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Environment-Friendly Material Planning and Control System for Managing Construction Materials

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Abstract: There are many material planning and control systems in use in the construction industry but general focus has not been on the reduction of construction waste which adversely affects the environment. Creating an environment friendly system should be able to make adequate use of the internet. The purpose of this study is to develop an environment-friendly material planning and control system for managing construction materials. The study used case diagrams and a MVC Model in designing the web-based platform for planning and control of construction materials. The study revealed that using a web-based system assessed via. the internet can help store building materials data thereby reducing the manual/paper-based system of planning and controlling construction materials. The system been environmentally-friendly helps to reduce waste during construction by ensuring the right calculation of quantities needed and delivery at the right time. In conclusion, the web-based system reduces the need for stockpiling which would have unnecessarily put pressure on the depletion of natural resources. The study recommended the high use of the internet to achieve an environment-friendly system in managing the crucial nature of construction materials and processes in the construction industry.

Key words: Construction materials, environment-friendly, internet, material planning and control, web-based systems, delivery

INTRODUCTION

The influence of materials in the building and construction industry is paramount and cannot be over emphasized. Studies from Formoso and Revelo (1999) and Dey (2001) indicated that in developing countries, material costs can make up as much as 60-65% of the total working capital of any industrial organization or construction project. According to Dey (2000), Chan (2002) and Kasim *et al*. (2005), the critical nature of construction materials during handling and management is crucial in that it can influence the total project cost, time and the quality.

Materials are vital in the activities of any industry since unavailability of materials can impede production. Unavailability of materials is not the only phase that can cause problems. Excessive quantities of materials could also make serious problems to managers. Storage of materials can raise the costs of production and the overall cost of any project. Equere and Tang (2010) stated that stockpiling time of materials cause extended tied down capital that would otherwise have been better invested, requiring extensive storage facilities and space.

Traditional material procuring processes done on a paper-based system have many associated drawbacks: low accuracy, time consumption, labor consumption, loss of data and high uncertainty (Hadikusumo *et al*., 2005). Ineffective planning and control of materials have been traced to problems of time overrun, cost overrun, dissatisfaction of client, high wastage, theft, low quality, abandonment of projects, etc. A major concern lately has been the issue of climate change resulting from the alarming nature of waste generated.

The Nigerian Environmental Study/Action Team (NEST) by Oyeniyi (2011) reported that Nigeria generated over 40 million tonnes of waste between 2005-2010 while the construction waste generated on construction sites in Nigeria has been put at over 15% (Babatunde, 2012). Adeagbo and Kunya (2003) revealed that construction professionals pay little attention to the value of materials on site and they see waste as the inevitable consequences of the construction process. With issues of climate change, sustainability and spread of infectious diseases, building materials waste generation needs to be brought to a minimum. Edwards and Hyett (2001) stated that more than half of all resources consumed globally are used in construction. Hussin *et al*. (2013) noted that the

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built environment is considered the most environmental unfriendly human activity because it consumes large amounts of natural resources and produces a great deal of pollutants. Construction materials alone inform of material extraction, transport and utilization contribute in many of the world's environmental and social problems. In addition, this is responsible for 40% of the Green House Gas (GHG) emissions.

The building materials waste generated on construction sites categorized by Babatunde (2012) include cutting waste (reinforcement bars-over 19%), transit waste (tiles-over 20%), theft and vandalism waste (reinforcement bars, timber, cement-over 18%) and application waste (plaster of paris, mortar, concrete-over 14%). Waste production on construction sites can be attributed to some poor material management principles applied on some building construction sites. Such poor material management is often due to inadequate storage and protection, poor or multiple handling, poor site control, over-ordering of materials, bad stock control, lack of training and damage to materials during delivery, poor planning (Ekanayake and Ofori, 2000; Formoso *et al*., 2002; Zhao and Chua, 2003; Senaratne and Wijesiri, 2008) and ordering error (Lu *et al*., 2011; Polat and Ballard, 2004).

According to Hussin *et al*. (2013), waste has direct impact on the productivity, material loss and completion time of project resulting in loss of a significant amount of revenue. Mohamed and Stewart (2003), Kasim *et al*. (2005) and Oladapo (2006) stated that the traditional construction methods apply more paper-based work in its data and document management during the construction process, whereas, the emergence of ICT systems could transform conventional to modern methods in managing construction activities. Islam *et al*. (2013) opined that 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. In this dynamic and changing environment, Faniran and Caban (1998), Kasim *et al*. (2005) and Hadikusumo *et al*. (2005) encouraged that there is a need to make use of more computer-based systems to improve material management on construction sites. With over 60% of construction professionals connected to the internet (Oladapo, 2006), Nigeria is yet to massively deploy computer based production and inventory systems compared with other developed economies of the highly industrialized nations (Oladokun *et al*., 2009). Therefore, the study intends to make use of the internet and programming language to develop an environment-friendly material planning and control system for construction materials.

MATERIALS AND METHODS

The system developed has focused only on the planning and control of selected structural construction materials such as cement, granite, sharp sand, blocks and steel reinforcement. This is because these materials are crucial to the delivery of construction projects. Construction managers tend to stock pile most of these materials and the unavailability of one of or all these materials has the tendency to lead to project failure. The study made use of case diagrams to illustrate the relationship between variables in the proposed system. According to Wasserman (2006), the development of a successful web application (website) involves many different kinds of design, including functional design, software architecture, business process or workflow design, user interface design and database design. The purpose of the Web Based-Material Planning and Control (WB-MPC) Model is to have an interactive web-based interface which allows construction professionals to be able to estimate and store building material quantities while planning and controlling the usage of building materials per time. The system is designed in a way that a shortfall in quantities of selected building materials can be brought to the notice of the construction professional by periodic Short Messaging Systems (SMS) or email format. Figure 1 showed the architectural or system design of the Web Based-Material Planning and Control (WB-MPC) system. Figure 1 tried to show the variables and the relationship between them. Figure 1 describes the organization of the information managed by the application in terms of pieces of content that constitute its information base and their semantic relationships. The system is setup in such a way that it can only be accessed via. an online platform through web browsers on desktop systems. The material planning and control system for construction project delivery application was developed using the PHP (PHP Hypertext Preprocessor) Language. PHP is very diverse with a few frameworks. For this particular application a MVC (Model View Controller) PHP framework Laravel 5.3 has been used. Before the project development began a rough sketch of what was to be expected was drafted based on already prescribed project requirements, enabling the proper division of the project segments into the MVC Model. The model and view were the first parts of the project to be worked on while the Controller was completed last. The application uses an ORM (Object Relational Mapper) called Eloquent to ensure cohesion of data between the model, view and controller.

The model structure was developed using MySQL a real-time open source transactional database system. It is

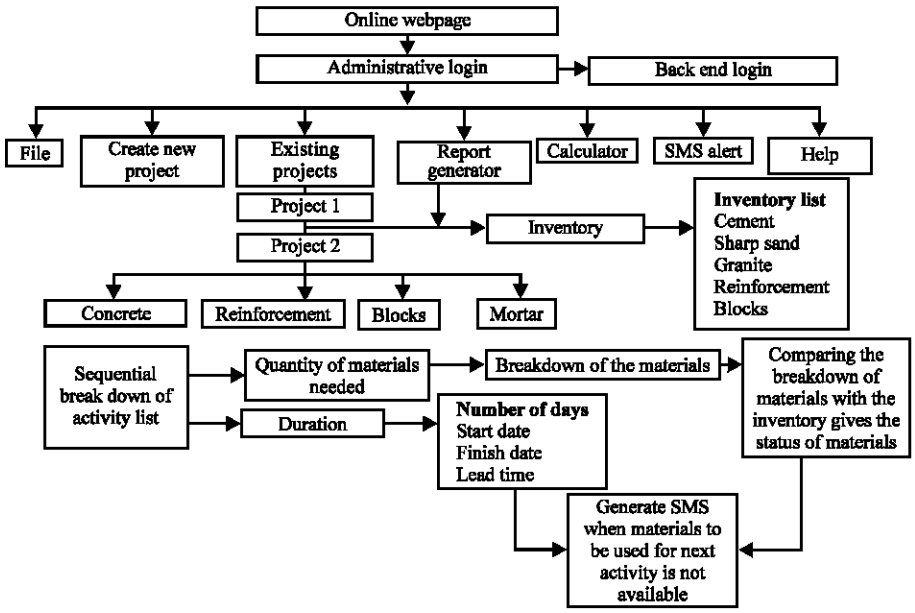

Fig. 1: Architectural design of the Web-Based Material Planning and Control (WB-MPC) system

important to note that the data in the database is dynamically inputted by the users of the system. Hence, a framework of empty tables, records and fields were first created to accommodate any data to be stored or moved through the database.

During the project development, HTML 5, CSS3 and JavaScript 1.8.5. were language used to design the product interface. This interface (view) was designed to ensure easy navigation of its users and simplicity in delivering the project functions.

In order to have the database filled with data produced by the user through the view a server side scripting language was introduced in the case PHP making the data base a Dynamic Database Management System (DBMS). PHP was used is link each of the functions presented in the view to their storage points in the database. PHP has also been used to create sessions and link user accounts to the database assigning access levels to different types of users (the system administrators and the ordinary users). As earlier mentioned the framework of PHP used was Laravel 5.3. In order to ensure the integrity of the data entered into certain fields the AJAX (Asynchronous JavaScript and XML) framework was introduced. This helped ensure that data entering the database was the right kind of data. JavaScript was also used to carry out all calculations that may be required as data may not remain constant and certain variables may need to be constantly recalculated e.g., items in the inventory etc. and results from these calculations are automatically updated into the database by the controller. The project has been developed using adobe Dreamweaver and NetBeans IDE.

RESULTS AND DISCUSSION

The environment-friendly web-based integrated material planning and control system for construction project delivery describes the features, character and benefits engendered on the platform of the WB-MPCS. The following would be discussed as the characteristics of the web-based system.

Login page: Visiting this application with the required URL takes you to a welcome page. As the application is auth-based, you must login to access the information and functionalities that the system provides. Click the login button on the welcome page. This takes you to the login page. Submitting a valid email and password will take you to the home page of the application. If you do not have access to the system, you can contact the administrator. Making it internet based ensures that it can be accessed from any location, it is not susceptible to virus attack and can be monitored by several parties involved in the project. Figure 2 showed the screen shot of the login page.

Home: The home page provides an overview of the whole application as well as a navigation point to key areas

Fig. 2: Login page of the web-based material planning and control system

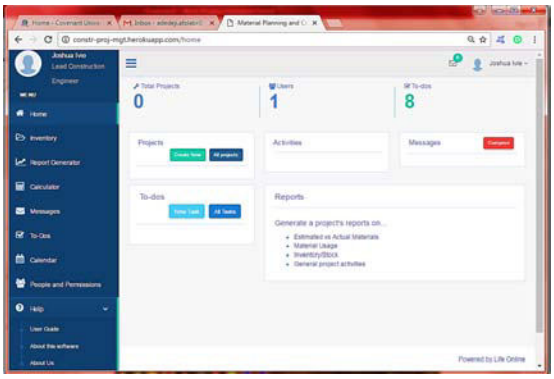

Fig. 3: Home page of the web-based material planning and control system

in the system. Figure 3 shows the Home page of the web-based material planning and control system. You are provided: a summary of the latest projects, a list of upcoming activities, sent/received messages, to-dos, etc.

Projects: From the home page, you can view available projects by clicking the 'all project's link. Click on any project to view it. You can create a new project by clicking the 'new project' link and filling the form thereof as shown in Fig. 4. These projects consist of activities. After creating a project, you can visit the project from the 'all project's page. The 'add new activity' form allows you create a new activity on each project. Input the activity name, type, start date, finish date and lead time. This system is unique in that the lead time is a date set as a result of several factors that may affect the selected construction material. Therefore, the project manager estimates a workable time prior to the start date of the activity when the selected construction material would be on the construction site. The 'inputs keys' and 'inputs values' fields allow you specify for each kind of activity, the parameters required. Not inputting the right parameters might lead to errors. The information inputted on the project interface is crucial to the successful use of the web-based material planning system due to the number of activities that would be performed on this interface. The information such as the activity list and quantities required which is extracted from a bill of quantities, timeline of activities (start date, finish date and lead time) which can extracted from the programme of work or inputted at the discretion of the project manager and a breakdown estimate of materials needed to complete task. This requires input values and constants that were programmed into the application. The materials considered include concrete of mix ratio of 1:1:2, 1:2:2, 1:1.5:3, 1:1.67:3.33, 1:2:3, 1:2:3.5, 1:2:4, 1:2.5:3.5, 1:2.5:4, 1:3:4, 1:2.5:5, 1:3:5, 1:3:6 and 1:4:8 which are a representation of cement (bags), sharp sand (tonnes) and granite (tonnes), respectively. The reinforcement had different sizes ranging from 6, 8, 10, 12, 14, 16, 18, 20, 25, 32 and 40 while the hollow sandcrete blocks had 3 specs of 100, 150 and 225 mm. In order to capture some other use of cement and sand on construction projects, mortar for laying of blocks, plastering and screeding of floors which is a mixture of cement and sharp sand was also considered. This appeared in the variants of 1:1, 1:1.5, 1:2, 1:2.5, 1:3, 1:4, 1:6 and 1:8. Figure 5 shows the case diagram of the relationship between the type and the input keys of the selected construction materials.

Inventory: The inventory interface has 3 main sections; the on hand inventory or stock system, inventory status (i.e., on hand inventory minus estimated quantities) on order inventory (quantities expected and receiving dates). 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). A filing system for storing scanned receipts, waybill and invoices of materials. As earlier stated that many construction sites use the study based method of filling construction material's 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.

Report generator: The report generator produces various reports which give one a cohesive summary of a project and helps in decision making. Figure 6 showed the report generator interface. Reports can be printed out with the 'print' button. The report generator shows charts or graphical depiction of planned estimated materials versus actual material on site (stock), material usage in terms of quantity and time, list of inventory (on hand and on order inventory), project activities summary and total materials used to date and other analysis as required. The system also provides a standard calculator for basic arithmetic operations.

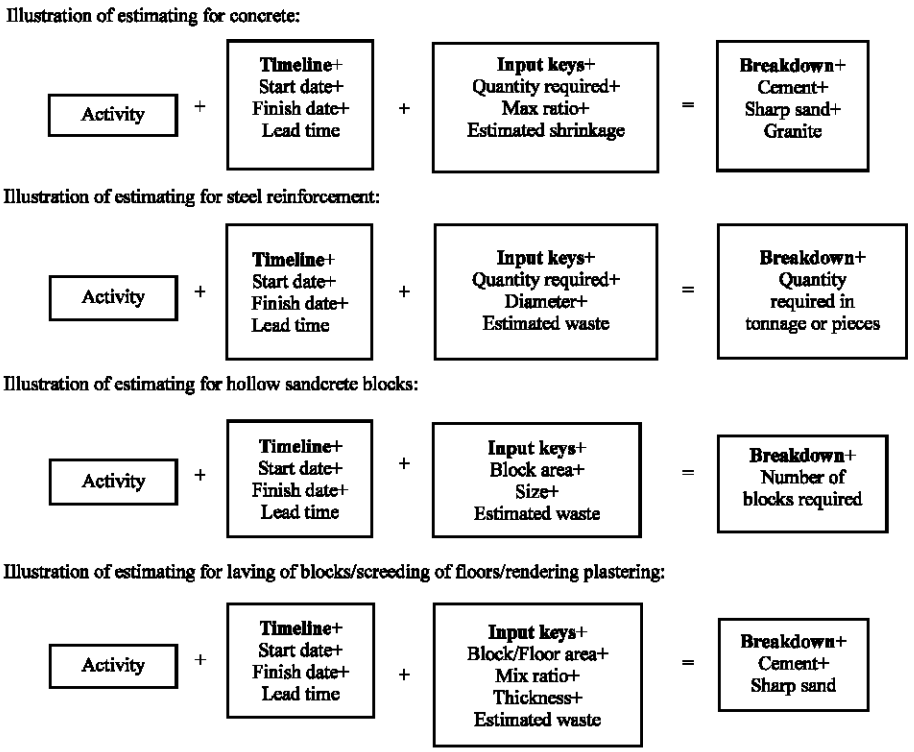

Fig. 4: Type and the input keys of the selected construction materials

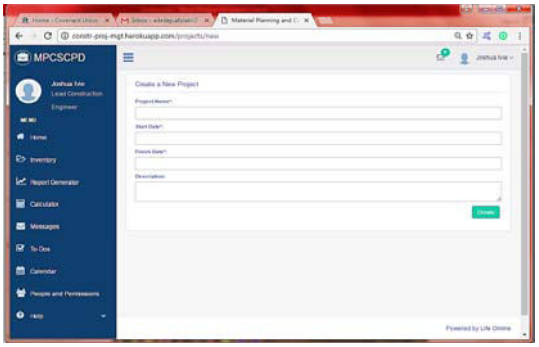

Fig. 5: Project page of the web-based system

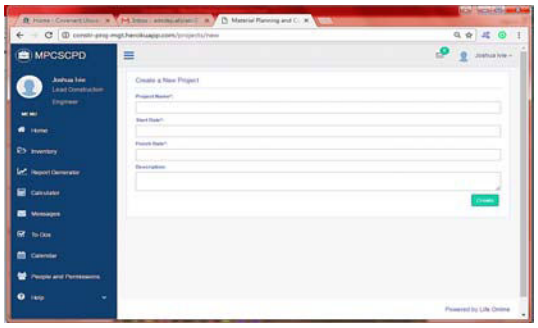

Fig. 6: Report generator interface

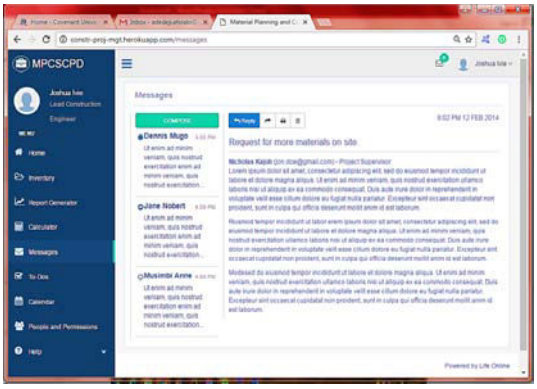

Fig. 7: Messaging platform on the web-based material planning and control system

Messages: The application allows you send to and receive messages from other users of the system. This follows with a corresponding email to/from the user. Figure 7 showed a messaging platform on the web-based material planning and control system. The interface show a list of messages that have been sent out as notifications to prompt the project manager via. the registered email of the materials needed for the next activity on the timeline because of the lead time that must have been assigned to the task.

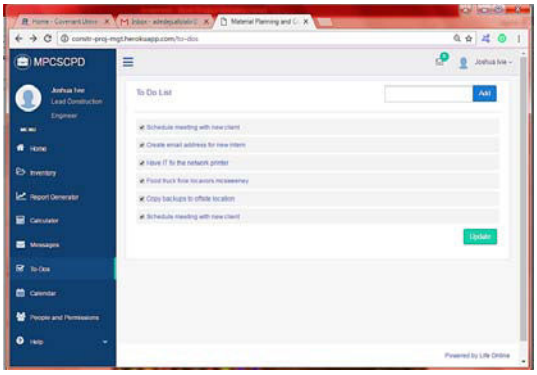

Fig. 8: To-do's interface of the web-based system

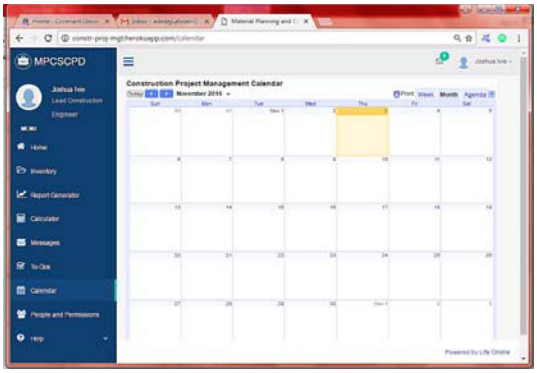

Fig. 9: Construction project management calendar

To-dos: Users of the system can create to-do lists of things they are required to do as regards the projects they are working on. To-dos are private to a user. The note taking platform helps project managers to write issues relating to the project, acting as an activity planner, someone to contact for material supply and delivery and set reminders. Figure 8 showed the to-do's interface of the web-based system. The interface helps to keep track of other materials not indicated in the project activities with dates and keep track of other activities that needs to be performed in relation to planning and control of construction materials. In addition, project managers can indicate the need to reach out to construction materials suppliers. The web app has a calendar which has been integrated to the platform. Figure 9 shows the construction project management calendar. Project activities are displayed on the calendar.

People and permission: This section helps the administrator to be able to give access to back end login users such as client and head office personnel and also the level of accessibility in terms of what data can be seen and adjusted. Figure 10 showed the people and

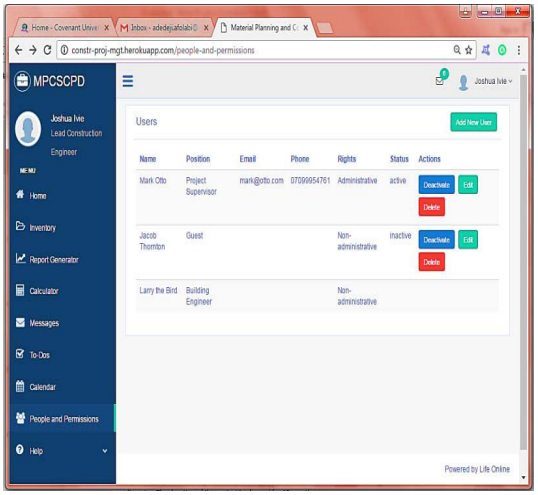

Fig. 10: People and permission interface of the web-based system

permission interface of the web-based system. The administrator registers the back end users with their emails and names so that they can access the project they have been assigned through the login page on a web browser via. the internet.

CONCLUSION

Programming and the internet is taking over human activities including the way of life. A web based material planning and control tool would help to integrate the use of internet with a material planning and control technique ensuring that decision making is done quicker in a fast paced world. Making a material planning and control system web based ensures that information regarding building materials can be accessed anywhere in the world. Also, it helps protect the data, ensuring that it is not lost when the hardware is damaged or due to virus attack. The construction industry must adapt to this changing trend of using web based applications to solve some critical construction related activities. The study revealed that using a web-based system assessed via. the internet can help store building materials data thereby reducing the paper-based system of planning and controlling construction materials. The system been environmentally-friendly helps to reduce waste during construction by ensuring the right calculation of quantities needed and delivery at the right time. In addition, the web-based system reduces the need for stockpiling which would have unnecessarily put pressure on the depletion and over-exploitation of natural resources.

RECOMMENDATION

The study recommended the high use of the internet to achieve an environment-friendly system in managing the crucial nature of construction materials and processes in the construction industry.

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