relative to average daily traffic (ADT). From the data source, Benin-Agbor (2-lane), Benin-Ore (3-lane) and Benin-Sapele (2-lane) were the most significant truck haulage routes recording a total of 679 large truck crashes observed between years 2011 to 2015. With the aid of roadway navigational softwares such as Google maps, Google earth and Geographic Information System (GIS), these roadway layouts indicating geometrically deficient sections were identified. Also, the observed crash areas for each roadway were identified.

2.2. Method

The three (3) critical geometric design elements identified from the route layouts investigated were: degree of horizontal curvature, vertical grade and roadway lane width. The degree of horizontal curvature was obtained from the radius of curvature via curve lengths, central angles and super-elevations associated with each horizontal alignment across roadway chainages. This parameter was defined by the central angle subtended by an arc, mathematically expressed as (Ficker and Whitford, 2005):

$$D = \frac{100}{\frac{360 \times 2 \pi R}{2 \pi R}}$$

where:

D = Degree of horizontal curvature,
R = Radius of curvature.

The vertical grades across road sections were identified by slope change and presence of an angle or inflection point across sections. On the other hand, the roadway lane width was obtained via GIS navigational software and direct observation and measurement upon inspections across sections.
Throughout each roadway layout across chainages, these geometric design elements were investigated for design deficiencies on the basis of each roadway functional class, design speed as well as terrain condition in accordance with AASHTO’s geometric design policy (AASHTO, 2001). The calibration of design variables was carried out for statistically significant parameters. The descriptive statistics for the data-base employed through the calibration process is given in Table 1 below.

### Table 1: Descriptive Statistics for significant Roadway Variables

#### Benin-Ore Roadway

<table>
<thead>
<tr>
<th>Variables</th>
<th>Average ($\mu_i$)</th>
<th>Std. Dev. ($\sigma_i$)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash frequency (yi)</td>
<td>8.35</td>
<td>3.16</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>Vehicular Average daily Traffic per lane (ADT/L)</td>
<td>3351.13</td>
<td>2109.17</td>
<td>1,850</td>
<td>11,972</td>
</tr>
<tr>
<td>Section length (km)</td>
<td>3.12</td>
<td>0.95</td>
<td>1.25</td>
<td>4.55</td>
</tr>
<tr>
<td>Horizontal Curvature (°)</td>
<td>3.03</td>
<td>2.34</td>
<td>0</td>
<td>13.46</td>
</tr>
<tr>
<td>Vertical Grade (%)</td>
<td>3.62</td>
<td>3.00</td>
<td>0</td>
<td>12.40</td>
</tr>
<tr>
<td>Lane Width (m)</td>
<td>3.20</td>
<td>0.20</td>
<td>2.95</td>
<td>3.65</td>
</tr>
</tbody>
</table>

#### Benin-Agbor Roadway

<table>
<thead>
<tr>
<th>Variables</th>
<th>Average ($\mu_i$)</th>
<th>Std. Dev. ($\sigma_i$)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash frequency (yi)</td>
<td>5.33</td>
<td>2.40</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Vehicular Average daily Traffic per lane (ADT/L)</td>
<td>3027.14</td>
<td>1178.05</td>
<td>1,826</td>
<td>14,912</td>
</tr>
<tr>
<td>Section length (km)</td>
<td>2.05</td>
<td>0.63</td>
<td>0.25</td>
<td>3.15</td>
</tr>
<tr>
<td>Horizontal Curvature (°)</td>
<td>4.33</td>
<td>4.08</td>
<td>0</td>
<td>17.79</td>
</tr>
<tr>
<td>Vertical Grade (%)</td>
<td>3.68</td>
<td>1.33</td>
<td>0</td>
<td>6.20</td>
</tr>
<tr>
<td>Lane Width (m)</td>
<td>3.55</td>
<td>0.15</td>
<td>2.95</td>
<td>3.65</td>
</tr>
</tbody>
</table>

#### Benin-Sapele Roadway

<table>
<thead>
<tr>
<th>Variables</th>
<th>Average ($\mu_i$)</th>
<th>Std. Dev. ($\sigma_i$)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash frequency (yi)</td>
<td>4.93</td>
<td>2.42</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Vehicular Average daily Traffic per lane (ADT/L)</td>
<td>3987.67</td>
<td>2104.66</td>
<td>3,730</td>
<td>17,760</td>
</tr>
<tr>
<td>Section length (km)</td>
<td>1.68</td>
<td>0.74</td>
<td>0.35</td>
<td>2.88</td>
</tr>
<tr>
<td>Horizontal Curvature (°)</td>
<td>1.50</td>
<td>1.04</td>
<td>0</td>
<td>3.65</td>
</tr>
<tr>
<td>Vertical Grade (%)</td>
<td>1.66</td>
<td>0.70</td>
<td>0</td>
<td>3.00</td>
</tr>
<tr>
<td>Lane Width (m)</td>
<td>3.25</td>
<td>0.41</td>
<td>2.75</td>
<td>3.65</td>
</tr>
</tbody>
</table>

### 3.0. Results and Discussions

#### 3.1. Critical Geometric Parameters of Routes Examined

Three (3) significant truck haulage routes were investigated over a combined length of 189.4 km. Records obtained from the FRSC crash data base indicate that 679 large truck crashes were recorded within a five (5) year period, from 2011 to 2015 (FRSC, 2016). The critical geometric design parameters observed to be deficient across each roadway crash section were: degree of horizontal curvature, vertical grade and roadway lane width.

Table 2 shows the roadway lane width for sections of the road where large truck crashes were observed to be prevalent. From the table, it can be seen that the roadway lane widths measured for all the affected sections fall below the minimum lane width of 3.65m for urban roads, as prescribed by AASHTO. Of the three roadways studied, the Benin-Agbor road was observed to contain the highest number of sections with large truck crash prevalence, followed by the Benin-Ore road. However, comparing the lane widths of both roads, as seen in Table 1, it can be seen that the average lane width of the Benin-Ore road is lesser than that of the Benin-Agbor road. This would explain why the crash frequency was higher for the Benin-Ore road as compared with the Benin-Agbor road.
Table 2: Chainages indicating roadway lane width on sections with large truck crash prevalence

<table>
<thead>
<tr>
<th>Chainages</th>
<th>Benin-Ore (94 km)</th>
<th>Benin-Agbor (50.8 km)</th>
<th>Benin-Sapele (44.6 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chainages</td>
<td>Roadway lane width (m)</td>
<td>Chainages</td>
<td>Roadway lane width (m)</td>
</tr>
<tr>
<td>From</td>
<td>To</td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>11.5</td>
<td>13</td>
<td>4.5</td>
<td>5.4</td>
</tr>
<tr>
<td>13.7</td>
<td>14.6</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>35</td>
<td>46</td>
<td>7</td>
<td>7.5</td>
</tr>
<tr>
<td>59.5</td>
<td>62.3</td>
<td>9</td>
<td>9.4</td>
</tr>
<tr>
<td>72.8</td>
<td>73.8</td>
<td>10</td>
<td>10.6</td>
</tr>
<tr>
<td>74</td>
<td>76.6</td>
<td>15</td>
<td>15.7</td>
</tr>
<tr>
<td>78</td>
<td>81</td>
<td>16.4</td>
<td>16.8</td>
</tr>
<tr>
<td>84</td>
<td>85</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>86</td>
<td>87</td>
<td>29</td>
<td>29.4</td>
</tr>
<tr>
<td>90</td>
<td>90.5</td>
<td>30</td>
<td>30.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
<td>40.9</td>
</tr>
</tbody>
</table>

Table 3 shows the degree of horizontal curvature for the sections of the roadway where large truck crash was prevalent. As observed in Table 2, the Benin-Agbor road also contained the highest number of affected sections, followed by the Benin-Ore road. The maximum degree of horizontal curvature as recommended by AASHTO (2001) is 6°. Of the three roads studied, only the Benin-Sapele road met with this requirement. This explains why it had the lowest crash frequency, as seen in Table 1.

Table 3: Chainages indicating degree of horizontal curvature on sections with large truck crash prevalence

<table>
<thead>
<tr>
<th>Chainages</th>
<th>Benin-Ore (94 km)</th>
<th>Benin-Agbor (50.8 km)</th>
<th>Benin-Sapele (44.6 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chainages</td>
<td>Degree of horizontal curvature (°)</td>
<td>Chainages</td>
<td>Degree of horizontal curvature (°)</td>
</tr>
<tr>
<td>From</td>
<td>To</td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>11.5</td>
<td>13</td>
<td>4.5</td>
<td>5.4</td>
</tr>
<tr>
<td>13.7</td>
<td>14.6</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>59.5</td>
<td>62.3</td>
<td>7</td>
<td>7.5</td>
</tr>
<tr>
<td>72.8</td>
<td>73.8</td>
<td>9</td>
<td>9.4</td>
</tr>
<tr>
<td>74</td>
<td>76.6</td>
<td>10</td>
<td>10.6</td>
</tr>
<tr>
<td>78</td>
<td>81</td>
<td>15</td>
<td>15.7</td>
</tr>
<tr>
<td>84</td>
<td>85</td>
<td>16.4</td>
<td>16.8</td>
</tr>
<tr>
<td>86</td>
<td>87</td>
<td>29</td>
<td>29.4</td>
</tr>
<tr>
<td>90</td>
<td>90.5</td>
<td>30</td>
<td>30.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
<td>40.9</td>
</tr>
</tbody>
</table>

The vertical grade of sections where large truck crashes were observed is shown in Table 4. Again, the Benin-Agbor road was seen to have the highest number of affected sections. A value of 12.4% was recorded in the Benin-Ore road. This is far higher than the value recommended by AASHTO, which is 3.0%, and will thus explain why this road recorded the highest truck crash rate.

3.2. Parameter Estimation

The Poisson’s regressions modeling method was employed to ascertain parameter estimates for the investigated variables at 95% confidence interval (Galadima et al., 2017), before experimental adjustments were made to critical design parameters across observed deficient crash sections in order to meet optimum design specifications outlined by AASHTO’s geometric design policy (AASHTO, 2001).

The identified critical geometric design parameters (horizontal curvature, vertical grades and lane width) were adjusted along roadway sections that were observed to be deficient so as to follow required standards that would facilitate enhanced accommodation and safety of such large trucks vehicles on roadways. The criterion for the adjustments was in accordance with AASHTO’s geometric design...
policy (AASHTO, 2001) based on design speed limits (80 - 110 km/h), terrain condition (plain/level) and roadway functional class (free-ways). The maximum degree of horizontal curvature and vertical grade was set at 6° and 3% respectively, while minimum lane width was set at 3.65 m. Estimates at significance level beyond 0.05 benchmark were regarded redundant with no improvements recorded.

Table 4: Chainages indicating vertical grade on sections with large truck crash prevalence

<table>
<thead>
<tr>
<th>Chainages</th>
<th>Vertical curvature (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benin-Ore (94 km)</td>
<td></td>
</tr>
<tr>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>10.8</td>
<td>15.2</td>
</tr>
<tr>
<td>24.7</td>
<td>39.3</td>
</tr>
<tr>
<td>42.6</td>
<td>44.8</td>
</tr>
<tr>
<td>49</td>
<td>51.3</td>
</tr>
<tr>
<td>58.6</td>
<td>62</td>
</tr>
<tr>
<td>79.6</td>
<td>82.7</td>
</tr>
<tr>
<td>17.4</td>
<td>18.6</td>
</tr>
<tr>
<td>18.6</td>
<td>19.5</td>
</tr>
<tr>
<td>28.5</td>
<td>29.6</td>
</tr>
<tr>
<td>29.6</td>
<td>30.8</td>
</tr>
</tbody>
</table>

Table 5 shows the degree of improvement obtained when the identified critical geometric design parameters were adjusted in line with AASHTO’s geometric design policy. Cumulatively, the total estimated truck crash reduction rate from geometric design variable improvement was 6.5% for Benin-Ore roadway, 13% for Benin-Agbor roadway and 4.7% for Benin-Sapele roadway. As shown by these estimates, it can be deduced that adjustments to critical design parameters at roadway sections found to be deficient can yield positive effects in mitigating large truck crash frequency and allow for better accommodation and operation of such truck vehicles on plied roadways thereby improving safety and convenience.

Table 5: Estimated Degree of Improvement for Critical design parameters

<table>
<thead>
<tr>
<th>Critical variables</th>
<th>Significance level (0.05)</th>
<th>Initial parameter estimate</th>
<th>Adjusted parameter estimate</th>
<th>Degree of improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_C (adjusted max. = 6°)</td>
<td>&lt;0.0001</td>
<td>1.083</td>
<td>1.047</td>
<td>3.6%</td>
</tr>
<tr>
<td>V_C (adjusted max. = 3%)</td>
<td>0.036</td>
<td>1.027</td>
<td>1.011</td>
<td>1.6%</td>
</tr>
<tr>
<td>L_W (adjusted min.) =3.65m</td>
<td>0.041</td>
<td>0.886</td>
<td>0.873</td>
<td>1.3%</td>
</tr>
<tr>
<td>H_C (adjusted max. = 6°)</td>
<td>&lt;0.0001</td>
<td>1.141</td>
<td>1.076</td>
<td>6.5%</td>
</tr>
<tr>
<td>V_C (adjusted max. = 3%)</td>
<td>0.013</td>
<td>1.040</td>
<td>1.018</td>
<td>2.2%</td>
</tr>
<tr>
<td>L_W (adjusted min.) =3.65m</td>
<td>0.038</td>
<td>0.832</td>
<td>0.789</td>
<td>4.3%</td>
</tr>
<tr>
<td>H_C (adjusted max. = 6°)</td>
<td>0.59</td>
<td>1.086</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>V_C (adjusted max. = 3%)</td>
<td>0.187</td>
<td>0.990</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>L_W (adjusted min.) =3.65m</td>
<td>0.045</td>
<td>0.963</td>
<td>0.916</td>
<td>4.7%</td>
</tr>
</tbody>
</table>

In Table 5, H_C = Horizontal curvature in degrees, V_C = Vertical grade in percent, L_W = Lane width in meters.

The estimated degree of improvement with respect to truck crash reduction rate on the plied roadways was carried out for tested critical variables only. However, other variables identified by
previous researches (Dissanayake and Niranga, 2012; Schneider et al., 2009; Milton et al., 1996), that were of significant effect to large truck haulage such as roadway shoulder widths (left and right), median width, super-elevation on horizontal curves, and posted speed limits were omitted due to data unavailability or inconsistency with measured roadway sections. Overall, the improvement of these geometric design features proffers reasonable measures to highway designers and policy makers in alleviating safety concerns and boosting operational requirements for existing and future truck vehicle configurations.

4.0. Conclusion

The safety of highway infrastructure is of paramount importance to vehicle operators and other road users hence highway designers often engage measures, practices and reviews to promote improvements in this regard. Large truck vehicles can pose problematic consequences particularly on geometrically deficient roadway segments due to their unique physical and operational attributes. Though legislations may be put in place to restrict the operation of these vehicles on significant traffic routes especially during peak travel hours, this measure appears seemingly inadequate to curb undesirable roadway effects resulting from their haulage. Hence geometric design improvements to better accommodate these truck vehicles represents a dynamic and efficient approach to mitigating roadway mishaps thereby enhancing safety.

From this study, three key elements were crucial to large truck haulage improvement for the roadways examined (Benin-Ore, Benin-Agbor and Benin-Sapele). Optimizing them across deficient roadway sections in accordance with AASHTO geometric design specifications yielded positive results (6.5%, 13% and 4.7% respectively) associated to crash rate reduction.

To improve vehicular operations and safety by mitigating traffic effects on roadway systems, alternative freight haulage means should be adopted. Waterways and rail transportation represent viable options if efficiently harnessed.

Acknowledgement

The authors would like to thank the Federal Road Safety Commission, Ikpoba Hill zonal division in Benin City, Edo State, Nigeria, for providing the primary crash data for the routes investigated in this study.

References


Application of GIS to Oil and Gas Pipeline Management
(A Case Study of South-South Nigeria)

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ABSTRACT

Over the years, the oil and gas industries have been engaging in traditional practices and procedures in their mode of operation in pipeline management. This has brought some drawbacks in terms of planning and mapping of pipeline facilities. Several challenges in terms of natural disaster, equipment failure, and human error could not be averted because the traditional methods could not produce survey maps and plans required for "real time" applications. The advent of Geographic Information System (GIS) technology in the oil and gas industries has brought about rapid changes and improvements in the activities of the oil and gas industries in terms of exploration, production and transmission of products from the field to the end users. In this research, digital maps showing oil and gas pipelines as well as other relevant features such as terrain, vegetation and settlements within the study area were generated. A relational database model was developed using pipeline attributes such as; the pipeline diameter, date of installation, pressure, coating and soil type. Queries on the database provided the required information such as; the required date of maintenance of pipes, areas prone to sabotage, areas with specific pipe diameters in various sections, previous spills and the affected areas.

Keywords: GIS, pipeline management, oil and gas, remote sensing, south-south

1.0. Introduction

Oil and Gas Pipelines are of great significance to the Nigerian economy. According to Nnah and Owei (2005), the petroleum pipeline is an essential mode of transportation and is an infrastructure of a highly specialized nature. Petroleum pipeline network presently measures over 7,000km in Nigeria (Agbazie, 2004; Nigerian National Petroleum Cooperation, 2002). Petroleum pipelines in Nigeria traverse the whole extent of the country’s geo-political zones, ranging from swamp forest and rain forest to savannah grass lands, and are exposed to diverse climatic and soil conditions, with varying consequences including leakages and seepages of petroleum products, with damaging implications for communities and the environment (Agbazie, 2004; Ekwo, 2011). Most of the pipes run across rivers, creeks, swamps and farmland in the Niger Delta, an environment that is wetland fragile, and highly sensitive to stress (Ogon, 2006). Pipelines are part of the major infrastructure of oil and gas production. They are necessary for the transportation, storage and marketing of natural gas, crude oil, and refined petroleum products. Though, most of the pipelines are buried underground, they can still pose a threat to human beings, wildlife and the environment as a whole. Unlike some other modes of transportation, such as roads, pipelines do not improve access for people living in the communities through which they pass. Rather, they impose constraints on interactions and, when located close to houses, constitute a hazard to life. Ogwu (2011) argues that even when a pipeline is no longer in use it is left to rust in the open field as the oil companies are not willing to pay the cost of dismantling it. After the construction phase, there is usually a lack of periodic monitoring. Graham and Thrift (2007) emphasized the importance of repair and maintenance in modern society, but lamented that this is usually overlooked. They underscore the way the culture of repair and maintenance has helped to sustain the activities of electricity and communication as well as auto-mobility. Monitoring is an important activity to ensure the integrity of pipelines and the safety of people in the vicinity. Roper and Dutta (2005) presented several GIS and remote sensing applications for pipeline security assessment. With the advance of modern computing technology and storage devices, the ability to capture new forms of data at a more rapid pace is feasible. Roper and Dutta (2005) go further to identify thermal imaging as useful for pipeline detection primarily...
because it offers the ability to distinguish pipelines at night, due to temperature differences between pipelines and the ground. This separates it from other optical sensors, which typically are only able to reveal useful information during the day with proper daylight, and with good weather (i.e., low cloud cover). Another application for GIS in pipeline security is in visualization and mapping. Visualizing and managing pipelines in GIS mapping systems can be very valuable in comparison with viewing information in tabular format. “The ability to visualize pipeline features has proven to be a powerful tool for decision-makers – saving valuable time and resources” (Clemonds & Isaacs, 2010).

However, the safety of oil and gas infrastructure from vandalization events is critical to quality, healthy and safe environment, Brume (2007). Blackouts and oil embargos are also a consequence of infrastructure attacks (Farrell, 2004). Whereas oil companies attribute most spills to sabotage, the communities argue that they are as a result of structural failure of the pipeline and consequent leakages (Ekwo, 2011). Some estimates put the potential oil revenues lost to spillage and theft over the past two years in Nigeria at close to $11 billion US dollars (Reuters, Nigeria Loses $10.9B to Oil Theft, 2013). Offshore oil rigs are at risk for pirate attack and ransom, with several reported cases taking place in Nigeria. GIS is a tool that has the ability to assist. Oil spillage involves the leakage of crude oil from pipelines. When there is an oil spill on water, spreading immediately takes place. The gaseous and liquid components evaporate, some get dissolved in water and even oxidize, and yet some undergo bacterial changes and eventually sink to the bottom by gravitational action. The soil is then contaminated with a gross effect upon the terrestrial life. As the evaporation of the volatile lower molecular weight components affect aerial life, dissolution of the less volatile components with the resulting emulsified water affects aquatic life other pipeline problems.

Other sources of concern in oil spillage are natural disasters due to earth movement, fire, flood and the neglect of the Oil and gas producing communities. It is difficult to prevent these types of events without knowing where the infrastructure is located. GIS and spatial analysis can assist by helping to predict where these attacks will occur in the future. This helps in contributing to a reduction in future attacks, as well as an improvement in response time once an attack or theft does take place. The objective of this paper is to use GIS as a tool for monitoring the status of oil and gas pipeline network from a central monitoring system in order to enhance pipeline integrity check i.e., to help pipeline managers minimize the cases of pipeline system failure, loss and respond swiftly if there is any. To identify sources of pipeline leakages and reduce response time so as to act promptly in dealing with them in case of pipeline emergencies without any danger to lives, property and the environment. To further evaluate the requirements for the real-time monitoring of pipeline network, making it possible for pipeline managers to monitor every aspect of the network from the comfort of a central base station.

1.1. Pipeline Management

The Pipeline network forms one of the most critical and intelligent components of the petroleum industry. The creation and management of a functional pipeline network requires in depth analysis and study of geographical locations, requirements and managed utilization of resources leading into optimal productions and transfer of crude and refined oil from petroleum reserves to refinery and then to storage units respectively. GIS as a support system for linear infrastructure management. GIS technology can play a decisive role in promoting economically and socially feasible solutions to the existing spatial problems of infrastructure management. This can be done by using GIS to collect the variety of information on the infrastructure and integrating this into a process for monitoring, and evaluating the infrastructure networks. GIS technology has the capacity to integrate and customize the spatial features needed for the management of the linear infrastructure.

1.1.1. Methods of Pipeline Management

There are several methods of pipeline management. It includes:

a) Physical Method

Gas pipeline monitoring could be done regularly by posting security personnel to physically monitor the pipelines on foot or by vehicles and Aircrafts to patrol the Pipeline Right of Way (PROW) and avert any deliberate damage to the pipelines by vandals. This method is effective for stopping the incessant attacks on pipelines.
b) Mechanical Method

i. SCADA: The term “SCADA” is defined as Supervisory Control and Data Acquisition is used to perform monitoring and control tasks required for pipeline operation from a remote station. It runs on UNIX platform and has distributed system architecture. The various system components such as operator workstations, database servers and main/stand-by computers are connected to a redundant Local area Ethernet Network. SCADA among other things can be used to monitor properties of the gas such as gas flow rate, temperature and pressure at different times that could determine the state of the gas. This method appears to be the most viable option as it involves the monitoring of pipelines in “Real-Time”. It is done from a Central Control Station. At the 1998 GIS/Remote Sensing Conference in Toronto, Canada, Fung et al. (1998) posited that remotely sensed data such as aerial photographs and satellite imageries could be used to monitor pipelines periodically. Real-time pipeline monitoring model uses special sensor described as “black boxes” in this study. A black box is a hardware that integrates dial-up connection (phone system) using Satellite Communication System and computing power in a single low-profile housing. The black boxes are installed at strategic points along the pipelines to be monitored. Gas properties such as gas flow rate; temperature and pressure measured in the network by the SCADA (Supervisory Control and Data Acquisition System) equipment are transmitted as data packets to the Central Monitoring Station through the dial-up network where it can be monitored, recorded and analysed. Data logged in the black boxes and uses a laptop computer to download the data. Polling is done by placing a short call lasting only a few seconds to the phone system in the black box. The whole monitoring systems is designed with a high level of intelligence to allow the black box to selectively transmit its position and other data when a special user-defined event occurs rather than periodically transmitting data throughout the day. These event reports provide much more specific data for pipeline monitoring and management while significantly reducing Communication costs.

The geographic co-ordinates of the boxes acts as a spatial databases because the accurate knowledge of the position of each of the black boxes will be helpful to the pipeline manager during emergencies. To make pipeline monitoring more versatile, a back-up communication system should be available to provide a secured and reliable alternative communication path in the event of primary system failure for example, if a failure occurs in the primary dial-up communications system, a back-up dial-up/satellite communication system should be provided to maintain SCADA communication from the central monitoring system to pipeline remote terminal stations.

ii. Poly Pigging: Pigging in pipeline maintenance can be defined as the process, by which cleaning is carried out in pipeline. However, the use of polyethylene pigs is used in this process. Pigging of pipes not only provides cleaner pipe-contents, but also increases flow. This means added life and greater efficiency for pipes and lower overall costs. In the long run, poly pigs come in a wide variety of styles (drying, wiping, scraping) to accommodate almost any application, such as oil and gas transmission, municipal water, petro-chemical, pulp and paper mine slurry and fire sprinkler systems. Pigs clean as well as they do because of their design. Each job requires careful selection of the pigs to be used to ensure desired results.

Poly Pigs have the ability to negotiate short radius bends, reduced port valves and multi-dimensional piping. They effectively have no distance limitations depending on the selection, design and material being cleared from the pipe. They have the capability to travel up to two thousand miles. The pigs form a “sliding seal” in the pipe and when pressure is applied the polyethylene bands try to expand causing a scraping action. Because of this sealing and scraping action, they remove product build-up foreign matter and loose sediment. It increases the carrying capacity of the pipeline, improve product quality, conserve energy and power by reducing pump pressure and flow integrity.

1.1.2. Geographic Information System (GIS) Approach to Pipeline Management

GIS technology facilitates the organization and management of data with a geographic component. It also eases data acquisition and utilization. GIS provides the pipeline operator with improved capability to manage pipeline integrity, improved efficiencies in pipeline operations, and improved response to business development opportunities. Competitive pressure and regulatory constraints are placing increasing demands on pipeline operators to operate in an efficient and responsible manner. Responding to these demands requires accessibility to information regarding geographically distributed assets and
operations. Cova (1999) states that GIS is gaining in favour in comparison with traditional methods of risk assessment. Several studies have used GIS to assess and model risk from a spatial perspective relevant to oil pipeline projects (Cova, 1999; Cutter, 2000; Greiving, 2006; Collins, 2009). Managing pipeline from a geographic viewpoint allows users a better way to assess assets and recognize possible dangers or hazards. One of the core functionalities of GIS is mapping, and thus the difficulty of implementing this type of solution in asset management is inherently low.

For most operators, alignment sheets are the mainstay for reference to pipeline facilities manually drafted many years ago, these alignment sheets are often out of date and pose a threat to operational integrity. Bringing the alignment sheets up to date is major project requiring validating existing information, acquiring new information, and drafting the updated alignment sheets. Using GIS or a hybrid GIS/CAD system can greatly reduce the time and money required to perform this task. GIS technology offers intelligent storage, management, and presentation of facility information, right-of-way data, and other data.

With the rapid expansion of communal cities in the construction of residential buildings commercial buildings in business areas, and with the increase of industries, oil companies thus need to provide monitoring services by laying the oil pipelines and various equipment. This application requires a map to show the system of oil production pipelines and users with detailed accuracy through modern technology to search and promptly use the information.

Therefore, this application utilizes the GIS system to gather all relevant information on oil pipelines along with other useful information, to display the following:

i. Map of oil production pipelines system, sumps and equipment showing information on all related details.

ii. Cross section map of every street at various intervals to show the path and depth of the oil pipeline network and other utilities.

iii. Map showing the location of piping equipment and various flow stations.

iv. Details of oil network pipelines, for example, type, size, depth, construction contract number, date of installation, road surface, etc.

v. Map showing locations of buildings and residential areas of fuel users along with details of the gas users such as license number of fuel user, size of gas meter, etc.

vi. Information on population in the area.

The gathering and storing of information in the GIS system will enhance the efficiency of the pipeline network maintenance and benefit the communal cities. The GIS system is beneficial to the implementation of oil industry in the following ways in engineering; enable network analysis of the structural flow of oil in the oil processing pipelines at various points thus benefiting management. In request for connection to the oil pipeline, by knowing only the address of the fuel user, map of the pipelines will display whether a main pipeline exists or not in the area, thus consideration can be made instantly for the connection to the service pipes. Monitor and promptly repair cracks and leaks of pipeline, because the map clearly depicts the details of the pipe location, for example, type, depth, pipe age, road conditions, enabling accurate and prompt preparation of repair equipment and planning. Provide an overview of the information from all sides, including pipeline systems, number of communities and other, for their analysis and investment plans.

GIS can be used in the site location process to minimize impacts to the environment during construction and from accidental release, as well as to lessen the costs of permits and liability risks associated with accidental releases. Ecological variables developed from publicly available spatial data sets can be utilized in this process. The themes and variables used as input in this process mainly address direct construction costs and pipeline efficiency once the pipeline has been completed. Some of the variables include: shortest distance from source to market, least grading (removal of trees, etc.), costs associated with right of way, slope of terrain, number of stream, road, and railroad crossings, substrate (rock, soils,
etc., associated with burial), existing laws and regulations (wetlands, etc.), proximity to population centers and utilization of existing utility corridors and easements.

1.2. Coverage Analysis

The potential costs of environmental impacts during construction as well as ecological and liability costs that may result from accidental releases after construction also accounts to the cost factor of the petroleum company. Some of these costs can be substantial (potentially millions of dollars) and include: environmental damage, litigation and settlement costs, environmental response and investigation, criminal and civil penalties, environmental remediation, damage to reputation and community relations. An increasing number of environmental spatial data sets have become available to the general public, offering a great opportunity for companies to avoid these environmental and liability risks with relatively little effort by incorporating them into their normal GIS setting procedures.

GIS technology facilitates the organization and management of data with a geographic component. It also eases data acquisition and utilization. GIS provides the pipeline operator with improved capability to manage pipeline integrity, improved efficiencies in pipeline operations, and improved response to business development opportunities.

2.0. Methodology

2.1. Data Creation and Conversion

In any GIS implementation, the creation of attribute and spatial data is of great importance. Since GIS is computer based, the spatial and attribute data used has to be converted to digital format if it is not digital already. Spatial data is created by digitizing and scanning methods. For this project, the following procedures were adopted for creating the spatial data for the pipeline network in the study area i.e. south-south Nigeria (see Figure 1). Scanning was done by conversion of an analogue map to a digital map using a raster data structure format. A raster data structure format is a cellular based structure in which data is stored sequentially by rows and columns of a group of gridded cells called pixels. Each cell or group of cells must be rectangular and also represent a feature.

Figure 1: Map of Nigeria showing the south-south region (Source: World Journal Cardiology, 2012)
2.2. Attribute Database Structure

To create an attribute data in GIS, firstly, a database file was first created and saved in a database format such as database IV format in Microsoft Excel before linking it to objects in a GIS software. However, some GIS software allows you to enter your database directly in it. For this study, the database was entered directly into Arc GIS.

A relational database model was used in this study to build the attribute database structure. These database tables have a “key” which associates (relates) the data to a particular entity. This key serves as a unique facility identifier or equipment identifier, or the key may be positional such as a line identifier and station location on that line. This positional identification was utilized for data such as pipe specification (wall thickness, coating type, etc.). Techniques for defining the tables to hold this data are well established.

A sample of the attributes used for each of the fields and their different keys includes the followings:

- Road (RoadID, Road Type, Length, PipeID) Primary Key is RoadID and the Foreign Key is PipeID.
- Settlement (SettleID, State, Local government area, PipeID) Primary Key is SettleID and the Foreign Key is PipeID.
- River (RiverID Area, RiverType, PipeID) Primary Key is RiverID and the Foreign Key is PipeID.
- Pipe (PipeID, Length, Diameter, Pressure, Temperature, Flow-rate) where PipeID is both the Primary Key and the Foreign Key.

2.3. Query in GIS Environment

A total of seven queries were performed in GIS environment for the pipelines and these include:

Query 1
The Control Monitoring Station department of Mobil producing company in Nigeria found out that some pipelines have malfunctioned due to equipment failure. In this query, Arc GIS was used to detect the pipelines susceptible to failures by comparing the installation date with the date that maintenance was last carried out and the present date.

Query 2
A pipeline explosion has occurred and information has been sent to the occupants in the affected area. Due to the pipeline hazard within that region, the area is being left unfertile and unusable for local farmers and they desire to move to the nearest suitable location to carry out their occupation of farming. In this query, the occupants want to obtain information relating to the nearest location that is most conducive for agricultural use.

Query 3
In this case, we wish to determine, from the incident mentioned above, the townships of the affected settlements and the terrain-geology, soil type and soil structure to enable the pipeline managers get to the location with the most appropriate equipment and transportation.

Query 4
An inside source from the Niger Delta has revealed that angry youths wish to carry out a demonstration by busting oil pipes as they have done in the past. In this query, we can predict the likely location of the next from existing database. From available data, the highest value for number of occurrence is 8 thus; the location with this record can be noted.

Query 5
This query is performed to determine the locations of the various pipeline sizes and their coating. This will aid the channelization of pipeline network to reduce the work load of each pipe.
Query 6
This query is performed to locate a pipeline leakage on the map. The parameters that indicate occurrence of leakages include the tolerance limit set for pressure and flow rate measurements in pipes.

Query 7
This query is performed to determine the abnormal rise in temperature due to frictional force between the pipe contents (oil and gas flowing through the pipe) and the pipeline itself. Given the standard tolerance limit of pipes not greater than $40 \pm 22^\circ C$.

3.0. Results and Discussion

Results of the seven queries are shown in Figures 2 – 11. Query 1 in Figures 2 & 3, Query 2 in Figure 4, Query 3 in Figures 5 & 6, Query 4 in Figure 7, Query 5 in Figures 8 & 9, Query 6 in Figure 10, and Query 7 in Figure 11.

In Query 1, prediction data or period was carried out for routine maintenance of pipelines. It was observed that data update could easily be achieved due to the flexibility of the ArcView software used for this research work. An example to display this was shown in the query. The date of installation for a pipe was July 1976 and November 1975 while the date it was last maintained was February 1982. From the database of the pipeline, the date of next maintenance is displayed as well as the location of the pipe and other relevant data on the map (highlighted in yellow). Therefore, prediction of routine maintenance can be carried out by regularly checking the database for the pipes and updating them when needed.

The spillage of oil due to blowout or sabotage can greatly affect the condition of the environment where such has occurred. Due to the oil spill that occurred as seen in Query 2 which made the location very unfertile for agriculture, the occupants, notably farmers, desire to move to the nearest fertile environment to carry out agriculture. Therefore, the query was made to obtain the nearest fertile area or communities taking note of vegetation type and agricultural use.

Results of Query 4 showed areas that are prone to pipeline attacks by vandals. The security requirements of these are should be more using both physical and mechanical processes. In the distribution of pipelines, various sizes and coating are used because of market requirement and the effect of geology on the pipes. Query 5 shows part of the pipeline network with 24inches diameter and also part of the pipeline network with mastic coating.

In any pipeline operation to determine a leakage in a pipe, some of the factors considered include the valve ID (valve identification), flow rate of pipe contents, pressure in pipe etc. Determination of leakages is dependent on the decrease or increase in flow rate as well as increase or decrease in pressure. A sample check is carried out to determine an increase in flow rate and a decrease in pressure, taking to note that the sample testing of the Niger Delta pipeline allows tolerance limit for normal flow rate measurement range of 170-250psi. A decrease or increase in this would signify a pipeline leakage. Likewise, pressure ranges from 170-300psi. Any increase or decrease would be suspected for a pipeline leakage.

The examples in queries 6 and 7 to detect leakage are such that a pipe was shown to have a flow rate measurement of 265.004m$^3$ while the pressure was measured as 168.000 N/m$^2$. The query automatically displayed the pipes involved as well as their location and other relevant data on the map by highlighting the particular pipes and their attributes in yellow.
Figure 2: Query Showing areas installed in July 1976

Figure 3: Query Showing areas installed in November 1975

Figure 4: Query showing areas conducive for Agriculture
Figure 5: Query showing areas with Clay loamy soil.

Figure 6: Query showing areas with Heavy clay and Limestone

Figure 7: Query showing areas prone to sabotage
Figure 8: Query showing Pipeline with 24 inches Diameter

Figure 9: Query Showing pipes covered with mastic coating

Figure 10: Query showing pipelines with pressures above 200psi
4.0. Conclusion

GIS can be used to simulate networks, create maps and link images with attributes to better enable decisions and actions to be taken quickly. The development of databases and automation of record keeping among others enhance the planning and implementation of GIS for effectively monitoring the status and condition of pipelines from a central monitoring station. Application of GIS in pipeline management is an efficient and cost effective that must be developed to ensure that oil and gas industries acquire high safety standards, reduce risk to the environment and also reduce response time during pipeline emergencies.

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The Role of the Federal University of Technology, Akure Cooperative Multipurpose Society in Housing Finance

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ABSTRACT

Housing finance in Nigeria is facing a lot of problems among which are inadequate mortgage finance, inaccessibility to other form of formal loans from other financial institutions due to stringent conditions attached to its access; urbanization brought about by ever increasing human population; and the economic recession being experienced in Nigeria. Housing development financing and shelter provision among the low and medium income groups become more critical because of lack of access to credit; and these groups constitute the vast majority of the urban households in Nigeria. There are no robust and pragmatic housing finance systems on ground. The reality on ground led to evolution of informal housing finance system of which thrift and credit cooperative is one. Against this background the paper examine the role played by the Federal University of Technology, Akure cooperative multi-purpose society in the provision of housing finance to its members, Secondary data were collected for this study through the use of structured questionnaire from 29.5% of its members. Secondary data were equally obtained from archival data of the society and analysed. The study revealed that majority of their members relied on collection of loans from the cooperative society for their housing development finance. The preferences for this form of finance were given as: ease of processing loan application; low interest rate charge on loan; and ease of amortization. The paper posits that government should intervene in housing finance through methods such as site and service scheme, provision of low interest loans with longer moratorium periods, and special political consideration and leverage be given to the housing need of low and medium income earners to ameliorate poverty among this group.

Keywords: Housing finance, Cooperative society, Low and medium income, Member

1.0. Introduction

Housing problem in Nigeria is diverse and complex, manifesting in the form of overcrowding, homelessness, substandard housing, slum and squatter developments. The quality and quantity of housing in Nigeria is inadequate when compared with the population. It is reported in literature that housing deficit in the country was estimated as 8 million in 1991 and between 12 and 14 million in 2007 (Olujimi, Bello, Fasina, Ojo and Rotowa, 2013). Hence, about N35 trillion would be required to fund such deficit (Olujimi et. al., 2013). Problems associated with housing in Nigeria are high rent in the housing market, inadequate mortgage financing and inaccessibility to mortgage loans (Aribigbola, 2012). The housing situation is getting worse because of population increase, urbanization, industrialization, economic recession and inadequate general prosperity, lack of access to sources of funding. The availability of proper and adequate housing development finance is pivotal to an effective and sustainable shelter provision. Lack of access to suitable form of credit has always been a major obstacle to the provision of shelter for the low-income groups, which constitute the vast majority of the urban households in developing countries.

The housing sector plays a critical role in the welfare of the citizens of a country as it directly affects not only the well-being of the citizenry but also the performance of other sectors of the economy (Sanusi, 2003). Housing development finance is pivotal to shelter provisions and is very important due to the following reasons. First, it is one of the three most important basic needs of mankind, the others being food and clothing. Second, housing is a very important durable consumer item, which impacts positively on productivity, as decent housing significantly increases workers’ health and well-being.
Third, it is one of the indices for measuring the standard of living of people across societies. Investment in housing necessitates the perceived or imagined pecuniary or non-pecuniary benefits. Such benefits varies according to the aspiration of the investor. Invariably, such gain might be financial, prestige, privacy, or security. Consequently, greater attention is needed in the recognition of the critical importance of financing housing delivery system.

The focus of finance has been very prominent for obvious reasons. This is because housing provision requires a huge capital outlay which is often beyond the capacity of the medium/low income groups. A major area of concern is that most of the institutional sources of housing finance are often inaccessible to most Nigerian households, especially low-income earners (Olufemi, 1993; Onibokun, 1985; Falegan, 1985; Olatoye, 2005). Experts’ projection of the population having decent houses does not bring immediate succour as most see the situation as likely to worsen. A shelter provision gap exists in Nigerian because its population growth rate of about three point eight per cent (3.8%) annually, is not been matched by a corresponding increase in home ownership (Adegboye, 2004). The federal government is aware of this, hence the setting up of the presidential Technical Board of the Federal Mortgage Bank of Nigeria whose chairman, Professor Akin Mabogunje posits that “without mortgage finance, the average worker cannot own a house.

The failure of the formal housing development finance institutions in Nigeria to adequately address the need of the vast majority in the area of home ownership led to the evolution and existence housing finance system of which also include thrift and credit (World Bank, 1982). The pertinent questions are thus: how does the low income and medium income earners cope with sourcing for finance for home ownership? What are the strategies adopted? What are the requirements of these non-conventional methods of housing finance and what is the level of patronage? What are its effectiveness and limitations? Hence, this paper will evaluate the contribution of Federal University of Technology, Academic Staff Cooperative Society (FUTASCOOP) in the provision of home ownership among its members. The problems highlighted above, has been particularly identified with developing countries and the impact of the informal institutions for housing development finance cannot be properly quantified because they are largely uncoordinated, scattered and varied in scope and operational depth.

In Nigeria, methods adopted for housing financing before and during the colonial era include village development scheme, social club contributions, and loans from traditional setting. These methods are now replaced with modern ones to reflect the growing complexities emerging in the economic sectors; these methods can be classified into the formal and the informal sectors (Nubi, 2000). The formal sector operates within statutory guidelines provided by the federal government. Major players are the Federal Mortgage Bank of Nigeria Finances, commercial Banks, Specialise Development Banks, Insurance Companies and Pension/Provident Funds. On the other hand, the informal sector is dominated by individual money lenders, voluntary savings, personal or family savings and Cooperative Societies. However they are gradually becoming unreliable because of the low propensity to save. This is further exacerbated by bank and liquidation of banks and non-compensation of affected people.

Similarly, the gap between income and shelter cost in Nigeria is very wide. The low-income earners are completely eliminated from the housing market. This is attributed to high cost of building materials, astronomical inflationary rate in the economy, excessive fees demanded for by the professionals involved in housing finance and excessive profit of contractors (Windapo, 2000 and Okupe, 2000). Olatoye, (2005) noted that financing the real estate investment has in recent time become more problematic due to the complex interaction of several factors. Among these are high interest rates charged on loans, stringent repayment requirements, and almost impossible prequalification conditions imposed by lenders. The bulkiness and illiquid nature of real estate investment poses serious challenges in the uncertainty bedevilling the economy. In the housing sector, these problems are what culminate in high cost of housing delivery and lack of access to home ownership by a large section of the population that are in most need.

Nigeria is yet to develop a robust and pragmatic housing finance system. The level of operation is still at depository level and other traditional methods of housing finance characterized by absence of appropriate legal framework for housing development finance through functional mortgage and capital markets. In Nigeria, it has been difficult for owner occupier to finance their residential property development without resulting to a source of pooling capital together through cooperative efforts. This can be attributed to lack of well-developed mortgage market operation, lack of involvement of capital...
market financing of real estate development and an enabling environment for operation. It is therefore imperative that alternative funding approaches that can eliminate or at least mitigate the difficulties hitherto experienced in conventional housing finance be examined. There is the need to study the *modus operandi* (mode of operation), and the contribution of the cooperative society to home ownership among the working class since it is as alternative option open to them.

The International Cooperative Association (ICA) defined a cooperative society is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically controlled enterprise. A cooperative has been defined as a user-controlled business that distributes benefits on the basis of use (USDA, 1987). They are usually organized as a social association but with more commitment to financial activities of individuals and the collective interest of their members. They emerged because of prevailing social needs in Nigeria. Presently, the country is undergoing economic recession, which has reduced the purchasing ability of an average Nigerian. The cooperative societies have effective methods of generating funds from within and outside membership. Hence, they are good sources of fund generation which could be channelled to housing project and loans that could be diverted to house building. Olujimi et al (2013) outlined the benefits of cooperative societies to include: access to quality supplies and services at reasonable cost; increased clout in the marketplace; share in the earning of cooperative business; enhancement and protection of local economy; and provision of monetary loan for re-investment into many sectors such as housing.

In addition, some cooperative society build houses for members on rotation, otherwise, own housing estates. The two prominent cited by Reis in Adediji and Olotuah, (2012) are Ibadan Cooperative Thrift and Credit Union (CTCU) and Owolowo Union. The authors equally mentioned Owo Multi-purpose Cooperatives, Credit Thrift Cooperative Society in Ondo State that facilitated housing ownership by members. Assistance was rendered in areas of acquisition of land, material purchase and processing of documents. The eight registered cooperative societies operating presently in the Federal University of Technology, Akure (FUTA) are: FUTA Housing Corporation; Senior Staff Association; Women’s Club Society; Association of Staff Union Cooperative Society; Federal University of Technology Akure Academic Staff Multi-Purpose Cooperative societies; God-favour Cooperative Society; Equipment Maintenance Centre Cooperative; and FUTA Primary Staff Cooperative Society. As could be observed, the services rendered by the cooperatives can be predicted by their names. Areas of specialities of these societies include rental services, funding of property development schemes and home ownership schemes. FUTAASCOOP the focal point of this study made impressive profits for the past three years as published in the annual report for 2014 to 2016. The study seeks to examine the role of the Federal University of Technology, Academic Staff Cooperative Society (FUTASCOOP) in providing finance of housing project to its members.

### 2.0. Research Methodology

The study was carried out among members of the Federal University of Technology Akure Academic Staff Multi-Purpose Cooperative societies (FUTAASCOOP) in Nigeria. The Federal University of Technology Akure (FUTA) is located on Latitudes 5° 45’ and 8° 15’ North of equator and Longitudes 4° 30’ and 6° East of Greenwich Meridian. The aim of FUTAASCOOP are: to promote the spirit of cooperative among academic staff members; to enhance the socio-economic well-being of members through investment in viable projects; to create a pool of fund for lending purposes to members and to provide opportunities for members for thrift savings. Others include arranging regular bulk purchase of essential commodities as and when necessary; provision of goods and services to members at reasonable cost and; to organize regular membership education.

FUTAASCOOP has about 677 members from which, a selected sample of two hundred (200) staff members amounting to about 29.5% were chosen for questionnaire administration. Data were obtained by questionnaire administration, direct observation and facility survey. There are eight registered cooperative societies in FUTA, which are representatives of cooperatives societies involved in housing finance in tertiary institutions in Nigeria. Secondary data, involving staff records and administration of housing finance were sourced from the Human Resources Department and various cooperative societies in the institution. A total number of one hundred and eighty five (185) questionnaire consisting 92.5% were retrieved for analysis. A set of questionnaire was administered on respondents who were
3.0. Results and Discussion

The financial performance of FUTAASCOOP is presented in Table 1. From a cursory look at table 1, it could be deduced that there is an increasing interest from members. It was observed that there was a rising trend in membership from 547 in 2013 to 677 in 2015. Equally, membership savings and share capital was on the increase during the period. The savings from the audited account reveals an increase from $473, 067,411 (Nigerian Naira) to $713, 792,786.59 Naira within the three year period. This reveals that the cooperative is viable. This was corroborated by the balance sheet where there was a surplus of $59, 070,169.20. Loanable fund for statutory activities will not be a problem in the cooperative society.

Table 1: Three years Annual Report 2014 to 2016 (Source: Audited Account of the 13th Annual General Meeting FUTASCOOP)

<table>
<thead>
<tr>
<th></th>
<th>December 2013</th>
<th>December 2014</th>
<th>December 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membership</td>
<td>547</td>
<td>585</td>
<td>677</td>
</tr>
<tr>
<td>Membership saving</td>
<td>$473,067,411.89</td>
<td>$592,936,928.60</td>
<td>$713,792,786.59</td>
</tr>
<tr>
<td>Share Capital</td>
<td>$25,836,570.83</td>
<td>$25,585,861.93</td>
<td>$26,240,368.21</td>
</tr>
</tbody>
</table>

3.1. Age of Respondents

Membership modal age of this cooperative is between 36 to 59 years, these constitute about 43.8% of respondents in the study. The age cohort from 51 to 60 were next in proportion, they account for 34% of respondents. The third age group that was revealed by the study were those below 35 years, while the last age group were those who were about to retire they were between age 60 and above. This implies that majority of respondents were in age brackets where they are either planning to build or are building.

Table 2: Age of Respondents (Source: Authors’ Fieldwork, 2016)

<table>
<thead>
<tr>
<th>Age Group (Years)</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 35</td>
<td>22</td>
<td>11.9</td>
</tr>
<tr>
<td>36 – 50</td>
<td>81</td>
<td>43.8</td>
</tr>
<tr>
<td>51 – 60</td>
<td>63</td>
<td>34</td>
</tr>
<tr>
<td>Above 60</td>
<td>19</td>
<td>10.3</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>100</td>
</tr>
</tbody>
</table>

3.2. Amount of Loans Obtained

Table 3 reveals that majority of respondents interviewed collected loans ranging from $300, 000 to $500, 000 (56.8%). This was followed by respondents that collect loans from $500, 000 to $1, 000,000. The proportion of respondents that collects loans below $300, 000 were 13.6%, while 10.7% collected loans above $1, 000,000. This implies that most of the respondents will not be able to complete their building project within one calendar year. This can be attributed to low propensity to save and high cost of houses in government housing schemes. For example, Adedeji & Olotuah (2012) submits that 2-bedroom at Michael Otedola, Jubilee Housing scheme cost about $300,000. In other housing estates, cost of completed houses range between $750,000 in Owotu Housing estate to more than One million naira at MKO Gardens in Lagos. In Akure, the cost of a completed bungalow at Ibule Housing scheme was about Three million naira. Residents of Akure could not purchase these buildings until the Federal University of Technology, Akure, bought the estate.
Table 3: Amount of Loans Obtained (Source: Authors’ Fieldwork, 2016)

<table>
<thead>
<tr>
<th>Loans Obtained (Naira)</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 300,000</td>
<td>25</td>
<td>13.6</td>
</tr>
<tr>
<td>301,000 – 500,000</td>
<td>105</td>
<td>56.8</td>
</tr>
<tr>
<td>501,000 – 1,000,000</td>
<td>35</td>
<td>18.9</td>
</tr>
<tr>
<td>&gt; 1,000,000</td>
<td>20</td>
<td>10.7</td>
</tr>
</tbody>
</table>

3.3. Sources of Housing Finance for Respondents

The sources of financing housing project as attested to by respondents were: personal savings, bank loans, cooperative society (FUTAASCOOP), and other sources. It was observed that 93.1% of respondents financed part of their housing project from loans obtained from the cooperative society. This implies a high patronage and reliance on the ability of the cooperative society to provide requisite fund when co-operators meet requirements.

Table 4: Sources of Housing Finance for Respondents (Source: Authors’ Fieldwork, 2016)

<table>
<thead>
<tr>
<th>Source</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Savings</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>Bank Loans</td>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>FUTAASCOOP</td>
<td>172</td>
<td>93.1</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>100</td>
</tr>
</tbody>
</table>

3.4. Reasons for choice of cooperative loans for Housing Development

In general, people look for loans from sources that charges low interest rate. This determines their ability to amortize such loans. Presently in Nigeria, the depressed economy makes take-home pay very small, as money spent on other purposes outside housing takes a great proportion of salaries and wages. At an exchange rate of $1 = N367, the minimum wage of N18,000 is just about $50. Therefore, the purchasing power of an average Nigerian is below the $1.25 level of absolute poverty. Table 5 presented the reasons for patronizing a cooperative society for loans. Close to one third of respondents (32.97%) say they patronize the cooperative society because of ease of processing loan application. In addition, about a fourth of respondents (24.87%) submit that low interest on loans attracted them to the cooperative society. Another one fourth of respondents (24.32%) reports that the reason for applying for a cooperative loan is due to timeliness/promptness of granting the loan. The study reveals that only about a fifth of respondents (17.84%) patronize the cooperative society because of ease of repayment of loans collected. Aggregating the reasons for choosing cooperative for housing loan reveals that housing loans are pecuniary, the purchasing power of respondents will not support them looking for loans from financial institutions.

Table 5: Reasons for choice of cooperative loans for Housing Development (Source: Authors’ Fieldwork, 2016)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of processing of application</td>
<td>61</td>
<td>32.97</td>
</tr>
<tr>
<td>Low interest on loan</td>
<td>46</td>
<td>24.87</td>
</tr>
<tr>
<td>Timeliness of granting the loan</td>
<td>45</td>
<td>24.32</td>
</tr>
<tr>
<td>Ease of repayment of loans by respondent</td>
<td>33</td>
<td>17.84</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>100</td>
</tr>
</tbody>
</table>
4.0. Conclusion

The paper addresses the financing of housing projects by FUTAASCOOP cooperative society at the Federal University of Technology, Akure. This is in a view to discover how low-income people in developing countries circumvent financial and mortgage institutions to finance housing projects. The paper shows that the people interviewed were economically disadvantageous due to economic recession and low Naira to Dollar ratio. It was revealed that credit societies have provided housing finance to a substantial number of their members, enabling them to become home-owners.

The funds received most of the time were not the only source of funding the building projects. This was due to unstable and high cost of building materials. The proportion of people involved in cooperative societies is still infinitesimal when placed side-by-side with the wider population that are not cooperative members. Therefore, housing low-income earners is still a problem in Nigeria, in term of funding housing projects.

The paper posits that government should intervene in housing finance through methods such as: site and service scheme, provision of low interest loans coupled with long moratorium enabling the people to pay for a long time. When the housing need of low and medium income earners are met, poverty would have been ameliorated, and the people can concentrate on other profitable ventures.

References


Comparison between Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI)
Assessment of Vegetation Indices

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ABSTRACT

The Landsat system has contributed significantly to the understanding of the Earth observation for over forty years. Since May 2013, data from Landsat 8 has been available online for download, with substantial differences from its predecessors, having an extended number of spectral bands and narrower bandwidths. The objectives of this research were majorly to carry out a cross comparison analysis between vegetation indices derived from Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) and also performed statistical analysis on the results derived from the vegetation indices. Also, this research carried out a change detection on four land cover classes present within the study area, as well as projected the land cover for year 2030. The methods applied in this research include, carrying out image classification on the Landsat imageries acquired between 1984 – 2016 to ascertain the changes in the land cover types, calculated the mean values of differenced vegetation indices derived from the four land covers between Landsat 7 ETM+ and Landsat 8 OLI. Statistical analysis involving regression and correlation analysis were also carried out on the vegetation indices derived between the two sensors, as well as scatter plot diagrams with linear regression equation and coefficients of determination ($R^2$). The results showed no noticeable differences between Landsat 7 and Landsat 8 sensors, which demonstrates high similarities. This was observed because Global Environmental Monitoring Index (GEMI), Improved Modified Triangular Vegetation Index 2 (MTVI2), Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), Leaf Area Index (LAI) and Land Surface Water Index (LSWI) had smaller standard deviations. However, Renormalized Difference Vegetation Index (RDVI), Anthocyanin Reflectance Index 1 (ARI1) and Anthocyanin Reflectance Index 2 (ARI2) performed relatively poorly because their standard deviations were high, the correlation analysis of the vegetation indices that both sensors had a very high linear correlation coefficient with $R^2$ greater than 0.99. It was concluded from this research that Landsat 7 ETM+ and Landsat 8 OLI can be used as complimentary data.

Keywords: Landsat 7, Landsat 8, Vegetation Indices, Normalized Difference Vegetation Index (NDVI), Land Cover Change

1.0. Introduction

Vegetation Indices (Vis) are mathematical transformations, usually ratios or linear combinations of reflectance measurements in different spectral bands, especially the visible and near-infrared bands. They are widely used in remote sensing practice to obtain information about surface characteristics from multi-spectral measurements, taking advantage of differences in the reflectance patterns between green vegetation and other surfaces (Payero et al., 2004).

Researchers have proposed a number of spectral vegetation indices premised on the contrasts in spectral reflectance between green vegetation and background materials (Rouse et al., 1974; Richardson et al., 1977; Tucker, C.J., 1979; Jackson, R. D., 1983; Omodanisi and Salami, 2014). Of the indices, Normalized Difference Vegetation Index (NDVI) (Rouse et al., 1974) is the most commonly utilized which is based on infrared and red reflectances. NDVI has been used for fuel mapping, foliar moisture stress detection, burn severity mapping, vegetation classification, forest type mapping, invasive weed detection, and land degradation model. The usual form of a vegetation index is a ratio of reflectance...
measured in two bands, or their algebraic combination. Spectral ranges (bands) to be used in Vegetation Indices calculation are selected depending on the spectral properties of plants.

The first Landsat satellite was launched in 1972 with two earth viewing imagers - a return beam vidicon and an 80-meter multispectral scanner (MSS). Landsat 2 and 3, launched in 1975 and 1978 respectively, were configured similarly. In 1984, Landsat 4 was launched with the MSS and a new instrument called the Thematic Mapper (TM). Landsat 5, a duplicate of 4, was launched in 1984 and is still returning useful data. Landsat 6, equipped with a 15-meter panchromatic band, was lost immediately after launch in 1993 (U.S. Geological Survey, 2016). Landsat 7 was launched in April, 1999, while Landsat 8 was launched in February 2013 (U.S. Geological Survey, 2016). Table 1 shows the band properties between Landsat 7 ETM+ and Landsat 8 OLI.

### Table 1: Band properties for Landsat 7 ETM+ and Landsat 8 OLI (U.S.G.S, 2015)

<table>
<thead>
<tr>
<th>Band Name</th>
<th>Wavelength (µm)</th>
<th>Resolution (m)</th>
<th>Band Name</th>
<th>Wavelength (µm)</th>
<th>Resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 - Blue</td>
<td>0.45 – 0.52</td>
<td>30</td>
<td>Band 1 - Coastal</td>
<td>0.43 – 0.45</td>
<td>30</td>
</tr>
<tr>
<td>Band 2 - Green</td>
<td>0.52 – 0.60</td>
<td>30</td>
<td>Band 2 - Blue</td>
<td>0.45 – 0.51</td>
<td>30</td>
</tr>
<tr>
<td>Band 3 - Red</td>
<td>0.63 – 0.69</td>
<td>30</td>
<td>Band 3 - Green</td>
<td>0.53 – 0.59</td>
<td>30</td>
</tr>
<tr>
<td>Band 4 - NIR</td>
<td>0.77 – 0.90</td>
<td>30</td>
<td>Band 4 - Red</td>
<td>0.64 – 0.67</td>
<td>30</td>
</tr>
<tr>
<td>Band 5 - SWIR 1</td>
<td>1.55 – 1.75</td>
<td>30</td>
<td>Band 5 - NIR</td>
<td>0.85 – 0.88</td>
<td>30</td>
</tr>
<tr>
<td>Band 6 - PAN</td>
<td>0.52 – 0.90</td>
<td>15</td>
<td>Band 6 - SWIR 1</td>
<td>1.57 – 1.65</td>
<td>30</td>
</tr>
<tr>
<td>Band 7 - SWIR 2</td>
<td>2.09 – 2.35</td>
<td>30</td>
<td>Band 7 - SWIR 2</td>
<td>2.11 – 2.29</td>
<td>30</td>
</tr>
<tr>
<td>Band 8 - PAN</td>
<td>0.52 – 0.90</td>
<td>15</td>
<td>Band 8 - PAN</td>
<td>0.50 – 0.68</td>
<td>15</td>
</tr>
<tr>
<td>Band 9 - Cirrus</td>
<td>1.36 – 1.38</td>
<td>15</td>
<td>Band 9 - TIRS 1</td>
<td>1.6 – 11.19</td>
<td>100 ** 30</td>
</tr>
<tr>
<td>Band 10 - TIRS 1</td>
<td>1.6 – 11.19</td>
<td>100 ** 30</td>
<td>Band 11 - TIRS 2</td>
<td>11.5 – 12.31</td>
<td>100 ** 30</td>
</tr>
</tbody>
</table>

* ETM+ Band 6 is acquired at 60-meter resolution. Products processed after February 25, 2010 are resampled to 30-meter pixels (USGS, 2015).

** TIRS bands are acquired at 100-meter resolution, but are resampled to 30 meters in delivered data product (U.S.G.S, 2015).

The Landsat family satellites have contributed significantly to the understanding of the Earth observation for over forty years. As the application of multi-sensored data is growing importantly and effectively in this era of global environment changes (Li et al., 2014), comparison research on the differences between multiple sensors could confirm whether those data are highly related or not; therefore, contributing to the use of various sensors. This is especially helpful particularly in the case of the Landsat system when Landsat 5 was officially retired in January 2013 (Holm, 2013) and Landsat 7 has experienced the scan line corrector failure since 2003 with an estimated 22 percent of data missing per scene (U.S. Geological Survey, 2014).

To be able to carry out effective multi-sensor data analysis, there is a need to compare the results derived from these sensors. Recent literatures have carried out comparison between multiple Landsat sensors to determine if they can be used as complimentary data.

The aim of this study was to carry out a comparison of Vegetation Indices derived from Landsat 7 ETM+ and Landsat 8 OLI Sensors using the Kosofe Local Government Area in Lagos State as a case study. Four sample plots covering four major land cover classes of Built Up area, Heavy Forest, Light forest and Water body, were used to compare the differences and correlation between vegetation indices derived from Landsat 7 ETM+ and Landsat 8 OLI.

### 2.0. Materials and Methods

#### 2.1. Study Area

The study area for this research study is the Kosofe Local Government Area (LGA) of Lagos state. Kosofe LGA is located on the north part of Lagos State within latitudes 6°32′N and 6°38′N and longitudes 3°22′E and 3°28′E, with a land mass of about 81 sq.km. It is bounded on the north by Ogun State, on the west by Ikeja LGA, on the southwest by Shomolu LGA, on the southeast by the Lagos
Lagoon and on the east by Ikorodu LGA. Kosofe has a tropical wet and dry climate that borders on a tropical monsoon climate.

The vegetation of Kosofe is the swamp forest which had been encroached by construction of houses, markets and other infrastructures. The area has a reasonable amount of built up with vegetation covers around Owode area. The mangroves behind the Ketu area are gradually being encroached on due to construction purposes. The major river in Kosofe LGA is the Ogun River which links to Ogun state. Nigerian Population Commission (2006) puts the population of Kosofe at 682,772 people with 358,935 males and 323,887 females.

![Location Map of Study Area](image)

**Figure 1:** Map of Lagos showing location of Kosofe Local Government

2.2. Data

The various data types used for this research and their respective sources are given in the Table 2 below.

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Resolution</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 5 TM Imagery</td>
<td>United States Geological Surveys (USGS)</td>
<td>30m</td>
<td>1984</td>
</tr>
<tr>
<td>Landsat 7 ETM+ Imagery</td>
<td>United States Geological Surveys (USGS)</td>
<td>30m</td>
<td>2000</td>
</tr>
<tr>
<td>Landsat 7 ETM+ Imagery</td>
<td>United States Geological Surveys (USGS)</td>
<td>30m</td>
<td>2006</td>
</tr>
<tr>
<td>Landsat 7 ETM+ Imagery</td>
<td>United States Geological Surveys (USGS)</td>
<td>30m</td>
<td>2015</td>
</tr>
<tr>
<td>Landsat 8 OLI Imagery</td>
<td>United States Geological Surveys (USGS)</td>
<td>30m</td>
<td>2015</td>
</tr>
<tr>
<td>Sentinel 2A Imagery</td>
<td>European Space Agency</td>
<td>10m</td>
<td>2016</td>
</tr>
<tr>
<td>Administrative Map of Lagos</td>
<td>Other sources</td>
<td></td>
<td>2015</td>
</tr>
</tbody>
</table>

2.3. Methodology

2.3.1. Image Preprocessing

Landsat imageries already come geometrically corrected, but for this study each Landsat imagery had to undergo atmospheric correction to convert the digital number values (DN) to surface reflectance values, necessary for calculating vegetation indices. This correction was done using the Radiometric Correction tool in ENVI 5.0 software. In the Radiometric Calibration tab, the Calibration Type was set to Reflectance.
2.3.2. Image Classification

All bands of each imageries of 1984, 2000, 2006, 2015 and 2016 were layer stacked and colour composites were created to aid image enhancement. The study area of Kosofe LGA was used to clip each image using the subset tool in ERDAS Imagine environment. Based on the prior knowledge of the study area and a brief reconnaissance survey with additional information from previous research in the study area, a classification scheme was developed for the study area after (Anderson et al., 1976). The four land cover types used are shown in Table 3.

Table 3: Land cover classification scheme

<table>
<thead>
<tr>
<th>Code</th>
<th>Land Cover Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Built-Up</td>
</tr>
<tr>
<td>2</td>
<td>Low Forest</td>
</tr>
<tr>
<td>3</td>
<td>Heavy Forest</td>
</tr>
<tr>
<td>4</td>
<td>Water Body</td>
</tr>
</tbody>
</table>

The classification scheme given in table 3 is a modification of Anderson Classification Scheme of 1976. Urban Area or Built-Up Land is comprised of areas of intensive use with much of the land covered by structure. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communication facilities. Low Forest may be broadly defined as land used primarily for production of food and fiber. High Forests have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with tree capable of producing timber or wood products. Water body includes all areas within that persistently are water covered, provided that, if linear, they are at least 1/8 mile (200m) wide and, if extended, cover at least 40 acres (16 hectares) (Anderson et al., 1976).

Maximum Likelihood Classification was carried out for all images of 1984, 2000, 2006, 2015 and 2016 using the four land cover classes.

2.3.3. Accuracy Assessment of Classification

Accuracy assessment of the classification was determined by means of a confusion matrix (sometimes called error matrix), which compares, on a class-by-class basis, the relationship between reference data (ground truth) and the corresponding results of a classification. Such matrices are square, with the number of rows and columns equal to the number of classes, in this case, 4. The error matrix, producer’s accuracy, user’s accuracy, overall accuracy and kappa accuracy was computed for each year.

2.3.4. Cross Comparative Analysis of Vegetation Indices

Ten vegetation indices were carried out on Landsat 7 and Landsat 8 imageries of 2015. These vegetation indices majorly covered between the Red, Near Infrared (NIR) and Shortwave Infrared (SWIR) bands. The corresponding formulas for these indices are given below:

i. Anthocyanin Reflectance Index 1 (ARI1) = \( \frac{1}{R_{550}} - \frac{1}{R_{700}} \)  

ii. Anthocyanin Reflectance Index 2 (ARI2) = \( R_{800} \left[ \frac{1}{R_{550}} - \frac{1}{R_{700}} \right] \)

iii. Global Environmental Monitoring Index (GEMI) = \( \eta (1 - 0.25 \times \text{eta}) - \frac{\text{RED} - 0.125}{1 - \text{RED}} \)

\[ \eta = \frac{2(NIR^2 - \text{RED}^2) + 1.5 \times \text{NIR} + 0.5 \times \text{RED}}{\text{NIR} + \text{RED} + 0.5} \]

iv. Improved Modified Triangular Vegetation Index 2

\( \text{(MVTVI2)} = \frac{1.5 + [1.2 \times (\text{NIR} - \text{GREEN}) - 2.5 \times (\text{RED} - \text{GREEN})]}{\sqrt{(2 \times \text{NIR} + 1)^2 - (6 \times \text{NIR} - 5 \times \text{RED} - 0.5)}} \)

v. Leaf Area Index (LAI) = (3.618 \times \text{EVI} - 0.118)

\( \text{EVI} = 2.5 \times \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + 6 \times \text{RED} - 7.5 \times \text{BLUE} + 1)} \)
vi. Land Surface Water Index (LSWI) = \frac{\text{NIR} - \text{SWIR1}}{\text{NIR} + \text{SWIR1}} \quad (8)

vii. Normalized Burn Ratio (NBR) = \frac{\text{NIR} - \text{SWIR2}}{\text{NIR} + \text{SWIR2}} \quad (9)

viii. Normalized Difference Vegetation Index (NDVI) = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad (10)

ix. Normalized Difference Water Index (NDWI) = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}} \quad (11)

x. Renormalized Difference Vegetation Index (RDVI) = \frac{\text{NIR} - \text{RED}}{\sqrt{\text{NIR} + \text{RED}}} \quad (12)

2.3.5. Statistical Analysis

Statistical analysis methods are widely used in cross-comparison between various satellite sensors. Statistical analysis mainly consists of two parts in this study. Firstly, the average values of differenced vegetation indices for six polygons to demonstrate the similarity or difference between Landsat-7 ETM+ and Landsat-8 OLI sensor were cross-compared. Secondly, scatter plots of vegetation indices for cross-comparisons were applied to calculate the coefficients of determination ($R^2$) based on linear correlation analysis. Also, the linear regression equation was also computed and displayed on each sample plot.

2.3.6. Change Prediction for 2030

Change prediction was carried out on the study area for the year 2030. The year 2030 was chosen due to the time difference between acquired images. This was necessary to have a view of the land cover of the study area in the future. Change prediction was carried out using the Idrisi Selva software, which uses a transition matrix from two consecutive years of land cover classification to calculate the probability of the land cover change in the future.

3.0. Results and Discussion

3.1. Land Cover Change Detection

Table 4 shows the results of the areal cover for the landcover types for each year under study. It presents the area covered by each land cover class for each year under study as well as the percentage cover.

<table>
<thead>
<tr>
<th>Land Cover Analysis</th>
<th>1984 (Sq. Km)</th>
<th>Area (%)</th>
<th>2000 (Sq. Km)</th>
<th>Area (%)</th>
<th>2006 (Sq. Km)</th>
<th>Area (%)</th>
<th>2015 (Sq. Km)</th>
<th>Area (%)</th>
<th>2016 (Sq. Km)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Body</td>
<td>15.60</td>
<td>19.32</td>
<td>15.67</td>
<td>19.40</td>
<td>9.36</td>
<td>11.59</td>
<td>12.55</td>
<td>15.54</td>
<td>8.72</td>
<td>10.80</td>
</tr>
<tr>
<td>Built Up</td>
<td>15.30</td>
<td>18.95</td>
<td>33.99</td>
<td>42.08</td>
<td>30.57</td>
<td>37.85</td>
<td>36.87</td>
<td>45.64</td>
<td>41.74</td>
<td>51.68</td>
</tr>
<tr>
<td>Total</td>
<td>80.75</td>
<td>100.00</td>
<td>80.77</td>
<td>100.00</td>
<td>80.77</td>
<td>100.00</td>
<td>80.78</td>
<td>100.00</td>
<td>80.76</td>
<td>100.00</td>
</tr>
</tbody>
</table>

From Table 4, built up covered 15.30 sq.km of the total study area, which is about 18.95% in 1984. This increased to about 42.08% with 33.99 sq.km in 2000. There was a slight decrease in 2006 with 30.57 sq.km and an increase to 36.87 sq.km and 41.74 sq.km in 2015 and 2016 respectively. Water body covered 19.32% of the study area with 15.60 sq.km in 1984. It slightly increased to about 19.40% in 2000 with 15.67 sq.km. in 2015 and 2016, water body covered 12.55 sq.km and 8.72 sq.km, respectively.

In 1984, heavy forest covered 24.46 sq.km., in 2000 it decreased to about 21.69 sq.km. Heavy forest experienced a decrease with 26.88 sq.km, 18.06 sq.km and 16.53 sq.km. in 2006, 2015 and 2016 respectively. Light forest on the other hand, experienced a fluctuating coverage, covering 31.44% in
1984 to 11.66% in 2000. It increased to 23.93% with 19.33 sq.km. in 2006 and decreased to 13.30 sq.km and 13.77 sq.km in 2015 and 2016 respectively.

3.1.1. Land Cover Maps

Figure 2 below shows the classified land cover maps for all years under study. Built up is represented in red colour, heavy forest in dark green, light forest in light green and water body in blue. This colour representation is a modification of (Anderson et al., 1976).

![Figure 2: Classified Land Cover Maps](image_url)

3.1.2. Accuracy Report

The accuracy report for 2016 is shown in Table 5.

<table>
<thead>
<tr>
<th>Classified Data</th>
<th>Reference Total</th>
<th>Classified Totals</th>
<th>Number of Correct</th>
<th>Producer's Accuracy (%)</th>
<th>User's Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Body</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>80.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Built Up</td>
<td>100</td>
<td>120</td>
<td>100</td>
<td>100.00</td>
<td>83.33</td>
</tr>
<tr>
<td>Heavy Forest</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>99.00</td>
<td>99.00</td>
</tr>
<tr>
<td>Light Forest</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>99.00</td>
<td>99.00</td>
</tr>
<tr>
<td>Total</td>
<td>400</td>
<td>400</td>
<td>378</td>
<td>94.50</td>
<td>95.33</td>
</tr>
</tbody>
</table>

Overall Accuracy – 94.50%
Overall Kappa Accuracy – 92.67%

3.2. Cross-Comparison between the Values of Vegetation Indices Derived from ETM+ and OLI

Figure 3 shows the graphs of the mean values of differenced vegetation indices for all four sample plots between Landsat 7 ETM+ and Landsat 8 OLI. Sample plot 1, 2, 3 and 4 represents heavy forest, built up, light forest and water body respectively. From the graph of ARI1, it can be seen that it has a higher
standard deviation. The mean differences of heavy forest and light forest are more closely fixed compared to mean differences of built up and water body. In ARI2, the mean differences of heavy forest, light forest and built up are more closely clustered compared to that of water body. This also has a high standard deviation.

GEMI has a standard deviation of 0.011 and the mean values of the sample plots are closely related. LAI has a standard deviation of 0.16, it can be seen that the mean values are scattered around the mean. LSWI, MNDWI, MTVI2, NBR, NDVI and RDVI have standard deviations of 0.041, 0.039, 0.012, 0.030, 0.032 and 0.182 respectively. This shows that the mean differences between Landsat 7 ETM+ and Landsat 8 OLI are not so noticeable. AR1, AR1, LAI and RDVI have higher standard deviations which indicates that there were higher differences between Landsat 7 ETM+ and Landsat 8 OLI in these vegetation indices.

![Figure 3: Mean Values of Differenced Vegetation Indices Derived from Landsat-7 ETM+ and Landsat-8 OLI Images within Five Sample Plots](image)

3.3. Statistical Analysis of Vegetation Indices Derived from ETM+ and OLI

Figures 4-13, shows the scatter plot diagrams with linear regression equation and coefficients of determination ($R^2$) between Landsat 7 ETM+ and Landsat 8 OLI for each vegetation index in all four sample plots. For each diagram, the linear regression equation and the coefficient of determination ($R^2$) is given. In each plot, Landsat 8 OLI derived vegetation indices values are displayed on the X-axis while Landsat 7 ETM+ derived vegetation indices values are displayed on the Y-axis.

The diagrams show that the coefficient of determination ($R^2$) for all plots were greater than 0.99. this demonstrates that vegetation indices derived from Landsat 7 ETM+ and Landsat 8 OLI are highly linearly correlated.

![Figure 4: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI AR1 values for the four sample plots](image)
Figure 5: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI ARI2 values for the four sample plots

Figure 6: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI GEMI values for the four sample plots

Figure 7: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI LAI values for the five sample plots
Figure 8: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI LSWI values for the four sample plots

Figure 9: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI MNDWI values for the four sample plots

Figure 10: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI MTVI2 values for the four sample plots
Figure 11: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI NBR values for the four sample plots

Figure 12: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI NDVI values for the four sample plots

Figure 13: Statistical relationship between Landsat-7 ETM+ and Landsat-8 OLI RDVI values for the four sample plots
3.4. Land Cover Projection for 2030

Table 5 shows the result of the projected areal cover for each land cover class for year 2030. It shows that by the year 2030, Built Up area would have covered about 64.87% of the study area while other lands cover classes like light forest, heavy forest and water body would reduce.

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (sq. Km.)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Forest</td>
<td>11.38</td>
<td>14.08</td>
</tr>
<tr>
<td>Water Body</td>
<td>7.46</td>
<td>9.24</td>
</tr>
<tr>
<td>Built Up</td>
<td>52.39</td>
<td>64.87</td>
</tr>
<tr>
<td>Light Forest</td>
<td>9.56</td>
<td>11.83</td>
</tr>
<tr>
<td>Total</td>
<td>80.77</td>
<td>100</td>
</tr>
</tbody>
</table>

3.5. Discussion

In this study, Landsat imagery (Landsat 7 and Landsat 8) of 2015 covering the Kosofe LGA were used. The comparison was carried out in two parts; comparison of the mean differences between the vegetation indices derived from Landsat 7 and Landsat 8 and statistical analysis involving regression and correlation analysis. Four sample plots covering four land cover types of built up, heavy forest, light forest and water body were used for the comparison.

In comparing the mean differences of vegetation indices derived for each plot, it was observed that there existed subtle differences between Landsat 7 and Landsat 8 sensors, which demonstrates high similarities. This finding agrees with (Peng et al., 2014) and (Nguyen & Pham, 2014). This was observed because GEMI, MTVI2, NBR, NDVI, MNDWI, LAI and LSWI had smaller standard deviations. NDVI had mean difference value of 0.0069, GEMI with -0.16, MTVI2 with 0.0038, NBR with 0.049, MNDWI had 0.033, LAI with -0.05 and LSWI with 0.036. MTVI2 might be the optimum parameter with a mean difference of close to zero, followed by GEMI and NDVI.

However, RDVI, ARI1 and ARI2 performed relatively poorly because their standard deviations were higher and their mean difference values were -0.084, 0.50 and 0.75 respectively. One very important factor that could have led to the fluctuations of the differenced values of vegetation indices might be the different land cover types among the selected four sample plots.

It was also observed from the correlation analysis of the vegetation indices that both sensors had a very high linear correlation coefficient with \( R^2 \) greater than 0.99. This also agrees with (Peng et al., 2014) and (Nguyen & Pham, 2014). The subtle differences and high correlation of vegetation indices demonstrates that Landsat 8 OLI and Landsat 7 ETM+ imagery can be used as complimentary data.

The land change analysis revealed that considerable change had occurred in the study area between 1984 and 2016. Between 1984 and 2016, built up land experienced a 172.81% increase from 15.30 sq.km in 1984 to 41.74 sq.km in 2016. Heavy forest experienced a -32.42% decrease with 24.46 sq.km in 1984 to 16.53 sq.km in 2016. Light forest also experienced a decrease by -45.77% with 25.39 sq.km in 1984 to 13.77 sq.km in 2016. Water body experienced a decrease of -44.10% with 15.60 sq.km 1984 to 8.72 sq.km in 2016. These decrease in vegetation land cover types is mostly associated to human developments which has led to a high rate of deforestation. Built up area increased drastically during the period under study due to the same urbanization and economic factors.

It is projected that built up land will have an increase of 25.52% from 41.74 sq.km in 2016 to 52.39 sq.km in 2030, covering about 64.87 sq.km of the total study area. However, heavy forest, light forest and water body are projected to experience a decrease of -31.16%, -30.57% and -14.45% respectively in 2030. This is highly due to urbanization and development.

4.0. Conclusion

This research study carried out a comparison between vegetation indices derived from Landsat 7 ETM+ and Landsat 8 OLI. It used Landsat images of 2015 covering the Kosofe LGA in Lagos state for this comparison. Comparison between the different vegetation indices derived from both sensors basically
demonstrated that there are no noticeable differences between the Landsat-7 ETM+ and Landsat-8 OLI sensors. This was clearly shown by GEMI, MTVI2, NBR, NDVI, MNDWI, LAI, and LSWI, because their standard deviations were closer to zero. However, RDVI, ARI1 and ARI2 performed relatively poorly, because the standard deviations were higher. Also, correlation analysis of the vegetation indices indicated that both sensors had a very linear correlation coefficient, with $R^2$ greater than 0.99. The subtle differences and high correlation of vegetation indices demonstrated that Landsat-7 ETM+ and Landsat-8 OLI imagery can be used as complementary data.

References


Public Cemeteries of Benin City: Examining a Neglected Dimension of Urban Nigeria

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ABSTRACT

Creating a sustainable urban landscape demands adequate provision for all categories of land use and the effective management of such spaces. However, urban management in Nigeria appears to pay little attention to space for the dead as can be observed in the poor physical and environmental conditions of public cemeteries. This situation amounts to an omission of, as well as a failure in, the duty to plan for, and effectively manage, all urban land needs. This paper investigates the three public cemeteries in Benin City to ascertain their physical and environmental conditions and management practices. Data for this study was gathered through primary and secondary sources: the cemeteries and their surroundings were physically inspected; data on cemetery management obtained directly from the responsible local officials; other data came from literature, publications and the archives. The findings confirm all three cemeteries to be in a neglected state; are challenged by a dearth of skilled staff, the absence of modern equipment and management techniques; and, being fenced-off from public view and almost always in an overgrown state, effectively are excluded from the urban environment. The recommendations are for an overhaul of these facilities and the institution of modern management charged with a mission to create environmentally-friendly, physically attractive and visually accessible cemeteries.

Keywords: Land use planning, Public cemeteries, Cemetery management, Sustainable urban management, Benin City

1.0. Introduction

Planning for all land uses is a pre-requisite for the sustainable use, management and development of the urban landscape. It is for this reason that Keeble (1983) avers that a cardinal aim of town planning is the “Allocation of sufficient space for all urban needs”. In the Nigerian milieu which is characterised by “unplanned land use and weak development control” (Omuta, 1988) all urban needs tend not to been given adequate attention leading Agboola and Agboola (1997) to conclude that Nigeria’s cities have grown in spite of planning laws. Usually, public authorities in allocating state land directly or through state agencies, are mainly concerned with residential, industrial, commercial and institutional land uses such as schools, hospitals and stadia even as the population of the country grew from 70 million in 1973 to nearly 200 million in recent years. Again, given that land use in Nigeria’s urban areas is usually shaped more by private players acting in the absence of the state regulatory framework (Ikejiofor,2009;Aluko,2011),the land use pattern is mostly not rationally founded. In such a situation, the low priority given to the cemetery may be seen as being reflective of the kind of attention given to its management.

The term “cemetery” is used to describe the resting place of departed people. It was the practice in the cemeteries of old to give earth burials to the deceased meaning that human remains were interred inside graves. In modern times, the cemetery definition has come to encompass more than earth burials. To illustrate, the Cemetery Regulation Act of Michigan State in the United States of America, for instance, states that: “cemetery means one or a combination of more than one of the following: “(i) A burial ground for earth interments(ii) A mausoleum for crypt entombments (iii) A crematory for the cremation
of human remains (iv) A columbarium for the inurnment of cremated remains”. In Nigeria’s Lagos metropolis also, modern cemeteries developed by private entrepreneurs such as Victoria Vaults, Ebony Vaults and Ikoyi Vaults and Gardens now provide for more than earth interments, especially following the trail-blazing passage of a law (Lagos State Government, 2013) approving cremation as a legal option of burial. The cemetery is an institutional land use which is a necessity in urban areas. Its effective management is both a statutory and environmental duty: the proper disposal of the dead being a civic duty, just as is the maintenance of a hygienic environment. The adequate provision and effective management of cemeteries is justified simply by the facts that: “Human death and burials are part of human life, while cemetery management is part of human settlement development” (South African Local Government Association, 2016).

The cemetery is a place of importance for many reasons apart from the obvious. In countries with an established tradition of good record-keeping and maintenance, cemeteries are heritage sites which possess cultural and historical value; they are also seen as places for recreation (Matero and Peters, 2003). In such jurisdictions where modern practices obtain, cemeteries are also places of solace, their environments lushly vegetated and offer a biodiversity which supports conservation and the ecosystem. In effect, the cemetery presents as an environmentally-friendly form of land use.

1.1. Human Burial and the Environment

The issues of death and burial can be viewed from the general as well as the municipal angles. In general terms, after death, there are certain obligations which the living owes to the dead. The first is to provide a good environment as a last resting place; second, to inter the remains of the deceased in a decent manner and third, to ensure that the prepared place of rest is decently and hygienically managed and maintained thereafter. From the municipal viewpoint, the burial of the dead is seen as an important and necessary public service which is compelled by law. The maintenance of good environmental standards and public hygiene lies behind the statutory provision for the disposal of deceased humans in a manner which would not pose a risk of epidemic outbreaks. Of necessity, the cemetery should be well located, well laid out, properly maintained and administered. The obligation for a decent handling of the dead is not only individually accepted, but cuts across cultures and societies.

It is the view of environmentalists that the cemetery should be a healthy urban habitat just like other areas of the urban environment (Harker, 2012; Uslu et al, 2009). Of vital importance in the quest to make the cemetery more eco-friendly is the selection of an appropriate location. Achieving this objective requires addressing ecological concerns in choosing cemetery locations, in planning, design, maintenance and especially in burial practices which do not give rise to environmental problems such as pollution and the contamination of soils and groundwater. As Uslu et al(2009) state “Depending on the form of burial and the subsequent practices at the cemeteries, the burial areas can become areas threatening the environment, polluting underground water and creating negative effects on fauna and flora”.

The environmental advantages of burial practice which foregoes chemical embalmment and hardwood caskets have been pointed out by Harker (2012). Similarly, Uslu et al (2009) believe that ecological concerns would be taken care of if burial practice avoids embalmment of corpses, uses biodegradable materials for coffins and actually protects the biodiversity of the burial area. It would appear then that traditional burial practice in ancient Africa which predates embalmment and preservation technology, requiring that corpses be interred same day or not later than the second day (as in old Bini kingdom), was more environmentally friendly than what is widely practiced today in the same environment. Whilst the modern way, which is consequential to society's change from its agrarian origin to an industrial state has not totally displaced the traditional, it constitutes ecological challenges because of the introduction of embalmment (to preserve bodies for months before burial), the use of coffins constructed with materials (e.g. pillows, metals such as zinc, copper lead and iron), soft coffin linings, burial clothing) which upon getting into the soil become pollutants. Burial practice in many parts of the country has changed from old tradition to a system which has long-term implications for ecology and environment.

In recognition of environmental and ecological concerns, Uslu et al (op cit) recommends that a suitable site for a cemetery must have: (1) a soil that is neither loose nor rocky; (2) located away from underground water basins and potable water; (3) a slope of 0 to 10% for easy decomposition; (4) the
land must not be flat in order to drain easily; (5) the soil must be water permeable with sufficient micro-
organic activity within it. The authors add that “The main purpose is to decrease the negative impacts
of the cemeteries on the underground water, natural vegetation and fauna existing in the burial area, to
use materials biodegrading more rapidly and to minimize the ecological footprint of the individual”.

1.2. Origins of the Cemetery

In the course of humankind’s terrestrial existence, land has been found to be essential not only for
sustenance, but also, for the repose of the departed. In spite of the existence of cremation in some
cultures, earth burial remains the most widespread manner of handling human remains across the world,
an enduring fact which is encapsulated in the Christian burial expression: “earth to earth, ashes to ashes
and dust to dust” indicating the umbilical relationship between terrestrials and the terrenum. As
humankind evolved from the stage of hunting and gathering to settled existence, places naturally
became designated in communities and settlements as burial grounds or places for burying the dead.
Cemetery is the new name for burial grounds. Fogli (2004) as cited in Uslu et al (2009) defines the
functions of the cemetery as:

i. Place of deposit and transformation of dead bodies without dangers for the public health.

ii. Place of visit for those people wanting to remember a dead person and at the same time a
symbol of the historical memory of a collectivity”.

1.3. Public Cemeteries in Nigeria

In pre-colonial times, amongst the conglomeration of over 450 ethnic groups which occupy the present-
day Nigerian space the widespread cultural practice was to bury the dead literally amongst the living:
either near or within their homes. This practice had spiritual, religious and cultural connotations. The
belief was that the physically dead were considered still as having an existence as living dead which
family members wished to have around them and be associated with. These beliefs are the bases for the
practice of home burial.

Public cemeteries in Nigeria are essentially, therefore, the consequence of interaction between the
British (colonialists as well as the church missions) and the many cultures of Nigeria. According to
Duru (2013), due to “western influence however, the tradition of burying the dead in the family
compound paved way for the use of public cemeteries. Public cemeteries started when missionaries
acquired land to bury their colleagues. This was later followed by the acquisition of land to bury
deceased church members. The development gave rise to government-owned cemeteries, and
subsequently, private ones”. The very first cemetery in the Nigeria was established in the late 19th
century in Lokoja, then the seat of government, and it is the final resting place of
colonial administrators,
soldiers, merchants, interpreters and missionaries. The colonialists discouraged home burials whilst
encouraging the use of public and church mission cemeteries.

The church missions created cemeteries adjoining their premises for the interment of deceased converts.
In these places, the various grave sites were marked with headstones, a practice previously unknown in
these climes. The church burial grounds were not large and the spaces were soon filled up. These
cemeteries were, however, not patronized by most of the congregants, an overwhelming number of
whom preferred burying their dead in the old way.

Public commentary on the state of Nigeria’s public cemeteries has been very uncomplimentary. The
definite impression conveyed is that these facilities are not well managed. Some of the commentaries
are as follows:

“Public cemeteries in Lagos are in a decrepit state that makes it impossible for the dead to rest in peace.
Perhaps the state of public cemeteries in Lagos is a clear indication that Nigerians have no value for
history; no regard for culture; no knowledge of the importance of preservation, and no respect for the
souls of the departed”.

Elusoji (2015) on Atan and Matori cemeteries in Lagos

“...the graves are overgrown with weeds and have become steady grazing grounds for sheep and goats
that roam the premises”.

Onwuanyi et al., 2017
Duru (2013) on Atan cemetery, Lagos (second largest in Nigeria)

“The cemetery is overgrown with dry, elephant grasses, weeds, shrubs and climbers. The facility lies forlorn...residents use it as a refuse dump”.

Omegoh (2016) on the European Cemetery, Lokoja (first and largest in Nigeria)

“...these cemeteries have challenges of space, access and location. The existing cemeteries are old and overstretched. Used graves have been ‘unknowingly’ re-used... most of the cemeteries have not recruited new staff in the last 10 years...the system is left with an ageing staff with declining efficiency ...

Douglas (2013) on public cemeteries in Rivers State, Nigeria

1.4. The Study Area

The study area is Benin City, administrative capital of Edo State, a sub-national governmental unit of the Federal Republic of Nigeria. It is a city occupied mainly by the Bini-speaking people of the Edo ethnic nationality. The city population in the last national census of 2006 was 1.15 million persons (National Bureau of Statistics, 2009) and applying the National Population Commission’s growth rate of 3.5% p.a., for urban centers in Nigeria, its 2017 population is estimated at 1.56 million persons which is projected to be 2 million by 2020 and 5.5 million by 2050. There are three public cemeteries in the city named 1st Cemetery, 2nd Cemetery and 3rd Cemetery and they constitute the subjects of this study.

Although Benin City falls into four different local government council jurisdictions, all three public cemeteries are located within only one of the four, the Oredo local Government Council. Before the 1980s local government reforms, all three cemeteries as well as the entire city fell under a single entity, the Benin City Council.

![Figure 1: Location Map of the Public Cemeteries in Benin City](image)

The thesis of this paper is that the cemetery is an important consideration in land use planning and urban management just as are schools, hospitals, markets and public buildings. Sustainable urban management calls for a sustainable cemetery policy. As asserted by Uslu et al (2009): “If cemeteries … are treated as areas where ecological concerns have priority as is the case in all fields of life with respect to planning, management and design, they will be important sources of making the cities healthy, aesthetic and livable places”.

Onwuanyi et al., 2017
Against the background impression that public cemeteries in Nigeria are in a decrepit state, this paper investigates the three cemeteries in Benin City in order to ascertain their physical condition, subsisting management policies and practices with a view to suggesting improving measures in accordance with best practice. To achieve these objectives, the following issues would come up for resolution:

(a) What is the state of the public cemeteries in Benin City?
(b) What are the challenges of public cemetery management in Benin City?
(c) What steps may be taken to improve public cemeteries in Benin City?

2.0. Material and Methods

The first two research questions recommended the gathering of primary data. The state of the cemeteries was established by physical inspections undertaken by the authors. A prepared list of questions was used as a guide in gathering data on management issues through interactions with the Oredo Local Government Council Parks and Environmental Department officials whose duty it is to administer the cemeteries. Particularly, data was sought as to annual funding, staffing, training, equipment deployed, income from burial fees and annual running costs. Archival data was also sought as to the acreages of the cemeteries and legal responsibility for their management. On the third research question which addresses ways in which the cemeteries can be improved physically, functionally and managerially, recourse was made to literature, other publications and the archives. This particular issue is treated in the discussion section. Data is presented in descriptive tables, photographs and by satellite imaging.

3.0. Results and Discussion

3.1. State of the Cemeteries and Cemetery Management

3.1.1. Physical Inspection Report

Physical inspections were made of each of the three cemeteries. Note was taken of the internal and external environments, the physical condition of the fences, gates and the structures seen. The results of the physical inspections are presented in Figures 1, 2 and 3 and in Table 1. The archives and responses from cemetery management officials are the sources of the data presented in Table 2.

Figures 1-3 which display the entrances to the cemeteries are indicative of their environmentally unattractive and neglected states. Table 1 presents a description of the environment, the structures and available facilities and security arrangements. It was observed during the inspection that all of the cemeteries are surrounded by residential areas. All of the cemeteries are fenced off from the public by sandcrete block walling.

![Figure 1: (a) Entrance Gate of First Cemetery (b) Entrance of Second Cemetery (c) Entrance Gate of Third Cemetery](image_url)

<table>
<thead>
<tr>
<th>Table 1: State of the Cemeteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onwuanyi et al., 2017</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Land Area (m²)</th>
<th>Ownership</th>
<th>Internal Capacity</th>
<th>Vacant Space</th>
<th>Official Burial Fees (N)</th>
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</thead>
<tbody>
<tr>
<td>1st Cemetery</td>
<td>1st Cemetery Road</td>
<td>45,074</td>
<td>Oredo Local Government Area</td>
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<tr>
<td>2nd Cemetery</td>
<td>2nd Cemetery Road</td>
<td>24,389</td>
<td>Oredo Local Government Area</td>
<td>N/A</td>
<td>N/A</td>
<td>6,000.00</td>
</tr>
<tr>
<td>3rd Cemetery</td>
<td>3rd Cemetery Road</td>
<td>60,514</td>
<td>Oredo Local Government Area</td>
<td>N/A</td>
<td>N/A</td>
<td>6,000.00</td>
</tr>
</tbody>
</table>

N/A: Information not available

3.2. Interview Results

Data on cemetery management as garnered from interactions with local government officials are as follows:

3.2.1. Operational Data

In embarking upon this study, the expectation was that reliable data would be made available on issues pertaining to cemetery management over the preceding ten years. Such important information was expected in relation to annual budgets, maintenance, available plots and level of patronage. The contrary was proven to be the case as virtually no data could be accessed after six months of waiting. Even basic information such as the acreage of each cemetery and their establishment dates were unavailable.

Maintenance action in the past eight years has been virtually non-existent save for when the three cemeteries were recently cleared of bushy undergrowth following public complaints about their unkempt state. It transpired from interviews of officials responsible for the cemeteries that some management challenges are being faced. These are treated in the discussion section.

3.2.2. Management Policies and Operations

The law requires that a certificate of cause of death be presented for each deceased person. The system offers the option of burial at the cemetery or burial at the deceased’s residence for which different fees are charged by the local government. Where burial is to take place at home, the local government must beforehand inspect and approve the suitability of the venue; and where it is adjudged unsuitable, say due to objections by concerned parties or where the ownership of the burial site is in dispute, permission would be denied.

The three cemeteries have been always under the management of the local government, but in 2011, the state government intruded into the management of 3rd Cemetery (the largest of the three) by making
an arrangement with a private firm to run a portion of it ostensibly on a PPP arrangement. The impact of this arrangement was not externally visible as the 6-hectare cemetery space remained unappealing. Besides, this arrangement does not benefit the local government in any way as the fees for cemetery space do not come to its coffers; local government staff are not trained in the new systems and equipment introduced by the operator and this arrangement cannot, by any means, represent a long-term strategy to address cemetery management problems.

The cemeteries are still being managed by old methods which are labour intensive, technologically backward and wanting in new ideas. Indeed, cemetery management policy can be described as being as moribund as the cemeteries themselves. The common characteristic of overgrown bushes, broken fences and the absence of basic services, tell the story of neglect. Officials reveal that in the past five years, the now overgrown cemeteries have been cleared just once following complaints from members of the public. The impression created is that the cemeteries are places where the dead are interred and thereafter forgotten. This may explain why they are not serviced by public utilities (electricity, water) and there are no structures on site which offer shelter of any kind to visitors and even the few cemetery staff save for the little huts at their entrances. The current level of staffing as shown in Tables 3 and 4 are indicative of the of operational capacity (personnel) of the cemeteries and their capability (equipment) for servicing a city population of over 1.5 million and for maintaining the large acreage of the cemeteries which call for a sizeable standing grounds maintenance team with modern equipment.

### Table 3: Staffing of the Cemeteries of Benin City

<table>
<thead>
<tr>
<th>Role of Staff</th>
<th>First Cemetery</th>
<th>Second Cemetery</th>
<th>Third Cemetery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clerk</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Diggers</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

### Table 4: Equipment Deployed by Cemetery Grounds men

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick axes</td>
<td>Excavation</td>
</tr>
<tr>
<td>Shovels</td>
<td>Excavation/Infilling</td>
</tr>
<tr>
<td>Wheel Barrows</td>
<td>Removal of excavated soil</td>
</tr>
<tr>
<td>Cutlasses</td>
<td>Bush clearing</td>
</tr>
</tbody>
</table>

3.3. Findings

The findings of this study can be summarized as follows:

First, all the three cemeteries are in a state of physical and environmental neglect. Second, cemetery management is facing challenges of funding, staffing, modern equipment, basic infrastructure, services and new ideas. Third, constitutional responsibility for the “establishment and maintenance of cemeteries, burial grounds and homes for the destitute or infirm” (Constitution of the Federal Republic of Nigeria, 4th Schedule) belongs to local governments, in this case, the Oredo Local Government Council, through its Parks and Environment Department.

Arising from the findings, the discussion is divided into two parts. First, it looks at the reasons for, and the implications of, the poor condition of these cemeteries, and second, it considers the need and prospects for improvements in the physical appearance, facilities and management quality.

3.3.1. Reasons and Implications of Neglect

First, local governments as a tier of government are plagued by the problem of adequate capacity. Whilst poor capacity is a general public service problem in the country (Asiodu, 2013, 2015; Igbuzo, 2015), the malaise is accentuated at the state and local levels (Igbuzo, 2015) and this cannot but affect cemetery management.
Second, funding and political interference by the state are worthy of mention. From interactions with officials, the cemeteries of Benin City have a perennial problem of inadequate funding. This may have precipitated the decision of the past state administration (2008-2016) to introduce a PPP arrangement as regards 3rd Cemetery. The funding problem is vital as it would tend to affect the availability of resources, effective management and maintenance, the absence of which are reflected in the present state of the cemeteries.

There are two fundamental problems of local governance in all of Nigeria. Under the country’s revenue-sharing arrangement, the three tiers of government: federal, state and local respectively receive monthly 52.69%, 26.72% and 20.62% of monies accruing to the federation account. In addition to their allocation, local governments raise revenue from constitutionally-permitted sources such as market charges, cemeteries, permits and so on. There is, therefore, a reason to believe that local governments are financially equipped to handle their responsibilities if prudence, accountability and prioritisation were applied in practice. In the absence of evidence of budgetary allocations for cemeteries, a definitive position cannot be taken on the adequacy of funding.

However, a real problem is that the state, a second-tier authority, oversees the activities of local governments within its jurisdiction, in the process of which constitutionally allocated funding for the latter is channeled through a joint bank account operated by both tiers of government. In the course of accessing these funds, the local governments allege that they do not always receive the full benefit of their granted resources, with the state tending to take away a lion’s share under the guise of financing joint projects. This is the local governments’ rationalisation of their inability to pay their workers on a regular basis leading to a backlog of unpaid salaries and the stultification of projects. Given also, the poor accountability in the local government system (Human Rights Watch, 2007), the prospects of a rejuvenation of cemetery management appear dim. With the ready availability of the home burial option, it is highly unlikely that public cemetery services would be self-sustaining even when properly managed. The prospects are that this municipal service will in the foreseeable future need to be heavily subsidised.

State authorities in Nigeria tend to interfere in the political leadership of local governments, using the executive offices and, by implication the resources, for patronage of political party stalwarts and loyalists (Agbodike et al, 2014; Maja-Pearce, 2014). Such a situation has tended to create unfocused leadership, poor administrative practices and poor overall governance. The Edo State Government decision to outsource management of 3rd Cemetery to a private firm can be classified as an act of political patronage, interference and a usurpation of the constitutional duty of the local government. This arrangement not only deprives that authority of revenue, but prevents the development of capacity amongst the staff. Indeed, whilst the constitution allows the state to supervise local governments and even make laws which apply to them, the entry of the state into the management of 3rd Cemetery is more of an act of intrusion, rather than supervision.

Third, there is the problem of staffing and skilled personnel. With part of its responsibilities given out in political patronage, cemetery management is affected. A focused administration which has access to its funds is a necessity for developing the staff and personnel which would enable the achievement of set objectives. In so far as those requirements are not in place, the organisation would remain handicapped.

Obviousely, at the existing level of operations and resource constraints, it will be difficult, if not impossible, for the system to deliver quality. The question of manpower training which is important for improved performance on the job (of course with better equipment and technology) would seem impossible in the circumstances.

Fourth, there is a tradition and predilection for home burials in the city. However, some people opt for burial in the public cemetery. Residents who originally came from other parts of the country often transport their deceased to ancestral homes in other parts of the country for burial, usually not in public cemeteries but in the homestead whilst some others opt for the cemetery. The home burial option may be a factor in why due attention is not been given to cemetery management. But it can be argued also that the poor visage of these neglected cemeteries could be due to people’s continued preference for
home burial. An image change for the cemeteries should bring a change to the way that they are perceived.

3.3.2. Exploring Steps for Improvement of the Public Cemeteries

The cemeteries of Benin City need improvement in terms of physical condition, equipment, basic services and utilities and management. Above all, they have to be made visually accessible and best practice compliant. This argument for improvement can be sustained on several grounds.

First, the neglect of public cemeteries amounts to a neglect of the environment. Good environmental management cannot be achieved without the inclusion of every aspect of the environment. The objective of good environmental management must lie in delivering a sustainable landscape. A sustainable urban environment, the sustainable use of urban land cannot be achieved if a part of the environment is in a decrepit state.

Second, society must understand and accept that it is a duty owed by the living to the departed to have properly run cemeteries. The quality of public cemeteries constitutes a veritable index of the developmental state of any society. Sir William E. Gladstone (1809–1898), four-time British Prime Minister, is credited with the dictum: “Show me the manner in which a nation cares for its dead and I will measure with mathematical exactness the tender mercies of its people, their respect for the laws of the land and their loyalty to high ideals”. This pronouncement underscores the duty which the living, whether as individuals or as a society, owe to the departed.

Third, cemeteries offer services, the effectiveness of is determined by the quality of management. In explaining the need for a decent handling of the dead, the South African Local Government Association (2016, op cit) states that: “… cemetery management is part of human settlement development”. By this admission, other aspects of human settlement management such as housing, transport and so on are not more important than the cemetery dimension. The quality of management required in the handling of cemeteries is as great as that deployed in other activities considered also to be of importance.

Fourth, sandcrete block wall fencing built around the public cemeteries should be removed because it shuts them off from public view and helps to create the impression that they are not part of the urban landscape, but rather are like backwoods, places shut off from public access and every urban amenity. This situation is ironic in that it contradicts the African (and also Nigerian) cultural belief that the dead are buried amongst the living because, in spite of their physical absence, they are still seen as having a presence desired by the living. Visual accessibility would support the idea of closeness of the dead to the living. Additionally, the present walling style aids superstitious beliefs about the dead and the perpetuation of myths. Furthermore, hiding cemeteries from public view and behind high walls enables criminal activities like the nefarious desecration of graves, especially with the poor security staffing and absence of security lighting at night.

3.4. Creating Environmentally Sensitive Cemeteries

Another way in which cemeteries can be improved in an era of concern for sustainable development is to make them environmentally sensitive. In the case of Benin City, the already established urban structure places some restrictions on the extent to which the cemeteries can be modernised. For instance, as a result of unregulated urban growth patterns, all three cemeteries are now hemmed in by residential development, whereas this type of land use should not be in living quarters. This situation limits the pursuit of the ideal of creating environmentally sensitive cemeteries which would complement and promote a sustainable urban environment. However, in pursuit of this ideal, the vision should be to the make the public cemetery a complementary part of the urban landscape. Appropriately, the mission should aim creating physically and visually accessible cemeteries which are able to offer all-round security to the interred as well as to visitors. Environmental sensitivity can be pursued in the following ways.

First, for the existing cemeteries, protective, but alienating sandcrete block fencing have to give way to low-height vertical railings which allow visual access; the environment always kept clean and lighted up; paved paths created; onsite tomb location facilities made available; directional signs provided and
aesthetics improved. Visual access and neatness would enable the realisation that cemeteries are part of the urban landscape and not a symbol of urban blight, which impression, their present conditions convey. Old and collapsed tombstones have to be repaired and tidied up. In so doing specifications have to be issued as to design, height, colour and material in order to achieve quality, durability and a level of uniformity which would provide aesthetic appeal.

Second, for new cemeteries, planning and design must change to reflect modern methods. A conscious effort must be made to plan and design the cemetery as the institutional land use which it is. It has to be integrated into the urban landscape, made accessible, be aesthetically pleasant, ecologically friendly and properly landscaped, possibly as part of a comprehensive urban open space design. The South African Local Government Authority (op cit) succinctly captures this concept in the following manner: “From the outset, new cemeteries should be conceived for multiple uses, and integrated into urban areas as green space for parks and recreational activities as well as burials”. In this manner, the cemetery is integrated into the urban landscape and land used as cemetery cannot be regarded as being lost to urban use. Such land can therefore be seen as having been planned, developed and used in a sustainable way.

4.0. Conclusion

Working from the premise that Nigeria’s public cemeteries are generally neglected as suggested by their poor appearance and published commentary, this paper set out to examine the condition and management status of the three public cemeteries in Benin City. The findings are that the cemeteries, without exception, are neglected and poorly managed; that there is a need for an overhaul; and for new, environmentally sensitive cemeteries with modern standards of design and management which would complement the urban landscape.

Given the relatively short history of urban planning and public cemetery management in Nigeria, it would be unrealistic to compare these first generation public cemeteries to those in climes where the preservation of historic burial grounds and cemeteries has been established for centuries. Benin City’s cemeteries are, therefore, far from being places of cultural, historical, scientific and scenic importance and value as can be found in older countries. However, whilst the present cemeteries need upgrading and better management, tomorrow’s need to be planned, designed, constructed and managed to reflect ecological and environmental concerns, if it is acknowledged that the world now has become a global village in which the common objective is not only to undertake sustainable development, but also, to ensure that all development remain sustainable.

The implications which arise from this study are: First, the poor state of public cemeteries in Benin City suggests that the urban environment is not being properly managed. Second, the utter neglect of public cemeteries is a failure by society to do its duty by the dead and uphold high ideals of enlightenment as enunciated by Gladstone. Third, better managed and maintained cemeteries offer the possibility of discouraging the practice of home burials which, even though founded on cultural belief, is not beyond the influence of modernity.

It is, accordingly, recommended that: First, the public cemeteries of Benin City should be overhauled and made to complement the urban environment instead of the rural outlook which they currently depict. Second, management of 3rd Cemetery should be returned by the Edo State Government to the Oredo Local Government since its intervention in 3rd cemetery amounts to interference, not supervision. Third, cemetery management would benefit from the adoption of modern administrative techniques and technology which should bring about better resource management, better record-keeping, improved managerial capacity and greater accountability.

An Important Area for Investigation

The lack of public water supply in the city since the 1990s has encouraged the widespread use of boreholes in the alternative. Health risks might exist in the extensive use of borehole water, almost always without treatment, in residential areas which also are places of interment. Given the observation of Uslu (2009) on the need “to decrease the negative impacts of the cemeteries on the underground water, natural vegetation and fauna existing in the burial area, to use materials biodegrading more
rapidly and to minimize the ecological footprint of the individual”, the scenario in the study area might present a source of contamination of underground water, not only by cadavers, but also, non-biodegradable burial materials mostly consisting of metals (such as zinc, copper lead and iron), soft coffin linings and burial clothing which constitute sources of pollution upon entering the soil. These public cemeteries, being located in residential areas, is also a matter of concern.

References


Accident Prediction Model at Unsignalized Intersection Using Multiple Linear Regression Method

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ABSTRACT

The issue of road accidents is an increasing problem in developing countries. This could be due to increasing road traffic/vehicle occupancy, geometric characteristics and road way condition. The factors influencing accidents occurrence are to be analysed for remedies. The purpose of this research is to develop an accident prediction model as a measure for future study, aid planning phase preceding the designed intervention, enhance the production of updated design standards to enable practitioners design unsignalized intersection for optimal safety, reduce the number of accidents at unsignalized intersections. Five intersections were selected randomly within Benin City and traffic count carried out at these intersections as well as geometric characteristics and roadway conditions. The prediction model was developed using multiple linear regression method and the standard error of estimate was computed to show how close the observed value is to the regression line. The model was validated using coefficient of multiple determination. The establishment of the relationship between accidents and traffic flow site characteristics on the other hand would enable improvement to be more realistically accessed. This study will also enhance the production of updated design standards to enable practitioners design unsignalized intersection for optimal safety, reduce the number of accidents at unsignalized intersections.

Keywords: Unsignalized Intersection, Multiple Regression, Dependent Variable, Independent Variable, Accident Rate

1.0. Introduction

Accident can be defined as anything which happens by chance, anything occurring unexpectedly undersigned (Odugbemi, 2010). Road accident do not simply happen, they are caused. Nigeria has a high road traffic accident rate as well as one of the largest numbers of death per 10,000 vehicles (Sheriff, 2009). Nigeria is ranked second-highest in the rate of road accidents among 193 countries of the world (Agbonkhese et al., 2013). (Oladepo and Brieger, 1986) had argued that three-quarters of all accidents on Nigerian roads involve fatalities. The incidence of fatal road accidents in Nigeria is phenomenal. Trend analysis of fatal road accidents between June 2006 and May 2014 using Nigeria Watch database record gives 15,090 lives lost to fatal road accidents in 3,075 events, highest fatality occurred in 2013 (2,061 deaths), a 2.8% increase from the 2012 record of 1,652 deaths (Ukoji, 2014). Road accidents can happen in many forms. Generally, road traffic accident can be categorized into four common type: where the driver collide with another vehicle or a roadside object, when the driver leaves the lane where they are in, accidents at junctions include rear-end collision and angle or side impacts, accidents that involving pedestrians and cyclists and accident that collide with animals (Nicholas et al., 2003).

Accident at intersection gives high impact to the road users. In urban areas where the traffic volume are high, intersection provided must accommodate the high volume for turning movement that traverse to large areas. For this situation, the channelization is an effective means to make sure that the road intersection provides safety. Intersection channelization is used to separate turn lanes from through lane that consist of solid white liners or barrier which guide the traffic so that the vehicle can safely negotiate the complex intersection. (Nicholas et al., 2003)
An accident prediction model is generally an algorithm pitting a dependent variable against several independent variables, each of which is assigned a constant. The dependent variable in an accident prediction model is the number of accidents, while the independent variables may be quantitative variables such as traffic flow, section length, pavement surface condition, infrastructures geometric characteristics, lighting and driver behaviours (Rokade et al., 2010).

The estimation of the number of accidents is not only performed to determine the effect of design elements, but may also be used in estimating accident reductions attributed to changes in the cross section of roads, predicting accident costs and as a measure of safety (Manan, 2011).

2.0. Materials and Methods

2.1. Data Collection

Selection of sample intersections was made based on stratification by traffic flow and intersection characteristics to ensure that a wide range of flows and intersection characteristics were captured. For each intersection, detailed information regarding accidents, traffic flow, geometric characteristics, traffic characteristics etc. were collected.

Accident data covering the period of 2011 – 2015 inclusive of the intended selected intersection were retrieved from the Federal Road Safety Corps head office. The database was compiled from police using a standard accident report form. Traffic flow data collected included vehicle counts from both major and minor road not classified by type of vehicle and turning movement and spot speeds of vehicles as they approached the intersection area along the major arms. Traffic counts was conducted during the morning and evening peak periods from 7:00am to 9:00am hours and from 4:00pm to 6:00pm hours, respectively.

Intersection inventories were carried out to collect information relating to the site details. The information collected included intersection layout, type of major and minor roads (i.e whether single or dual carriageway), number of lanes, width of lanes etc. Also information regarding surface condition of the roadway and shoulder were noted based on visual inspection and as well the conditions of the drainage facilities were obtained from site.

2.2. Prioritization of Secondary Data

Prioritization involves assigning suitable weights to different factors so as to achieve a desired result. In this model, the various factors which tend to influence the occurrence of accidents on roads are assigned weights on a scale of 0-10 in such a manner that the factors which tend to increase the probability of the accidents have lower weights. In order to prioritize roads for occurrence of accidents, various factors were considered and the weights assigned to them as shown in Table 1. The final weight assigned to each road link was obtained by adding all the individual weights and normalizing the value using maximum weight (in this case 130) that can be assigned.

Hence,

\[
\text{Total weight} = \frac{\sum \text{Individual Weights} \times 100}{130}
\]  (1)
### Table 1: Factors used in prioritization with their weights

<table>
<thead>
<tr>
<th>S/N</th>
<th>Factors Affecting Occurrence of Accident</th>
<th>Possible Variation</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No of lanes in each direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Number of vehicles per day</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Less than 1000</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less than 2500</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less than 5000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greater than 5000</td>
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</tr>
<tr>
<td>3</td>
<td>Width of Road</td>
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<td></td>
<td>7.5 – 10.5m</td>
<td>6</td>
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</tr>
<tr>
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<td>6.1 – 7.5m</td>
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</tr>
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<td></td>
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<tr>
<td>4</td>
<td>Presence of Shoulder</td>
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<td></td>
<td>No</td>
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</tr>
<tr>
<td>5</td>
<td>Surface condition of road</td>
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<tr>
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<td>Drainage condition</td>
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<td>Length of road before</td>
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<td>100m</td>
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</tr>
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<tr>
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<td>12</td>
<td>Type of Vehicles</td>
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<tr>
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<td>Buses/Truck</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Two wheelers</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>visibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3. Weighted Average

The various factors considered for affecting the occurrence of accidents may not have similar effect. Every factor will have a different level of involvement for an accident to take place. For example Presence of Shoulder and Average Annual Daily traffic (AADT) cannot be given same weightage because more traffic may be a greater factor in occurrence of accident as compared to whether a shoulder is present on the side of a road or not. Table 2 shows the method of weighing.
Table 2: Classification of weights

<table>
<thead>
<tr>
<th>Weight</th>
<th>Accident prone level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very Low</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
</tr>
<tr>
<td>5</td>
<td>Very High</td>
</tr>
</tbody>
</table>

2.4. Regression Analysis

In statistics, regression analysis includes any techniques for modelling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps us understand how a typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables — that is, the average value of the dependent variable when the independent variables are held fixed. The regression equation for the model developed is given by Equation 2.

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7 + a_8X_8 + a_9X_9 + a_{10}X_{10} + a_{11}X_{11} + a_{12}X_{12} + a_{13}X_{13}$$  (2)

The dependent variable used in the model is the Number of Accidents (Y). The independent variables used in the model include:

i. Major Traffic (X$_1$)
ii. Minor Traffic (X$_2$)
iii. Turning traffic (X$_3$)
iv. Approach Width (X$_4$)
v. Presence of shoulder (X$_5$
vi. Turning Radius (X$_6$)
vii. Speed (X$_7$)
viii. Major Road Number of Lanes (X$_8$)
ix. Minor Road Number of Lanes (X$_9$
x. Roadway Surface Condition (X$_{10}$)
xi. Visibility (X$_{11}$)
xii. Number of Legs (X$_{12}$)

2.5. Model Validation

The validation of the model was carried out as follows:

i. By finding the Coefficient of Determination ($R^2$)
ii. By the comparison of results of total number of accidents found by model with the data obtained from Federal Road Safety Corps.

Coefficient of determination ($R^2$) is a number that indicates the proportion of the variance in the dependent variable that is predictable from the independent variable. It is a statistic used in the context of statistical models whose main purpose is either the prediction of future outcomes or the testing of hypotheses, on the basis of other related information. It provides a measure of how well observed outcomes are replicated by the model, based on the proportion of total variation of outcomes explained by the model.

The value of $R^2$ lies between 0 and 1, i.e. $0 \leq R \leq 1$ and it is given by Equation (3).

$$R^2 = \frac{SS_{reg}}{SS_{tot}} = \frac{SS_{reg}/n}{SS_{tot}/n}$$  (3)
In this form $R^2$ is expressed as the ratio of the explained variance (variance of the model's predictions, which is $SS_{reg} / n$) to the total variance (sample variance of the dependent variable, which is $SS_{tot} / n$). Where

$$SS_{reg} = \sum (f_i - \bar{Y})^2$$  \hspace{1cm} (4)

$$SS_{tot} = \sum (y_i - \bar{Y})^2$$  \hspace{1cm} (5)

$R^2$ is a statistic that will give some information about the goodness of fit of a model. In regression, the $R^2$ coefficient of determination is a statistical measure of how well the regression line approximates the real data points. An $R^2$ of 1 indicates that the regression line perfectly fits the data.

2.6. Previous Related Studies

Neumann and Glennon (1982) described a theoretical model that relates accident on crest curves to available sight distance. The development of this model was not based on accident data, rather the model relied on intuitively logical relationship and engineering judgment. The model is presented in Equation 6.

$$N = ARH(L)(V) + ARh (Lr)(V)(F_{ar})$$  \hspace{1cm} (6)

where,

- $N$ = Number of accident on a segment of highways containing a crest curve.
- $ARH$ = Average accident rate for specific highways
- $L$ = Length of highway segment in miles.
- $V$ = Traffic volumes in millions of vehicles.
- $Lr$ = Length of restricted sight distance in miles
- $F_{ar}$ = A hypothetical accident rate factor that varies according to both the severity of the sight restriction and the nature of the hidden hazard.

Zegeer et al (1992) developed an accident prediction model (Equation 7) for the 1991 FHWA study cost-effective improvements for horizontal curves.

$$A = [ (1.552)(L)(V) + (0.014(D)(V) - (0.012)(S)(V))(0.978)^W ]$$  \hspace{1cm} (7)

where,

- $A$ = number of total accidents on the curve in 3 years period
- $L$ = length of curves
- $V$ = volume of vehicles in million vehicles passing through (both direction) in a 5 Year time
- $D$ = degree of curve
- $S$ = presence of spiral
- $W$ = width of roadway (twice the lane plus shoulder width) on the curve.

To evaluate the combined effect of road elements, Transportation and Research Laboratory (TRRL) carried out research work in Kenya and Jamaica. The equations developed in this study are presented in Equations 8 (a-d).

$$Y = 1.45 + 1.02X_3 + .017X_3$$  \hspace{1cm} (8a) (KENYA)

$$Y = 1.09 + 0.031X_3 + 0.62X_3 + 0.0003X_4 + 0.062X_2$$  \hspace{1cm} (8b) (JAMICA)

$$Y = 5.77 + 0.755X_1 + 0.275X_3$$  \hspace{1cm} (8c) (JAMICA)

$$Y = 5.77 + 0.755X_1 + 0.275X_3$$  \hspace{1cm} (8d) (JAMICA)

where,

- $Y$ = rate per million vehicle kilometer per year
- $X_1$ = road width (m)
- $X_2$ = vertical curvature (m/Km)
- $X_3$ = horizontal curvature (degree/Km)
- $X_4$ = surface irregularity (mm/Km)
- $X_5$ = junctions per Km.

Zegeer et al (1995) developed Accident Relationships of Roadway Width on low-Volume Roads Horizontal curves represent a considerable safety problem on rural two lane highways. Accident studies further indicated that curves experience a higher accident rate than do tangents, with rates that range
from one and a half to four times higher than similar perhaps be more important in light of improvements being made related to resurfacing, restoration, and rehabilitation projects, commonly known as the 3R program. Total accident rate was given by Equation 9.

\[
\text{Accident} = (\text{ADT})(\text{Length})(1.94+0.24\text{Deg}-0.026\text{Width}-0.25\text{Spirals})
\]  

(9)

Miranda-Moreno et al (2005) developed Alternative Risk Models for Ranking Locations for Safety Improvement. The authors compared the performance and practical implications of these models and ranking criteria when they are used for identifying hazardous locations.

Brown et al (2006) considered the effects of access control on safety on urban arterial streets. Access control techniques are used to improve traffic performance and safety on highways. One important benefits of access control is improved safety. The objective of this research was to develop regression models to predict crash frequencies on urban multilane arterial segments.

Fajaruddin et al (2008) did his study on block spot study and accident prediction model using multiple regression linear models. The study area was federal Route (FT50) Batu Pahat – Ayer Hitam. The regression model is given by Equation 10 which had \( R^2 \) of 0.9987.

\[
\log_e(\text{APW})^{0.5} = 0.0212(\text{AP}) + 0.0007(\text{HTV}^{0.75} + \text{GAP}^{1.25}) + 0.0210(\text{85th PS})
\]

(10)

where,
- APW = accident point weight age.
- AP = number of access points per kilometre
- HTV = hourly traffic volume
- Gap = amount of time, between the end of one vehicle and the beginning of the next in second.
- 85th PS = 85th percentile speed

Fajaruddin et al (2008) developed a model for Black Spot Study and Accident prediction Model using Multiple Linear Regression. This approach is considered to be helpful for strengthening freeway management and reducing the likelihood of incidents. The freeway incident model developed in this study can constitute a useful decision support tool for analysis of traffic accident and the implementation of freeway patrol systems.

Ali et al (2009) used fractional factorial method for the sensitivity analysis of accident prediction model. The evaluation of sensitivity analysis indicated that average daily traffic (ADT), lane width (W), width of paved shoulder (PA), median(H) and their interactions (i.e., ADT-W, ADT-PA and ADT-H) has significant effects on numbers of accidents. The effects due to each parameter and parameter interactions are estimated using Equation 11.

\[
E_j = S E_j = S_j(X_i)/N_j
\]

(11)

In which Ej represent the effect of the jth factor (i.e., in jth column), n the total number of experimental runs (i.e., n=8), Sij represents the sign in row i and column j, Xi represents the value of the prediction variable obtained from the ith experimental run and N jis the number of “+” signs in column j. Accident prediction model developed is given by Equation 12.

\[
A = 0.0019(\text{ADT}^{0.882})(0.879)^*(0.919)^{PA}(0.932)^{H}(1.232)^{T1}(0.882)^{T2}
\]

(12)

Velmajasiniene et al (2011) analysis of accidents prediction feasibility on the roads of Lithuania. Modelling of the road accidents was carried out based on 1997-2011. Data on fatal & injury accidents on the main roads enabled the construction of mathematical models for the optimum selection of road safety improvement measures. One of the constructed mathematical models (Equation 13) allowed optimal selection of road safety improvement measures to reduce the number of people killed under unrestricted amount of trends.

\[
Y_S = 193.52+0.2t-67.7t1-69.5t2-14.48t3
\]

(13)
where
\[
Y = \text{forecasted average value}
\]
\[
T = \text{trend variable Ti variable taking the value in the quarter 1 of the year & value 0 in the other quarter the fourth quarter at the year is corresponding by the value of variable.}
\]

2.6. Regression Analysis of Accident Prediction at Unsignalized Intersection

The independent variables are variables that measures and influences the outcome (dependent variable) of a mathematical or statistical model. They are independent of each other. They can constantly and intentionally change to observe their effect on the dependent variable. Table 3 shows the values of the independent variables selected for project work.

Table 3: Independent Variables of the Accident Prediction Model

<table>
<thead>
<tr>
<th>S/N</th>
<th>Predictors</th>
<th>PZ Intsn.</th>
<th>RCC Intsn.</th>
<th>NNPC Intsn.</th>
<th>CJ Intsn.</th>
<th>BBP Intsn.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Major Traffic</td>
<td>5742</td>
<td>5906</td>
<td>4986</td>
<td>4110</td>
<td>4016</td>
</tr>
<tr>
<td>2</td>
<td>Minor Traffic</td>
<td>660</td>
<td>1000</td>
<td>1684</td>
<td>400</td>
<td>820</td>
</tr>
<tr>
<td>3</td>
<td>Turning Traffic</td>
<td>368</td>
<td>324</td>
<td>595</td>
<td>80</td>
<td>300</td>
</tr>
<tr>
<td>4</td>
<td>Approach Width</td>
<td>10.46</td>
<td>10.23</td>
<td>10.34</td>
<td>8.42</td>
<td>7.8</td>
</tr>
<tr>
<td>5</td>
<td>Number of Legs</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Surface Condition</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Flexible</td>
</tr>
<tr>
<td>7</td>
<td>Speed</td>
<td>63.008</td>
<td>56.500</td>
<td>58.900</td>
<td>58.716</td>
<td>45.23</td>
</tr>
<tr>
<td>8</td>
<td>Presence of Shoulder</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>9</td>
<td>Traffic Light</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>10</td>
<td>Lighting Condition</td>
<td>Very Poor</td>
<td>Very Poor</td>
<td>Very Poor</td>
<td>Very Poor</td>
<td>Very Poor</td>
</tr>
<tr>
<td>11</td>
<td>Number of Lanes</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Drainage Condition</td>
<td>Poor</td>
<td>Poor</td>
<td>Satisfactory</td>
<td>Satisfactory</td>
<td>No Drainage</td>
</tr>
<tr>
<td>13</td>
<td>Frequent Vehicle on the Road</td>
<td>Cars</td>
<td>Cars</td>
<td>Cars</td>
<td>Cars</td>
<td>Cars</td>
</tr>
</tbody>
</table>

2.7. Prioritization value of the Independent Variables

Prioritization involves assigning suitable weights to different factors that influences accident occurrence so as to achieve a desired result. Table 4 below shows the prioritized value of the accident predictors (independent variables).

Table 4: Prioritized Value of the Independent Variables

<table>
<thead>
<tr>
<th>S/N</th>
<th>Predictors</th>
<th>PZ Intsn.</th>
<th>RCC Intsn.</th>
<th>NNPC Intsn.</th>
<th>CJ Intsn.</th>
<th>BBP Intsn.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Major Traffic</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Minor Traffic</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Turning Traffic</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Approach Width</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Number of Legs</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Surface Condition</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Speed</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Presence of Shoulder</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>Traffic Light</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Lighting Condition</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Number of Lanes</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>Drainage Condition</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Frequent Vehicle on the Road</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
2.8. Weightage Point of the Independent Variable

This has to do with ranking of the prioritized values on a scale of 1 – 5 in such a manner that the factors which tend to increase the probability of accidents have higher weights. The final weight assigned to each prioritized values of the independent variables is obtained by adding all the individual weights and normalizing the value using maximum weight (in this case 130) that can be assigned. Table 5 shows the weightage point of the prioritized values. Table 6 shows the accident record at five different intersections within Benin City in five years accident record. The accident record per annum will form the bases of our dependent variable. The data in the table above were obtained from the head quarter of the Federal Road Safety Corps.

**Table 5: Weightage Point of the Prioritized Value of the Independent Variables**

<table>
<thead>
<tr>
<th>Y</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
<th>X10</th>
<th>X11</th>
<th>X12</th>
<th>X13</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>69</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
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<td>3</td>
<td>3</td>
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</tr>
<tr>
<td>25</td>
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<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
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</tr>
<tr>
<td>39</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
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<td>4</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6: Total Accident at Selected Intersections in Five years Accident record (Courtesy of FRSC)**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Name of Location</th>
<th>Total Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PZ Intersection</td>
<td>79</td>
</tr>
<tr>
<td>2</td>
<td>RCC Intersection</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>NNPC Intersection</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>College Road Intersection</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>Benin Bye Pass Intersection</td>
<td>57</td>
</tr>
</tbody>
</table>

2.9. Formulation of Regression Equation

The regression equations were thereafter formed as presented in Equations 14 – 27:

\[ a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 + a_6 x^6 + a_7 x^7 + a_8 x^8 + a_9 x^9 + a_{10} x^{10} + a_{11} x^{11} + a_{12} x^{12} + a_{13} x^{13} = 269 \]  
\[ a_0 + b_1 x + b_2 x^2 + b_3 x^3 + b_4 x^4 + b_5 x^5 + b_6 x^6 + b_7 x^7 + b_8 x^8 + b_9 x^9 + b_{10} x^{10} + b_{11} x^{11} + b_{12} x^{12} + b_{13} x^{13} = 10751 \]  
\[ a_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4 + c_5 x^5 + c_6 x^6 + c_7 x^7 + c_8 x^8 + c_9 x^9 + c_{10} x^{10} + c_{11} x^{11} + c_{12} x^{12} + c_{13} x^{13} = 1012 \]  
\[ a_0 + d_1 x + d_2 x^2 + d_3 x^3 + d_4 x^4 + d_5 x^5 + d_6 x^6 + d_7 x^7 + d_8 x^8 + d_9 x^9 + d_{10} x^{10} + d_{11} x^{11} + d_{12} x^{12} + d_{13} x^{13} = 884 \]  
\[ a_0 + e_1 x + e_2 x^2 + e_3 x^3 + e_4 x^4 + e_5 x^5 + e_6 x^6 + e_7 x^7 + e_8 x^8 + e_9 x^9 + e_{10} x^{10} + e_{11} x^{11} + e_{12} x^{12} + e_{13} x^{13} = 1037 \]  
\[ a_0 + f_1 x + f_2 x^2 + f_3 x^3 + f_4 x^4 + f_5 x^5 + f_6 x^6 + f_7 x^7 + f_8 x^8 + f_9 x^9 + f_{10} x^{10} + f_{11} x^{11} + f_{12} x^{12} + f_{13} x^{13} = 1288 \]  
\[ a_0 + g_1 x + g_2 x^2 + g_3 x^3 + g_4 x^4 + g_5 x^5 + g_6 x^6 + g_7 x^7 + g_8 x^8 + g_9 x^9 + g_{10} x^{10} + g_{11} x^{11} + g_{12} x^{12} + g_{13} x^{13} = 786 \]  
\[ a_0 + h_1 x + h_2 x^2 + h_3 x^3 + h_4 x^4 + h_5 x^5 + h_6 x^6 + h_7 x^7 + h_8 x^8 + h_9 x^9 + h_{10} x^{10} + h_{11} x^{11} + h_{12} x^{12} + h_{13} x^{13} = 1025 \]
$18a_0 + 68a_1 + 42a_2 + 36a_3 + 57a_4 + 69a_5 + 39a_6 + 65a_7 + 56a_8 + 86a_9 + 86a_{10} + 57a_{11} + 69a_{12} + 66a_{13} = 1982 \quad (27)$

### 3.0. Results and Discussion

Solution of equations yielded the following results:

1. $a_0 = 223.099$
2. $a_1 = -454.103$
3. $a_2 = 0.013$
4. $a_3 = -8.2 \times 10^{-12}$
5. $a_4 = 0.001$
6. $a_5 = 241.755$
7. $a_6 = -3.8 \times 10^{-13}$
8. $a_7 = 9.169$
9. $a_8 = 116.302$
10. $a_9 = 45.393$
11. $a_{10} = -3.668$
12. $a_{11} = 0.013$
13. $a_{12} = 206.936$
14. $a_{13} = -196.91$

The model obtained is given by Equation 28.

$$Y = 223.099 - 454.103X_1 + 0.013X_2 - 8.2 \times 10^{-12}X_3 + 0.001X_4 + 241.755X_5 - 3.8 \times 10^{-13}X_6 + 9.169X_7 + 116.302X_8 + 45.393X_9 - 3.668X_{10} + 206.936X_{12} - 196.910X_{13} \quad (28)$$

The standard error of estimate was computed using Equation 29 from parameters obtained from Table 7.

**Table 7: Standard Error Estimation from Equation (28)**

<table>
<thead>
<tr>
<th>Name of Location</th>
<th>Actual value of Y from FRSC</th>
<th>Value of Y from Model Obtained</th>
<th>Error(e) = Y – Ye</th>
<th>$(Y - Ye)^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ</td>
<td>79</td>
<td>78.995</td>
<td>0.005</td>
<td>0.000025</td>
</tr>
<tr>
<td>RCC</td>
<td>69</td>
<td>68.995</td>
<td>0.005</td>
<td>0.000025</td>
</tr>
<tr>
<td>NNPC</td>
<td>25</td>
<td>24.995</td>
<td>0.004</td>
<td>0.000025</td>
</tr>
<tr>
<td>CJ</td>
<td>39</td>
<td>38.996</td>
<td>0.004</td>
<td>0.000016</td>
</tr>
<tr>
<td>BBP</td>
<td>57</td>
<td>56.995</td>
<td>0.005</td>
<td>0.000025</td>
</tr>
</tbody>
</table>

$$\Sigma( Y - Ye) = 0.029 \quad \Sigma( Y - Ye)^2 = 0.000116$$

$$S.E = \sqrt{\frac{\Sigma(Y - Ye)^2}{N}} = \sqrt{\frac{0.000116}{5}} = \sqrt{0.00000232} \quad (29)$$

$$S.E = 0.00152$$

The standard error implies that 95% of the observation should fall within ±2*standard error of the regression from the regression line which is also a quick approximation of a 95% prediction interval. From the analysis above, it shows that 95% of the observed values are at an average distance of ±0.305% from the fitted line.

### 3.1. Model Validation

The computation of the Coefficient of Determination is presented in Table 8 and 9.

**Table 8: Total Sum of Error Estimation**

<table>
<thead>
<tr>
<th>Name of Location</th>
<th>Value of Y from Model Obtained</th>
<th>Mean of Actual Value of Y</th>
<th>$Y - \bar{Y}$</th>
<th>$(Y - \bar{Y})^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ</td>
<td>79</td>
<td>53.8</td>
<td>25.2</td>
<td>635.04</td>
</tr>
<tr>
<td>RCC</td>
<td>69</td>
<td>53.8</td>
<td>15.2</td>
<td>231.04</td>
</tr>
<tr>
<td>NNPC</td>
<td>25</td>
<td>53.8</td>
<td>-28.8</td>
<td>829.44</td>
</tr>
<tr>
<td>CJ</td>
<td>39</td>
<td>53.8</td>
<td>-14.8</td>
<td>219.04</td>
</tr>
<tr>
<td>BBP</td>
<td>57</td>
<td>53.8</td>
<td>3.2</td>
<td>10.24</td>
</tr>
</tbody>
</table>

$$\Sigma( Y - \bar{Y}) = 0 \quad \Sigma( Y - \bar{Y})^2 = 1924.8$$
$$\bar{Y} = \frac{\sum Y}{N} = \frac{79+69+25+39+57}{5} = \frac{269}{5} = 53.8$$

$$S_{YY} = 1924.8$$

### Table 9: Sum of Regression Error Estimation

<table>
<thead>
<tr>
<th>Name of Location</th>
<th>Actual value of Y from FRSC</th>
<th>Mean of Actual Value of Y</th>
<th>Y – (\bar{Y})</th>
<th>((Y - \bar{Y})^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ</td>
<td>78.995</td>
<td>53.8</td>
<td>25.195</td>
<td>634.788</td>
</tr>
<tr>
<td>RCC</td>
<td>68.995</td>
<td>53.8</td>
<td>15.195</td>
<td>230.888</td>
</tr>
<tr>
<td>NNPC</td>
<td>24.995</td>
<td>53.8</td>
<td>-28.805</td>
<td>829.728</td>
</tr>
<tr>
<td>CJ</td>
<td>38.996</td>
<td>53.8</td>
<td>-14.804</td>
<td>219.158</td>
</tr>
<tr>
<td>BBP</td>
<td>56.995</td>
<td>53.8</td>
<td>3.195</td>
<td>10.208</td>
</tr>
</tbody>
</table>

$$\sum(Y - \bar{Y}) = -0.029 \quad \sum(Y - \bar{Y})^2 = 1924.77$$

$$\bar{Y} = \frac{\sum Y}{N} = \frac{79+69+25+39+57}{5} = \frac{269}{5} = 53.8$$

$$S_{SE} = 1924.77$$

Residual Error \((SSE) = 1924.8 - 1924.77 = 0.03$$

$$R^2 = \frac{1924.77}{1924.8} = 0.99998$$

The coefficient of determination \(R^2\) which represents the percent of the data that is closest to the line of best fit, gives an indication from the analysis above, that 99.998% of the total variation in the observed value can be explained by the linear relationship between the factors influencing accident occurrence and the rate of accident per annual (as described by the regression equation). The other 0.00002% of the total variation in the rate of accident per annual remains unexplained.

The other form of validation was done by plotting a graph of the intersection location with the observed data and the estimated data as shown by the Figure 1.

![Figure 1: Comparison of total number of accidents found by model with the data obtained from the FRSC head office based on actual site conditions.](image)

The graph above shows a very high approximate fitness of the observed and estimated data for a particular intersection. This close fitness between the observed and estimated values indicates that the predictive model holds a better predictability tendency.
4.0. Conclusion

The proposed objective was to obtain a predictive model to establish a relationship between the factors influencing accident occurrence and number of accident and estimation of accident rate at some selected sites in Benin City. This project took into consideration total crash rate; a similar procedure which could be used for injurious crashes (minor or severity cases) or death case only. The predictive model developed using multiple regression method can be used for accident analysis on road network since most of the factors considered are similar.

However, the suitability of the model developed to the data can be measured using many coefficients but the coefficient of multiple determination and standard error of estimate was used in this project and as well the functional form of the model was designed to reproduce the data (observed). The accident predictive model presented here should be improved: more information will be needed and other variables should be analysed for this purpose while other variables will require further perfection.

The predictive model so obtained can contribute to planning phase preceding the designed intervention. This pertain to the programming of intersection operations (also laid out in regulations), which make it possible to target the spending of public funds by local of national administration or directing infrastructure, depending on the number of crashes predicted by the model. Especially as it concerns the evaluation and programming of road safety improvement operations which are to be adopted in the provincial road networks, concentrating on those areas of the infrastructural network that are deemed “critical” from a safety point of view is necessary.

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Estimation of Hydrological Outputs using HEC-HMS and GIS

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ABSTRACT

Estimating runoff and understanding of the relationship between rainfall and runoff are of great importance in the management of flood. Several computer based hydrological models have been developed and used in simulating runoff in various watersheds in different parts of the world and in water resource studies. This study focuses on the combination of Geographic Information System (GIS) with Hydrologic Engineering Center –Hydrologic Modelling System (HEC-HMS) hydrological model to simulate runoff process of the adjoining areas of the Lagos Island and Eti-Osa Local Government Areas (LGAs). The study makes use of LIDAR Digital Elevation Model (DEM), drainage data and land use map for catchment delineation and hydrological modelling, using HEC-GeoHMS and ArcGIS 10.2. In HEC-HMS 4.2.1, the delineated catchment with all hydrological parameters and average daily rainfall data, are used to simulate and compute rainfall runoff volume, peak discharges for 10 months (between Jan to October) and a total of three years (2012, 2015 and 2017) were considered. Direct runoff volume and depth estimation for the years under review were determined. Results show that the peak discharge occurred on the 2nd of July 2012 at a rate of 14m3/s with an estimated runoff volume at the basin outlet of 39,669.70 x 103m3 (this date tallies with the severe flood events that occurred in that year). The study shows that estimating hydrological outputs is possible with the use of HEC-HMS and GIS. It recommends the application of such technologies in the prediction and development of basic flood warning systems for the area.

Keywords: Hydrological Outputs, Flooding, HEC-HMS, LIDAR, DEM, GIS

1.0. Introduction

Modelling and predicting floods are of great importance in the management of floods in an urban area and one of the common factors that cause flooding in most urban areas is heavy rainfall and the presence of impervious surfaces. Simulating hydrological outputs such as rainfall runoff volume, runoff depth and water availability of a catchment directly affect flood prediction results. Accurately determining these hydrological outputs over a period, will aid the development of reliable flood early warning systems. With the advent of climate change, the normal hydrological cycle of various river basins and locations all over the world is threatened; this is due to rise in temperature because of the global warming effect, associated in disturbing the frequency and intensity of precipitation over a given climatic condition (Sintayehu, 2015). Because of this, continuous simulation of hydrological outputs for such locations will aid proper flood modelling and prediction.

Surface runoff estimation is a common analyses in hydrology and due to the fact that measuring all parameters that bring about a watershed runoff is not possible, making use of a model that has a simple structure, minimum input data requirements, suitable for determination of such hydrological parameters and has a judicious precision is important. This means that estimating hydrological outputs especially for locations that do not have can be better carried out at any point in time due to the availability of such models. Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS) is one of the models that meet these criteria. It has been widely used in different studies and at different times.

Majidi and Shahedi (2012) used HEC-HMS in estimating surface runoff in the Abnama watershed in Iran and this was based on the rate-received precipitation and quantifying discharge at outlet. They used
different methods like Green-Ampt, SCS Unit hydrograph and Muskingum routing for the estimation process. Hadi et al (2012) used another approach that involved the use of HEC-HMS and Hydrologic Engineering Center-River Analysis System (HEC-RAS) models to simulate runoff in Karun River, Iran. The modelling process offered in their study includes the use of some of the recently developed GIS tools for map production. Reshma T. et al (2013) carried out the simulation of an even based runoff using HEC-HMS model and the Walnut Gulch watershed located in Arizona, USA, was the case study. Computation of infiltration, rainfall excess conversion to runoff and flow routing were carried out and according to their work, the model performed satisfactorily and provided reliable results. In Ghana, Yaw et al., (2015) simulated Flood Volume of Dikpe Catchment using HEC-HMS. Results obtained were compared with the result gotten from direct computation of the precipitation volume and this provided satisfactory results. Olayinka and Irivbogbe (2017) used HEC-HMS and HEC-RAS in modelling and mapping flood vulnerable areas and the results obtained and validation carried out were very satisfactory.

From the above studies, it shows that the HEC-HMS model is an effective tool that can be used for the precise simulation of the hydrology outputs of watersheds. This present study focuses on the use of HEC-HMS and GIS in the determination of hydrological parameters and the estimation of hydrological outputs such as rainfall runoff, runoff depth and peak discharges within the study area for different years.

2.0. Methodology

2.1. Location of study

This study focuses on the adjoining areas of two Local Government Areas (LGAs) in Lagos state - Lagos Island and Eti-Osa Local Government Area (covering Ikoyi, Lekki Phase 1 and Victoria Island). These areas are dynamic in nature. The location share boundaries on the North with Lagos Lagoon, the largest coastal lagoon in Western Africa. Eti-Osa LGA directly shares its boundary on the south with the Atlantic Ocean. This location is densely populated and it covers a total land area of approximately 28 square kilometres. It is located within Latitude 6° 26’ 34” N and Longitude 3° 24’ 30” E on the left and Latitude 6° 29’ 04” N and Longitude 3° 39’ 09” E on the right. This location can be described as a place with a variety of land uses. It is a notable commercial area but also has a mixture of residential and institutional land uses.

Figure 1: Representation of the Study area
2.2. Data acquisition

Most of the data acquired for this study are from secondary sources. The data used include:

i. LIDAR DEM acquired in the year 2008, in classified text file format, covering the study area was obtained from the Office of the Surveyor General of Lagos State. A 5m resolution DEM was created from the text files.

ii. Drainage network covering the main channels of the study area from the Lagos State Drainage network manual produced in the year 2012.

iii. Landuse map covering the study area for the year 2002 was obtained from the Ministry of Physical Planning, Lagos State.

iv. Landuse map covering the western part (Banana Island inclusive) of the study area, for the year 2011.

v. Average Daily Precipitation data spanning a total period of 10 months (1st January - 31st October from year 2012 to year 2017) from Tropical Rain Measuring Mission (TRMM) Online Visualization and Analysis System (TOVAS), a member of Giovanni (GES-DISC Interactive Online Visualization and Analysis Infrastructure).

![Figure 2: Digital Elevation (DEM) of the study area](image)

![Figure 3: Landuse map of the study area](image)
2.3. **HEC-HMS and Soil Conservation Service (SCS)**

The HEC-HMS Hydrological Model (developed by the United States Hydrologic Engineering Centre) provides a platform over which robust hydrological modelling with the incorporation of accurate spatial data can be carried out. This modelling package has been used in various research works and it has been proven to be very helpful and viable in flood modelling, monitoring and management (Horritt and Bates, 2002; Bates, 2004; Knebl et al., 2005; Castellarin et al., 2009). The model is compatible with GIS applications like ArcGIS and it is suitable for the study area because over time, it has shown good practical use in modelling and management of runoff and floods respectively.

Over time, the HEC-HMS model is used to transform precipitation data into direct flow with great consideration of topography and surface characteristics of the location modelled. It takes into consideration parameters of routing, loss and flow transformation in the determination of runoff over land. It is able to perform its computation using a number of transform methods (Scharffenberg et al., 2010). A particularly important parameter is the infiltration rate as it has the highest effect in determining runoff loss (Jones, 1997). The **Soil Conservation Service (SCS) Curve Number (CN)**, a parameter that is used to quantify infiltration and storm runoff of an area, is used in this study.

In order to obtain excess precipitation amounting to runoff, Equation 1 is used (Feldman, 2000):

\[
P_e = \frac{(P-I_a)^2}{P-I_a+S}
\]  

The empirical relationship of \(I_a\) and \(S\), given as \(I_a = 0.2\ S\), as developed by the SCS, the equation is given as follows (Feldman, 2000):

\[
P_e = \frac{(P-0.2S)^2}{P+0.8S}
\]  

\(S\) is given as the maximum retention and this is related to the watershed characteristics through the curve number (CN). This relationship is given as follows by Equations 3 and 4 as follows (Feldman, 2000):

\[
S = \frac{1000 - 10\ CN}{CN}
\]  

\[
S = \frac{25400 - 254\ CN}{CN}
\]

Equation 3 is used for measurements in foot – pound system. Equation 4 is used for measurements in SI units.

Where,

- \(P_e\) = Runoff (accumulated precipitation excess at time t in mm);
- \(P\) = accumulated precipitation depth (at time t in mm);
- \(S\) = potential maximum retention (a measure of the ability of the watershed to abstract and retain storm precipitation; and
- \(I_a\) = Initial abstraction (loss).

CN values range from 100 (for water bodies) to approximately 30 for permeable soils with high infiltration rates. Channel routing computation is carried out with this model. It uses momentum.
equation and the continuity equation known as St. Venant equations (Yaw et al., 2015). It accounts for forces that act on a body of water in an open channel while considering the shape of the channel. A lag method is used and this is estimated using the Curve number parameters (Feldman, 2000).

2.4. HEC-HMS Hydrological Model development

The main reason for modelling hydrological processes is the limitation of hydrological measurements (Yaw et al., 2015). Hence, in order to (a) develop the hydrological model in HEC-HMS, (b) analyse the rainfall water volume and (c) estimate amount of runoff water volume over the years, three components are required - a basin model, a meteorological model and a control specifications component. Figure 3 shows the description of the HEC-HMS Hydrological Model development process.

![Figure 4: Hydrological Modelling process using HEC-HMS and ARCGIS](image)

2.4.1. Hydrological Model Parameters Estimation using HEC-GeoHMS and ARCGIS

The basin model was created using the ArcGIS extension of HEC-HMS, HEC-GeoHMS. The LIDAR DEM served as the foundation for this process. The basin model, which is the physical component of the hydrological model, was developed using the ArcGIS extension of HEC-HMS (HEC-GeoHMS). A terrain processing, basin process and hydrological parameter computation are the key work processes carried. A brief description of these is given as follows;

- **Terrain Processing**
  This is the first requirement for the creation of a basin model using this approach. This process involved the reconditioning of the DEM, spatial computation of flow direction, flow accumulation and the delineation of the catchment grid (which were required for the basin processing.)
Figure 5: Catchment Grid Delineation in ArcGIS environment

- **Basin Processing and characteristics determination**
  In order to perform the Basin Processing and characteristics determination, the HMS project was first generated, using the final output data from the terrain preprocessing. This was required because all parameters generated must be incorporated into the final basin model to be produced. At this stage, basin creation and Sub-basin division by maximum area, river merge, slope and length calculation, basin slope generation, longest flowpath, basin centroid, centroid elevation and centroid longest flowpath were determined and they form the basis for the computation of the hydrological parameters (curve numbers).

Figure 6: Basin processing in ArcGIS

- **Hydrological Parameters Determination:**
  Before exporting the project in a format readable by HEC-HMS, HEC-GeoHMS extension was used to define distributed hydrological parameters and inputs for the project area. Using HEC-GeoHMS was a better option because it would take a long time to define in HEC-HMS. The Soil Conservation Service (SCS) modelling method was used. This method uses the Curve Number (CN) Grid, which is a hydrological parameter, to calculate hydrological properties for the whole basin (US-SCS, 1986). The Curve number is considered to be the most important parameter and the CN grid was created using landuse map, soil classification of the landuse according to the US-SCS (1986) and CN look up table created for the project. The final basin model to be used for the hydrological modelling process was generated after creating the CN grid.
Figure 7: Curve Number (CN) Grid

Figure 8: GIS representation of the basin model used by the hydrological model

2.4.2. Modelling the Runoff process in HEC-HMS

In order to model a runoff process, the Metrological Model Manager in HEC-HMS modelling package was used to develop a meteorological model. Averaged daily precipitation data obtained from TRMM for a period of ten months were added to the HEC-HMS project generated using the Time Series Manager. This process provided the model with adequate amount of rainfall data to be used in the calculation of runoff and other hydrological outputs. The control specification specifies the time window for which the model calculates discharges. Control specifications for each time window that the model makes calculations was created. The Control Specification Manager was used to create control specification for each of the years considered in this study. Thus, a 24 hours’ time interval daily precipitation was obtained, the model was made to interpolate the precipitation data to produce results for a 30 minutes interval. HEC-HMS has the capability of producing results for up to 1-minute interval.
3.0. Results and Discussion

Effective application of the hydrological model depends on the practical capability of the hydrological model and the quality of the input data used. In this study, the model is calibrated manually for a one-year event based simulation and year 2012, 2015 and 2017 were considered and hydrological outputs (flow discharge, runoff volume and runoff depth) were obtained and compared. Figure 10 shows the diagram of the watershed (basin model) that served as the input data in HEC-HMS for the computation of the hydrological outputs.
Simulation runs were carried out for each of the years. The hydrological output estimated results were obtained from this process. Tables and Graphs showing results and analyses were extracted from the modelling package.

**Figure 11:** Showing HEC-HMS modelling and computation results (for year 2012 event)

Results obtained in this study are diverse. The Curve number and basin lag time (in minutes) extracted for each of the subbasins were obtained and these in turn were used to obtain the hydrological outputs.

The model estimated flow discharge, runoff volume and runoff depth for each subbasins, junctions and the basin outlet of the basin model.

Figures 12, 13 and 14 depict the total flow rate estimated by the model for the years considered.

**Figure 12:** Estimated Flow rate for year 2012
3.1. Analysing Peak Discharge and Runoff

Table 1 and 2 show the results for peak discharge, time of peak, runoff depth and run of volume, respectively.

Table 1. Peak discharge with Runoff height

<table>
<thead>
<tr>
<th>Year</th>
<th>Outlet point</th>
<th>Basin Area (km²)</th>
<th>Peak Discharge (m³/s)</th>
<th>Time to peak runoff</th>
<th>Runoff Depth (mm)</th>
<th>Runoff Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>14.8</td>
<td>02-Jul-12</td>
<td>1402.090</td>
<td>1.402</td>
</tr>
<tr>
<td>2015</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>10.4</td>
<td>02-Jun-15</td>
<td>1117.07</td>
<td>1.117</td>
</tr>
<tr>
<td>2017</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>15.2</td>
<td>11-Jun-17</td>
<td>1369.480</td>
<td>1.369</td>
</tr>
</tbody>
</table>
Figure 15: Estimated Runoff Depth for year 2012, 2015 and 2017

Table 2. Peak discharge with Runoff Volume

<table>
<thead>
<tr>
<th>Year</th>
<th>Outlet point</th>
<th>Basin Area (km²)</th>
<th>Peak Discharge (m³/s)</th>
<th>Time to peak runoff</th>
<th>Volume of Runoff (x 10⁶ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>14.8</td>
<td>02-Jul-12</td>
<td>39669.700</td>
</tr>
<tr>
<td>2015</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>10.4</td>
<td>02-Jun-15</td>
<td>31605.300</td>
</tr>
<tr>
<td>2017</td>
<td>AREA 1 OUTLET</td>
<td>28.293</td>
<td>15.2</td>
<td>11-Jun-17</td>
<td>38747.000</td>
</tr>
</tbody>
</table>

Figure 14: Estimated Rainfall Runoff Volume for year 2012, 2015 and 2017
3.2. Discussion

The modelling system used in this study has provided results that can be useful in monitoring runoff volume and flooding in the study area. From the results depicted by Figures 12, 13 and 14, we see that the highest peak discharges estimated by the model for the time considered occurred between June and July, which is considered to be the time in which severe flooding occurs in the study area. This also shows that at these times, runoff depth and volume are very high. Increase in runoff will lead to an increase in discharge.

From the results provided in Table 1, we see peak discharge at the outlet of the basin (Area 1 Outlet), for the different years, generated for the study area. The results show that in the year 2012, peak discharge occurred on the 2nd of July 2012 at a flow rate of $14.8 \text{m}^3\text{s}^{-1}$ with a runoff height of $1.402\text{m}$. The results also show that in year 2015, peak discharge on the 2nd of June 2015 at a flow rate of $10.4 \text{m}^3\text{s}^{-1}$ with a runoff height of $1.117\text{m}$ but in year 2017, 11th of June 2017 was the time of peak discharge at a rate of $15.2\text{m}^3\text{s}^{-1}$ and highest runoff depth at $1.369\text{m}$. The results show that the times of peak discharge and runoff for these years match the periods of high rainfall and subsequently severe flood events.

The study area does not have readily available weather stations. These weather stations would have provided real time discharge and water level data that would have been used for to validate the modelling results. However, past studies such as those carried out by Majidi and Shahedi (2012); Hadi et al (2012); Reshma T. et al (2013) and Yaw et al., (2015), validated modelling results using available hydrological data and these validation results were very satisfactory.

4.0. Conclusion

This study shows that Runoff estimation is mandatory to sustain the water resources and manage runoff volumes and floods in the region. In this particular study area real time, monitored data from weather stations are limited. The present study tries to study the efficiency of HEC-HMS model. After running the models repeatedly, the simulated streamflow results for each of the years considered were compared with each other. Year 2012 showed highest result in terms of runoff volume and depth and by way of face validity, it matches with the time there was severe flooding in the study area. Hence, this shows the usefulness of the HEC-HMS and its reliability in estimating, predicting and forecasting floods and runoff volumes in various watersheds.

It is therefore of great importance that great care must be taken to ensure that the data gathered for such studies are accurate. This will lead to accurate results and a further development of operational policies and regulations that should be implemented. It is also recommended that:
i. The provision of latest weather station that will provide real time hydrological output for this study area is necessary. This will aid continuous observation of water levels and provide reliable forecast information as regards flooding.

ii. Better quality of data should be used for such study. They should be treated as a valuable resource by the relevant authorities in the proper management of water in the study area.

iii. The development of good policy and proper planning with the results obtained from this project will go a long way in reducing flooding occurrences as well as help in the control and management of such occurrences in the study area.

iv. There should be better data provision, updating and management for such projects. With this in place, the ease of the execution of such projects more frequently will be possible.

v. Proper flood warning systems should be put in place for the study area for flood monitoring processes.

References


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Submission of Paper for Review

A. Structure of Paper

Paper submitted for review should generally be structured in the format given below:

Abstract
1.0 Introduction
2.0 Materials and Methods
3.0. Results and Discussion
4.0 Conclusions
Acknowledgments (If any)
References

NOTE: The abstract should be a single paragraph of not more than 300 words and summarizes the content of the paper. At the end of the abstract, 5 – 7 keywords should be provided for indexing purpose.
B. Paper/Article Format
Papers accepted for publication in NIJEST, will be required to be prepared in the format for publication according to NIJEST guidelines given below:

1. Author Affiliations
Do not abbreviate institution names. Do not use designations such as MBA, CPA or Ph.D.

2. Font Size and Style
   i) Paper Title: Title case, Size 16, Bold, Times New Roman
   ii) Authors Name and Affiliations: Title case, Size 12, Times New Roman
   iii) Main headings: Title case, Size 11, Bold, Times New Roman
   iv) Sub headings: Title case, Size 11, Times New Roman
   v) Document Text (Body of paper): Sentence case, Size 11, justified, Times New Roman
   vi) Text within tables: Sentence case, Size 8, Times New Roman
   vii) Notes to tables: Sentence case, Size 8, italic, Times New Roman
   viii) Tables & Figures Heading: Title case, Size 11, Times New Roman
   ix) Text within figures: Sentence or Title case, Size 8, Arial

3. Acronyms
The use of acronyms is allowed everywhere in the paper EXCEPT in the title or abstract. Acronyms should be defined when first used in the paper.

4. Tables
Place tables in the text as you wish them to appear and in conjunction with the corresponding discussion. Tables must include a title and be numbered consecutively as “Table 1: Description” and so forth. The title must appear outside the table. Titles for tables should be in title case in a Times New Roman Font of 11. Tables must be black and white only. Do not use colour in tables. Define all variables in your table within the table or in the note to the table and in the text of the document.

5. Figures
Place figures in the text as you wish them to appear and in conjunction with the corresponding discussion. Figures must be numbered consecutively as “Figure 1: Description” and so forth. Use the word “Figure” as the label. Titles for figures should be separate from the figure itself
and in title case, in a Times New Roman Font of 11. Use an Arial font of 8 for text within figures.

6. Equations
Create Equations using the Microsoft Word Equation Tool. Number equations consecutively on the right margin. For example:

\[ y = A + Bx_1 + Cx_2 + Dx_3 \] (1)

7. References
All reference works cited in the paper must appear in a list of references that follow the formatting requirements of NIJEST given below. References not cited should not be listed. Citing and Listing of references should be according to the following:

Citing references in the body of the paper
i) For citations with one author, include author’s name and year e.g. (Osamuyi, 2016). For two authors, include both authors' names e.g. (Ehiorobo and Izinyon, 2015). For citations with three or more authors, list only the first author's name followed by et al. e.g. (Osamuyi et al., 2014)

ii) Cite references chronologically e.g. (Osamuyi et al. 2014; Ehiorobo and Iznyon, 2015; Osamuyi, 2016)

iii) For multiple citations with the same first author, list single-author entries by year using 2014a, 2014b, etc. For example: (Osamuyi et al., 1996a).

Listing of References
In the reference section at the end of the document, include a single space between each reference. Do not indent references. For journal articles, be sure to include, author names, year of publication, article title, Journal Name, volume number, issue number and page numbers. References should appear according to the following:

i) List references with three or more authors only by year and without regard to number of authors or alphabetical rank of authors beyond the first.

ii) For articles with more than five authors, list the first five names and then et al.

iii) For multiple citations with the same first author published in the same year, list entries by year using 1996a, 1996b, etc. Alphabetize by second author.

iv) Sample journal article citation:

v) **Sample book citation:**

vi) **Sample chapter-in-book citation:**

vii) **Sample website citation:**