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Characteristics of a Web-Based Integrated Material Planning and Control System for Construction Project Delivery

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Abstract. For over 40 years that information and communication technology has been integrated in the construction industry, the adoption and use of the internet has been relatively low and slow. The use of the internet for the Nigerian construction industry has been mainly used for communication rather than for many other things the platform has to offer. The purpose of this study is to examine the characteristics of a web-based integrated material planning and control system for construction project delivery. The study used case diagrams and a MVC model in designing the platform for the web-based system. The study revealed that using a web-based system can have the characteristics of ensuring good inventory, good retrieval system, notifications and prompting system and a third party viewing for good over-sight of construction projects. The study recommended more innovative use of the internet for solving many challenges confronting the construction industry.

Keywords: Characteristics · Internet · Material planning and control · Project delivery · Web-based

1 Introduction

A global phenomenon among many construction business have been on how to preserve and ensure their competitiveness. This means that construction firms have to avoid extra cost which can lead to huge losses for the firm [1]. In meeting these goals, construction firms must look at maximizing the use of two (2) critical entities; construction materials and information and communication technology (ICT).

Materials are vital in the activities of any industry since unavailability of materials can impede production. It is worthy to note that unavailability of materials is not the only phase that can cause problems. Over-stocking excessive quantities of materials could also make serious problems to managers. In that, storage of materials can raise the costs of production and the overall cost of any project. [2] opined that stockpiling time of materials cause extended tied down capital that would otherwise have been better invested, requiring extensive storage facilities and space. Therefore, construction firms should focus on construction materials by lowering the total costs in supply chain,

shorten throughput times, drastically reduce inventories, expanding product choice, provide more reliable delivery dates and better customer service, improve quality, and efficiently coordinate global demand, supply, and production [3].

In order to attain this competitive edge, [4] suggested that construction professionals should adopt the use of information and communication technology (ICT). According to [5], 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. However, [4, 6, 7] noted that the traditional construction methods used in the Nigerian construction industry 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. In this dynamic and changing environment, [7–9] encouraged that there is a need to make use of more computer-based systems to improve material management on construction sites.

Traditional material processes done on a paper-based system have many associated drawbacks: low accuracy, time consumption, labor consumption, loss of data, aiding corruption, high theft and high uncertainty [9]. These are some of the ugly sides of the construction industry which this research intends to address. With over 60% of construction professionals connected to the internet [4], Nigeria is yet to massively deploy computer based production and inventory systems compared with other developed economies of the highly industrialized nations [10]. This study intends to examine the characteristics of a web-based system used for planning and control of construction materials for achieving construction project delivery of time, quality and cost.

1.1 Material Planning and Control

In order to plan and control a successful construction project, the three parameters of time, cost and quality should be considered [11]. [1] argued that in the analysis of the construction process an equilibrium must be established among the three primary concerns of time, cost and quality. [12] stated that these factors are like three points of a triangle and that neglecting one factor will have a corresponding detrimental effect upon the other two. [13] noted that there has been universal criticism of the failure of the construction industry to deliver projects in a timely way. According to [11], clients have been increasingly concerned with the overall profitability of projects and the accountability of projects generally. Cost overruns, in association with project delays, are frequently identified as one of the principal factors leading to the high cost of construction [14]. When the three components of time, quality and cost are successfully integrated, the project will begin to realize significant, measurable and observable improvements in the attainment of the clients' objectives [11]. This integration can be made possible through an effective and efficient planning and control system made available in crucial activities of the construction project.

An important aspect of material management that takes place on building construction sites is material planning. Planning is said to be the formalization of what is intended to happen at some time in the future. Although, a plan does not guarantee that an event will actually happen, therefore the need for controls to help cope with the changes that may occur. Materials planning in a construction process involves the process of

quantifying, ordering and scheduling of materials. [15] added that material planning process is incomplete until a proper record is setup and maintained while determining target inventory levels and delivery frequency. Fundamentally, a critical purpose of materials planning is to procure the materials for the dates when they are needed. [5, 16] stated that two crucial things lacking in material planning on construction sites are that construction professionals hardly keep proper records and most construction sites experience material delay. [17] argued that material planning is all about achieving the objectives of the organization such as quality (what is needed), time (when it would be available), cost (how much), location (where it is needed). These activities must be fulfilled in order to ensure that the material planning process is comprehensive.

An effective material planning system cannot be achieved unless there are controls put in place. Material controlling makes adjustments which allows the construction operation to achieve the objectives that the plan has set. Controls is on a short term basis, addressing the resource constraints that may occur par time. With cost of material alone in the building construction project been put at 55 to 65% [18, 19] suggested that an optimum material control on site should be adopted in order to reduce the cost of construction projects.

The construction sector is reported to be generating unacceptable levels of material and manpower waste and it basically due to the lack of effective material control systems on construction sites. All estimators allow wastage factors in pricing a bill of quantities. But, experience has shown that unless site management control of material is tight, wastage can frequently exceed, often by a large margin, than the figure allowed in the tender document. Planning and control is concerned with managing the ongoing activities of the operation so as to satisfy customer demand.

1.2 Web-Based Technologies

Many sectors have enjoyed the use of ICT and web-based systems in the management of its resources, which has helped to keep up-to-date records on the status of every inventory in stock [5]. Previous works on computer or web-based material planning and control systems have been focused on the manufacturing sector [5, 20, 21]. Some ICT integrated material management system include electronic mail (e-mail) and electronic commerce including electronic invoicing, payments and receipt of materials process [22], Construction Materials Planning System, CMPS [23], Material Handling Equipment Selection Advisor, MHESA [24], Construction Materials Exchange, COME [25], Barcode system - for material storage application [26], and most commonly used Microsoft Excel and Lotus 1-2-3 [27]. According to [28], ICT integrated material management would strongly ease unnecessary loss of materials, increase efficiency and productivity, higher customer service levels, better space utilization, employee satisfaction, integrated supply chain, ensure availability and quality of materials, ensure the right time and place of material delivery, reduction of errors and rework and reduction of time overrun and material waste.

A web-based material planning system is defined as a computer-based information system connected to the internet designed to keep inventory, control, estimate and keeps track of availability of materials to be used on a construction site at any particular period

of time. A construction research firm; Daratech, estimated that anywhere from 5 to 10% of a construction project's cost can be saved by using Web-based technologies [2]. 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. A large use of the internet integrated into the organizational system is the introduction of the Enterprise Resource Planning (ERP) [3, 29]. For the manufacturing sector, [20] designed a web-based material requirement planning integrated application that exploits distributed object technology to develop an enterprise application, integrating material requirement planning (MRP) with job shop simulator. [30] developed a web-based and automated method to assign and track project progress, provide periodic SMS alert to the project managers as well as generate periodic report on project implementation.

Every aspect of the construction process has the possibility of been integrated on a platform with vast potentials such as the internet. Its peculiarity as identified by [31] in that the internet is a form of central medium that allows information to be stored and exchanged in a single place accessible to all parties involved in a project.

2 Methodology

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. 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 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.

3   Characteristics of a Web-Based Integrated MPCS

The characteristics of the 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 1 showed the screen shot of the login page.
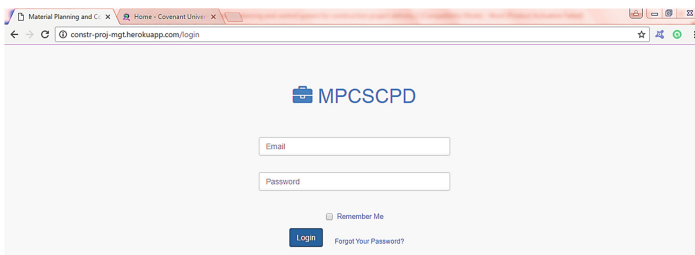

Fig. 1. Login page of the web-based material planning and control system.

Home. The home page provides an overview of the whole application as well as a navigation point to key areas in the system. You are provided: a summary of the latest

projects, a list of upcoming activities, sent/received messages, to-dos etc. It is a dashboard where other interfaces could be accessed (Fig. 2).
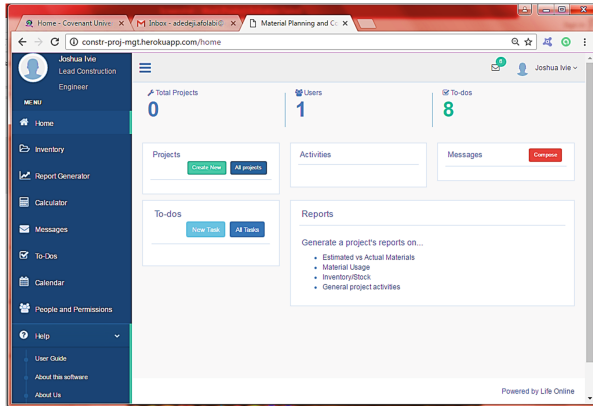

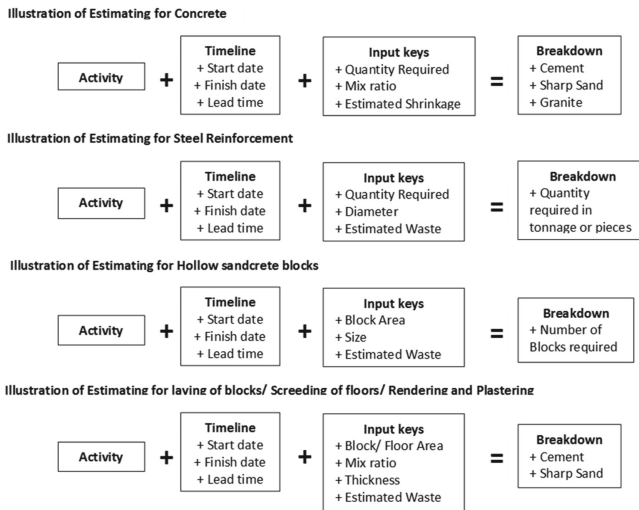**Fig. 2.** Home page of the web-based material planning and control system.

Fig. 3. Breakdown parameters for estimating quantities of materials in the system

Projects. From the home page, you can view available projects by clicking the 'all projects' 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 projects' 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). 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 mm, 150 mm 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 3 showed the case diagram of the relationship between the type and the input keys of the selected construction materials. From this illustration, the required quantities of each selected material is calculated and planned for.
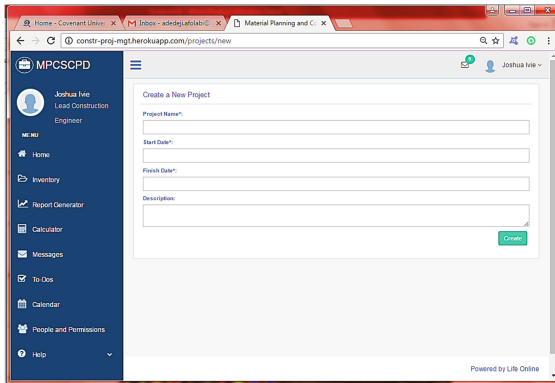

Fig. 4. Project page of the web-based system

Inventory. The inventory interface has three (3) main characters; 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 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.

Report Generator. The report generator produces various reports which give one a cohesive summary of a project and helps in decision making. 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.

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 5 showed the 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.
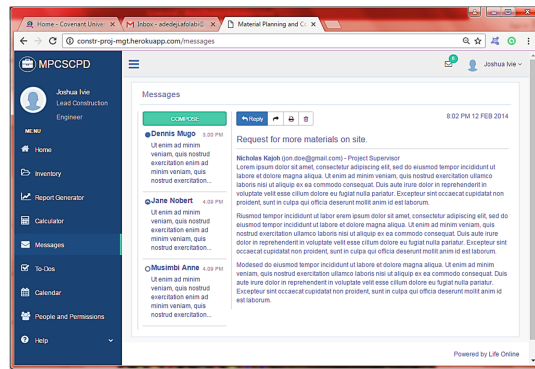

Fig. 5. Messaging platform on the web-based material planning and control system

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 & delivery and set reminders. 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. Project activities are displayed on the calendar as shown in Fig. 6.
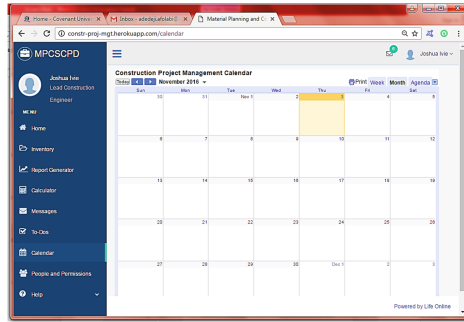
Fig. 6. Construction project management calendar

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. 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 as shown in Fig. 7. This is an advantage for making the system web-based, whereby, the web app can be accessed from any location by approved individuals. This platform ensures a proper monitoring system of the plans and control of construction materials by the project manager.
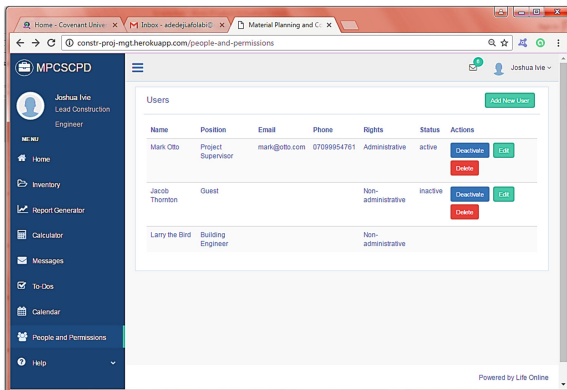

Fig. 7. People and permission interface of the web-based system

4   Conclusion and Recommendation

The characteristics of a web-based integrated system indicated that it can be accessed anywhere, giving a bird eye view of the planning process via the internet. The system involves a real time estimation where construction materials' details from different projects can be tracked, stored, retrieved and archived for future purposes. The system has up-to-date inventory system and a report generator to aid decision making and

comparison. The character of a messaging platform integrated with the user's email ensures that the user is prompted adequately on shortfalls and clarifications from the head office and other approved users. 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.

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