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DATA ARCHITECTURE OF BUILDING MATERIALS USING WEB-BASED TECHNOLOGIES FOR SUSTAINABLE MATERIAL MANAGEMENT

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ABSTRACT

Construction materials are vital resources in the running of the construction industry, whereas, the issues of unavailability, over-supply, storage of materials and construction waste have dire consequences for the environment. The study aimed to evaluate the concept of data architecture of building materials using web-based technologies with a view to ensuring sustainable material management. The study made use of a web-based system developed using HTML, PHP programming language and a database system through MySQL. An evaluation of the system showed the capabilities of using the web-based system to estimate building materials to be used on the construction project. The system showed the proficiency of storing the total inventory of building materials on a construction project. Finally, the web-based system is able to use raw data from the building materials to generate reports that can be used to achieve sustainable material management. Construction professionals are able to compare actual materials used on their projects versus the estimated values. These information can be useful in effective and efficient planning and decision making on ongoing projects and future developments.

Key words: Building Materials, Construction Industry, Data Architecture, Sustainable Material Management, Web-based Technologies.

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1. INTRODUCTION

The introduction of the World Wide Web (WWW) and the internet has been useful in meeting the demands of the commercial world and the social needs of men. The construction industry too, in one way or the other has not been left out in harnessing the benefits of these two (2) entities (Oladapo, 2006; Olalusi and Jesuloluwa, 2013). According to Islam et al. (2013), computers opened the door to an inventory system in material management helping to keep up-to-date records on the status of every inventory in stock. The inclusive use of computers in the management of materials are pointers to achieving a sustainable green environment. A combination of the desktop computers and the internet entity has led to concepts of e-Procurement (Ibem and Laryea, 2015; Ibem et al., 2016; Aduwo et al., 2016), e-business and other web-based systems (Afolabi et al., 2017; Afolabi et al., 2017) which have transformed the traditional roles of the construction industry. These innovative ICT tools have in one way or the other helped to reduce anti-sustainable issues such as the use of papers, which require that trees be cut down, and precise procurement of building materials thereby reducing the level of construction waste and the depletion of the limited earth's resources.

Since these ICT tools are able to gather big data from construction projects, the study posits that the data obtained can be used as a sustainable tool for now and future projects. Big data obtained from material usage can be used in future projects and the analysis can help project and plan in terms of waste reduction, purchase and supply and sustainability of the construction industry. Data architecture describes the data structure that can be used by construction businesses in any area where data is generated. Data architecture helps to address the data in use and data stored in the construction business and help map the data in quality and application. A general aim of the concept of data architecture is to help describe how data is processed, stored and utilized in an information system. The idea that raw data can be used for meaningful and useful purposes in the construction industry and for the environment is a big win for sustainable development.

Presently, Kasim et al. (2005) argued that the construction industry apply traditional construction methods in processing its information gathered during the construction process. These traditional construction methods involve the use of papers in form of receipts, invoices, drawings, and contract documents etc. that are not environmentally friendly. By using paper-based systems for the construction activities, it is hard to track changes appropriately; there is need to store piles of documents, which may not be easily retrieved when needed, and the need to fell more trees to provide paper for the construction industry. The material management stage in the construction process is a unique stage whereby several information is generated. It involves several processes from planning, controlling, procurement, stocktaking etc. In this dynamic and changing environment, Kasim et al. (2005) encouraged that there is a need to make use of more computer-based systems to improve material management on construction sites. These computer-based systems should be well integrated with the internet to harness the effective storage, ease of retrieval and protection of the construction data. In economic sense, the integration of web-based systems with the construction process can save up to ten (10) percent on the construction project (Equere and Tang, 2010). In sustainability terms, the use of web-based system is thinking green whereby the system becomes paperless and it can be used for seamless planning. In order to improve productivity in ordering and quotation activities, contractors and suppliers could change their activities from conventional to more sophisticated or innovated tools and techniques. Therefore, this re-search aimed at using a web-based system for sustainable material management with a view of estimating accurate building materials storing raw data for future planning and control of building projects.

2. SUSTAINABLE MATERIAL MANAGEMENT

World over, researchers and global organizations seem to agree on the concept of sustainability and what it aims to achieve. For those that do not agree, increasing pressures coming from national and Int. regulations have made them forcibly sub-missive. From the global definition of sustainability, a right thinking mind should admit that it is for a right course. The rationale for development in fast developing cities should also consider the development of the environment. On the other hand, Williams (1998) stated that sustainable development is beyond consideration for the environment but rather welfare of the consequences of our decision-making. Arising from different theorists, the issues about sustainability is multi-facetted requiring the input of several professions and collaboration of different fields of endeavors. From social, business and environment discourse, various other aspects of ensuring and attaining sustainability is constantly been explored and this is all for the same cause. This study explored the possibilities of using technology in ensuring sustainable development.

Le Blanc (2015) opined that the overall goal of sustainable development (SD) is only achievable through the integration and acknowledgement of economic, environmental, and social concerns throughout the decision making process. A major aspect in the discourse on sustainability is about materials. The study posits that construction waste is mostly generated when there is no plan on the required quantities needed to carry out a specific aspect of construction and ultimately no data information on the post-usage of building materials.

Materials play an important role in every aspect of life. It is safe to assume that no organization can operate without any material input (Mehr and Omran, 2013). Sadly, construction materials alone are responsible for 40% of the greenhouse gas (GHG) emissions. The efficiency of material availability, unavailability, right quality and quality affect the production success of any organization (Afolabi et al., 2016; Oyeyipo et al., 2016). It is crucial to note that sustainability can be achieved in the dimension of material management, which is the focal point of this study.

Materials management involves several stages in trying to manage construction materials from the inception to the completion of the construction project. The concept of an effective material management should be able to ensure that the right construction material is procured at the right price and is available at the point of use in the right quantity and quality. The ultimate goal of an efficient material management on a construction project ensures that construction waste is brought to a minimum. These definitions stresses the fundamentals of material acquisition, handling and usage in terms of quantity and quality. By utilizing material management, construction firms are able to maximize their operations and reducing cost in their inventories. Nevertheless, the problems associated with poor material management persists and this has dire consequences on construction projects and the environment. Equere and Tang (2010) reported that when construction materials are purchased when they are not yet needed, the construction project incurs storage charges and the money that could have been channeled to other activities becomes held up. The construction materials are also susceptible to theft, vandalism or even deterioration during storage, which is of no beneficial value to the construction project. The unavailability of construction materials when they are needed can also be a problem, thereby causing delay on the construction project. Over-ordering is a similar issue, which construction projects have to grapple with. Over-ordering of construction materials leads to wastage and pollution of the environment. This is dangerous to the discourse of social, business and environment sustainability. In essence, consideration for an effective materials management must ensure that waste is reduced, optimize material supply, limit deterioration of materials, reduce cost, and make construction materials available in the right quantity and quality. This call for effective planning and control by the construction professional handling the project.

The OECD working definition of SMM was developed in 2005, and states: "Sustain-able Materials Management is an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity". Four basic principles are encountered in Sustain-able Materials Management (SMM), which are natural capital preservation, life cycle thinking, diverse approaches and stakeholder responsibility. Sustainable Materials Management (SMM) is a relatively new approach that represents a shift from waste management (end-of-life) to materials management in support of sustainable development. Research has shown that waste management is often not the key process, nor is it the most efficient and effective process, for controlling material flows in the industrial and economic systems (OECD, 2010). An important aspect of ensuring sustainable development in material management can be in accurate estimation of the quantities of materials to be used thereby reducing the need to over supply-limited earth's re-sources and reducing construction waste. Another important feature is that the data information generated in this process can be checked for trends in current projects and used for effective and efficient planning of future construction projects.

Why should construction professionals buy excess materials that may later not be used for construction projects? By not adequately planning and controlling the use of construction materials, from transportation to the point of use, the construction processes are putting pressure on the world's ecosystem. The flow of construction materials should be adequately planned from extraction to the utilization on construction sites, to reduce the over-exploitation of renewable resources. It is worth to note that environmental pollution is a reflection that materials are not effectively and efficient used for the purpose they were intended. Therefore, a win-win opportunity for the environment and the economy will be such that captures improvements, which reduces pollution before and after the material is procured. Consequently, the buying manager for construction materials must be equipped with the right skill and techniques that ensures effective material management on the construction project. Although, Tunji-Olayeni et al. (2017) suggested that several other factors support the make or buy decision of acquiring raw materials. There is need to consider the sustainability of the process. Planning for a sustainable material management should start before the material is acquired and controls should be in place to ensure reduction in waste and pollution of the environment. By this, the introduction of computer and internet systems can help handle the economics of material management in a faster and effective manner.

3. RESEARCH METHOD

Based on the framework proposed by De Wolf (2014) in Figure 1, where there is an interaction between three (3) platforms of the web-interface, the connection and the database, the study developed a web-based material planning and control system. For data architecture to exist on the web-based system, the system used MySQL to design the database, where construction materials information can be stored and crosschecked per time with usage on the construction project. HTML was used to design the green, orange and red on a white background interface through Java and PHP computing language to be able to easily process the information inputted in the system back and forth. The significance of the web-based material planning and control system is to have an interactive interface that is able to estimate construction materials per time during the construction process and compare with available materials in the inventory to see if there is need to order for more construction materials before the start of the construction activity. When the materials are then used, the data is inputted to be able to keep track of the volume of construction materials that have been used in order to draw up decisions for better management of construction materials. The system is setup in such a way that it can only be accessed via an online platform through web browsers on desktop systems. In developing the

web-based system, sys-tem architecture and user case diagrams helped in understanding the sequence of the interface and the accessible users to the platform including the activities they can perform. The eventual input and output database designed system were analyzed and tested to check for system failure, usability and performance issues.

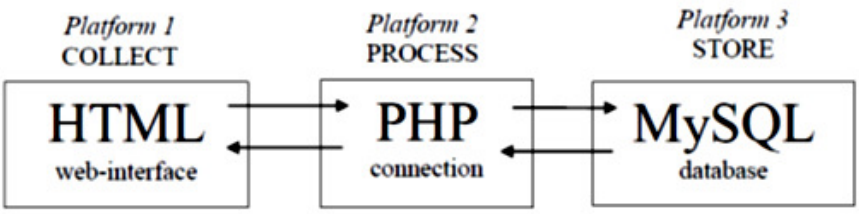

Figure 1 Interactive database system

Source: De Wolf (2014)

4. DISCUSION OF FINDINGS

Construction users via the internet can access the web-based system designed. The system was designed to be web-based so that it can be accessed from anywhere at any time and is available even after the project has finished or a crash of the hardware. For data architecture to take place, raw data has to be inputted from the ongoing construction project. For this study, a typical project is selected for analysis of raw data been used to describe how a web-based system can bring about sustainable material management. The project selected has project activities that have programmed timeline of start and finish date. Figure 2 showed the project activities of the selected project and the timeline for the delivery of the project.

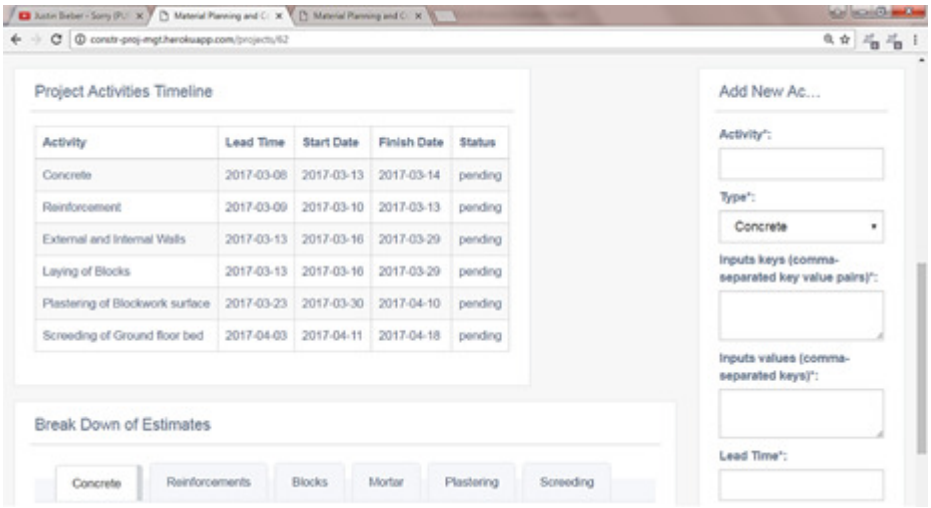

Figure 2 Screen shot of Project Activities Timeline Interface

Sustainable material management is achievable when project managers are able to give accurate estimate of the quantities of the building materials needed for a particular activity. The web-based system has been programmed to deliver accurate estimates with limited room for error. The areas to estimate in the construction project selected are concrete works, block works, steel reinforcement, mortar works for plastering, screeding and laying of blocks. Figure 3 – 8 showed the breakdown of the building materials from the project activities on the construction project. When accurate estimates are generated it would help project managers to procure building materials based on their needs rather than an over-supply of building materials to the construction site which has an adverse effect on the environment.

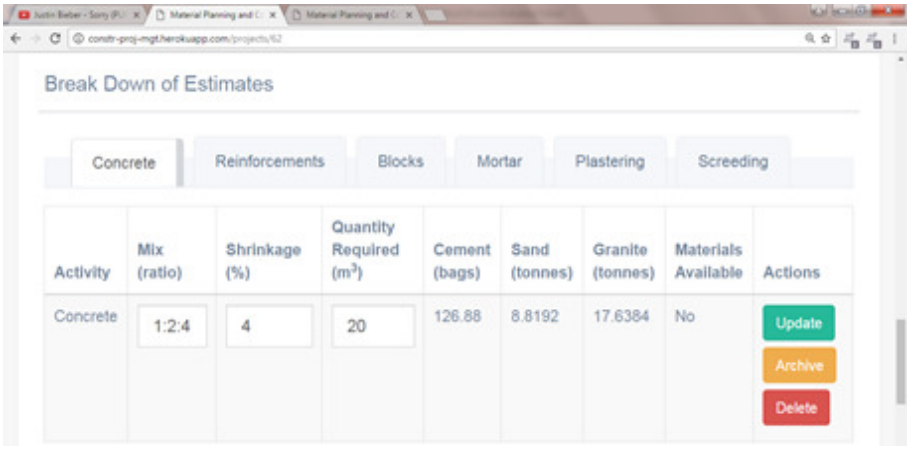

Figure 3 Screen shot of estimates for concrete works

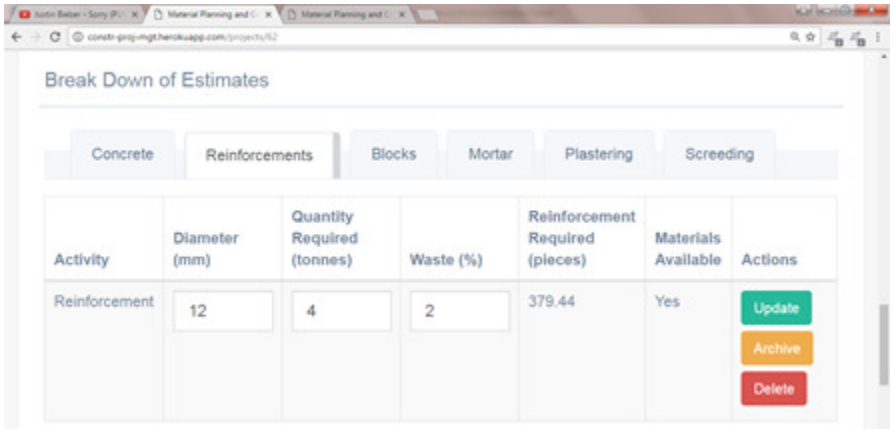

Figure 4 Screen shot of estimates for steel reinforcement details

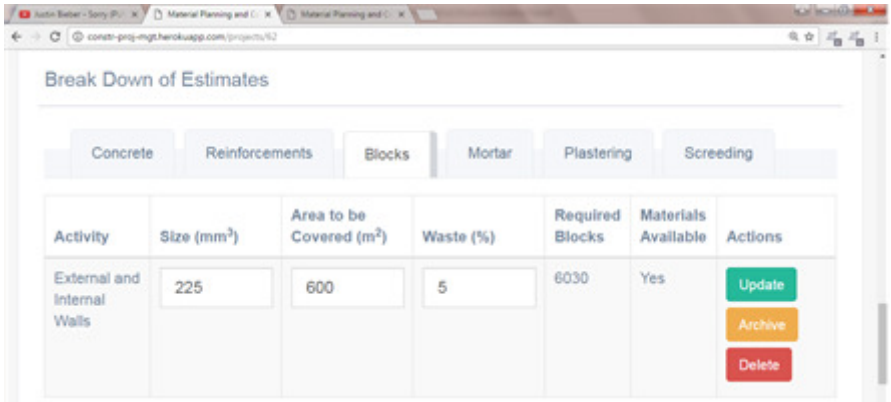

Figure 5 Screen shot of estimates for sandcrete block works

Figure 6 Screen shot of estimates for mortar in laying of sandcrete blockwalls

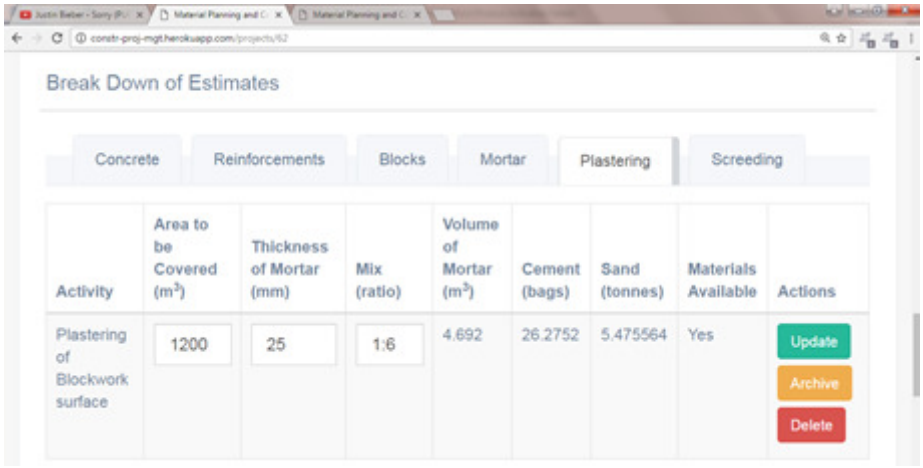

Figure 7 Screen shot of estimate in plastering blockworks

Figure 8 Screen shot of estimate in screeding concrete floor surfaces

In other to ensure sustainable material management, there is need for construction projects to have up-to-date building materials' information stored using ICT tools. Using paper-based methods in storing the raw data of building materials is prone to several drawbacks and it is not environment-friendly. Figure 9 showed the construction materials inventory page. The inventory is based on project location as the construction firm could have several ongoing projects and different inventory attached to them. The inventory interface has three (3) main characters; the inventory or stock system on-hand, inventory status (i.e. on-hand inventory

minus estimated quantities), on-order inventory (quantities expected and receiving dates). Figure 9 showed the fill form to input the type of inventory coming into site or on-order. The construction materials inventory is in terms of cement (in bags), sharp sand (tonnes), granite (tonnes), hollow sandcrete blocks (pieces) and steel reinforcement (tonnes or pieces). As earlier stated that many construction sites use the paper-based method of filling construction materials' document and these are subject to several drawbacks which do not allow easy retrieval when needed and inhibiting the process of auditing of material quantities used on the construction project. In addition, a paper-based method is anti-sustainable, therefore the need to use ICT tools to ensure a sustainable development in the material management process. Figure 9 showed the summary of an input of inventory materials of at-hand and on-order for a selected project. By having an up-to-date building materials' information the issues of construction waste can be reduced due to the fact that all building materials can be accounted for within the construction project.

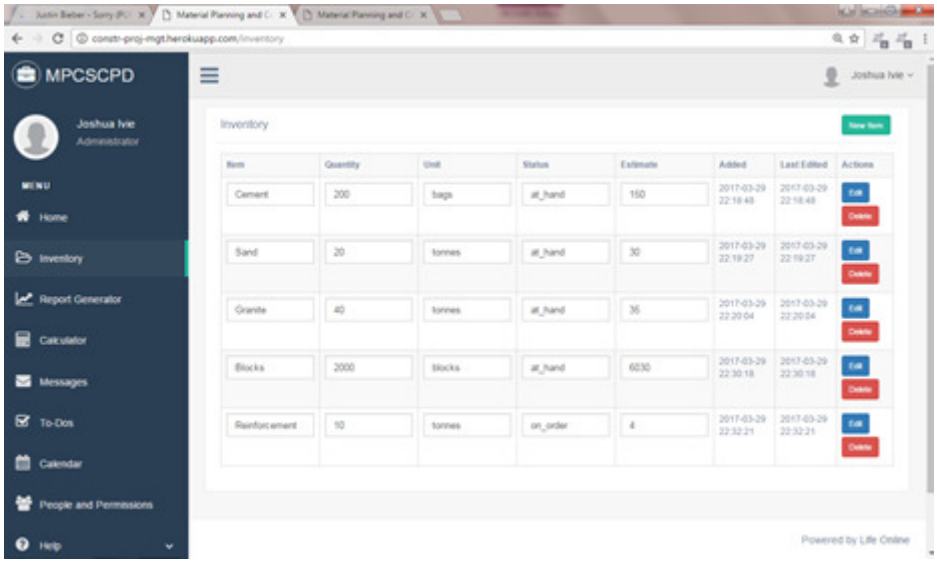

Figure 9 Screen shot of construction materials inventory page

In order to achieve data architecture, which makes use of the raw data that has been inputted into the system. The web-based system has an interface, which helps to process the data collected. By processing this data, construction stakeholders can plat within the ambit of the present project and future construction projects. The report generator produces various reports, which give one a cohesive summary of a project and helps in decision making. Figure 10 showed the reports that can be generated on the use of construction materials during the construction process. Various construction report such as the construction activities involved on the project, the summary of the construction materials to be used and utilized at present, a summary of construction materials stored on the construction site, data architecture comparing estimated construction materials and the actual construction materials used as shown in Figure 11 can be presented in this section. The study posit that data sustainable material management is also achieved when the actual building materials used on the project can be compared with the estimated building materials, thereby helping to make better decisions in the present project and future projects.

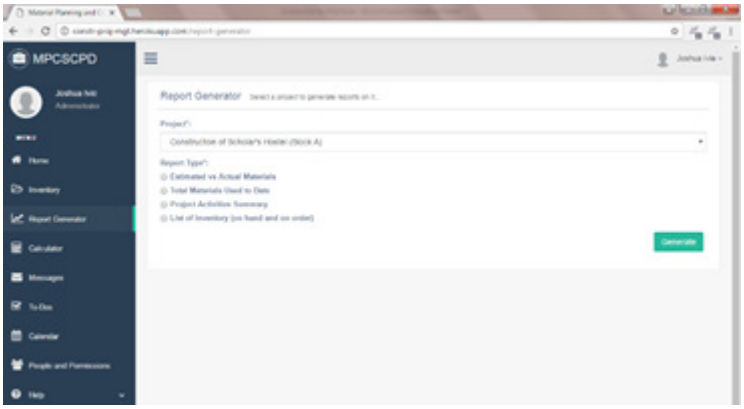

Figure 10 Screen shot of construction materials' report

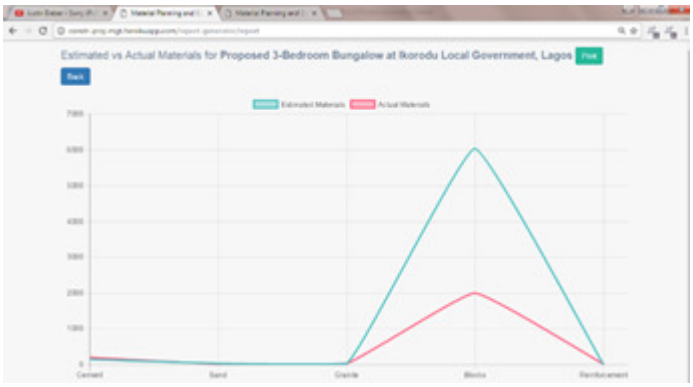

Figure 11 Screen shot of data architecture comparing estimated construction materials and the actual construction materials used

5. CONCLUSION AND RECOMMENDATION

The study evaluated the concept of data architecture of building materials using web-based technologies with a view to ensuring sustainable material management. In order to use the web-based system for data architecture, the system developed a project activity interface, material-estimating interface, material inventory interface and a report generator interface. An evaluation of the system showed the capabilities of using the web-based system to estimate building materials in sections such as concrete works, block works, steel reinforcement, mortar works for plastering, screeding and laying of blocks to be used on the construction project. The system showed the proficiency of storing the total inventory of building materials on a construction project. In ensuring sustainable material management, it is essential to estimate correctly and know the quantities of building materials used and to be used on a construction project. The inventory interface showed all the building materials on the construction project. Finally, the web-based system is able to use raw data from the building materials to generate reports that can be used to achieve sustainable material management. Construction professionals are able to compare actual materials used on their projects versus the estimated values. This information can be useful in effective and efficient planning and decision making on ongoing projects and future developments. Although, the construction industry is a traditional one in most developing countries there is need for construction professionals to adequately embrace the use of innovative ICT tools for managing construction materials to reduce the quantities of construction waste on construction project, which leads to loss of profit for the contractor, cost overrun and environmental pollution. The study posits that where there is efficient accountability in the material management process, the concept of sustain-able material management can be greatly achieved.

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REFERENCES

[1] Aduwo, E.B., Ibem, E.O., Uwakonye, O., Tunji-Olayeni, P. and Ayo-Vuaghan, E.K. (2016). Barriers to the uptake of E-procurement in the Nigerian building industry. *Journal of Theoretical and Applied Information Technology*, 89 (1), 115 - 129.

[2] Afolabi, A. and Dada, M. (2014). An evaluation of the factors affecting housing and urban development projects in Lagos State. Paper presented at the Proceeding of CIB W107 International Conference on Construction in developing countries and its contribution to sustainable development, University of Lagos, Lagos, Nigeria, 28th – 30th January.

[3] Afolabi, A., Fagbenle, O. I. and Mosaku, T. O. (2017). IT Management of Building Materials' Planning and Control processes Using Web-Based Technologies. In: Á. Rocha et al. (eds.), Recent Advances in Information Systems and Technologies, Advances in Intelligent Systems and Computing, 570, Chapter 2, Springer, Cham, 12 - 19.

[4] Afolabi, A. O., Oyeyipo, O., Ojelabi, R. A. and Tunji-Olayeni, P. F. (2017). E-Maturity of Construction Stakeholders for a Web-Based e-Procurement Platform in the Construction Industry. International Journal of Civil Engineering and Technology (IJCIET), 8 (12), 465 - 482.

[5] De Wolf, C. (2014). Material Quantities in Building Structures and their Environmental Impact. Unpublished MSc. Thesis, Department of Architecture, Massachusetts Institute of Technology (MIT), USA.

[6] Equere, E. and Tang, L. C. M. (2010). Dearth of Automation: The Consequences in Nigeria Construction Industry. Automation in Construction, 14 (4), 500 – 511.

[7] Ibem, E. O. and Laryea, S. (2015). e-Procurement use in the South African construction industry. Journal of Information Technology in Construction, 20, 364 - 384.

[8] Ibem, E. O., Aduwo, E. B., Tunji-Olayeni, P., Ayo-Vaughan, E. A. and Uwakonye, U. O. (2016). Factors influencing e-Procurement adoption in the Nigerian building industry. Construction Economics and Building, 16 (4), 54 - 67.

[9] Islam, M. S., Rahman, M. M., Saha, R. K. and Saifuddoha, A. M. (2013). Development of Material Requirements Planning (MRP) Software with C Language. Global Journal of Computer Science and Technology Software & Data Engineering, 13 (3), 12 – 22.

[10] Kasim, N. B., Anumba, C. J. and Dainty, A. R. J. (2005). Improving materials management practices on fast-track construction projects. 21st Annual ARCOM Conference, SOAS, University of London, 2, 793 - 802.

[11] Le Blanc, D. (2015). Towards integration at last? The sustainable development goals as a network of targets. UN/ Department of Economics and Social Affairs Working Paper No. 141, 1 – 19.

[12] Mehr, S. Y. and Omran, A. (2013). Examining the challenges affecting the effectiveness of materials management in the Malaysian construction industry. International Journal of Academic Research, 5 (2), 56 - 63.

[13] OECD Environment Directorate, OECD (2010). OECD Global forum on environment - focusing on Sustainable materials management. Policy Report 1, Policy Principles for Sustainable Materials Management, Working Document, 1- 55.

[14] Oladapo, A. A. (2006). The Impact of ICT on Professional Practice in the Nigerian Construction Industry. The Electronic Journal on Information Systems in Developing Countries, 24 (2), 1 – 19.

[15] Olalusi, O. C. and Jesuloluwa, O. (2013). The Impact of Information Technology on Nigerian Construction Industry. International Journal of Engineering and Innovative Technology, 2 (9), 1 – 5.

[16] Oyeyipo, O. O., Odusami, K. T., Ojelabi, R. A. and Afolabi, A. O. (2016). Factors affecting contractors' bidding decision for construction projects in Nigeria. Journal of Construction in Developing Countries, 21 (2), 21 – 35.

[17] D. Satish Chandra, SS. Asadi and M.V.S. Raju, Design of Web Based Decision Support System - Model Study of Vijayawada, A.P. International Journal of Civil Engineering and Technology, 7(6), 2016, pp.514–522.

[18] Dr. Suryakant B Patil, Ms. Ashlesha Sawant and Dr. Preeti Patil, Improvement In The Efficiency Of Web Based Search Engines By Increasing Page Rank Based On Referring Factors, Volume 5, Issue 1, January - April (2014), pp. 53-59, IJITMIS.

[19] Tijomon P.Issac, Dr.R.Jayabal and Supriya Susan Kurian, Web Based Information Retrieval Pattern of Faculty Members in St.Aloysius College, Edathua: A Study. International Journal of Libr ary & Information Science, 5(1), 2016, pp.58–68

[20] Tunji-Olayeni, P. F., Emetere, M. and Afolabi, A. O. (2017). Multilayer Perceptron Network Model for Construction Material Procurement in fast Developing Cities. International Journal of Civil Engineering and Technology (IJCIET), 8 (5), 1468-1475.

[21] Williams, M. (1998). Aid, Sustainable Development and the Environmental Crisis. The International Journal of Peace Studies, 3 (2), 8 – 15.