www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-7, Issue-2, March-April 2017

International Journal of Engineering and Management Research

Page Number: 359-364

A Model for Automated Material Management

K.Soumya Vijaykumar[1], Linu.T.Kuriakose[2]
[1]Scholar, Department of Civil Engineering, TIST, Ernakulam, INDIA
[2]Assistant Professor, Department of Civil Engineering, TIST, Ernakulam, INDIA

ABSTRACT

Building materials are one of the most important resources to be managed in any construction project. Hence, the goal of material management is to ensure that the correct quality and quantity of materials are procured in an effective manner, obtained at a reasonable cost, and available when needed. From the studies related to the relevance of this concept and the factors influencing it, with the help of field studies, surveys and reviewing literatures, it was found that utilisation of computer aided technologies lack in this field. Thus, the motive of the study was to develop a sample web application model for real time automated data collection for material management and control, which aims to be executed in the construction sites on a larger scale. The highlighting features of the tool are: cost effectiveness, simple and user friendly nature, better material tracking etc. Also, it is developed incorporating some of the basic and important concepts of material management. The model development is carried out in .NET framework, thus moving forth to the final stage of concept realisation. Elaborate literature survey and field studies are also carried out to perform detailed analyses on automation technologies.

Keywords— resource, material management, automation, material tracking, procurement, web application

I. INTRODUCTION

Construction materials are very much crucial as far as any construction project is concerned. Generally, they constitute about 50-60% of the total project cost and about 80% of the project management [1]. Material management has got its relevance as to minimize wastage of material, shortage of material, damage of material, lack of storage space, and delay in supply.

Material management is a scientific technique, concerned with planning, organizing and control of flow of materials, from their initial purchase to utilization. It contains mainly 4 phases i.e. planning, procurement, logistic and inventory [2].

The functions of Material Management may be listed as :

(i) Primary Functions :

- Materials Requirements Planning (MRP)
- Purchasing
- Inventory Planning and Control
- Ascertaining and Maintaining the Flow and Supply of Materials
- Quality Control of Materials
- Departmental Efficiency

(ii) Secondary Functions :

- Standardisation and Simplification
- Make and Buy Decisions
- Coding and Classification of Materials, ***Forecasting, Planning***

Having the potential of being one of the core areas in the entire course of construction management, it was chosen to be the field for this study, keeping the aim of introducing some innovative add-ons to the same. Surveying the literature depicted many instances and case studies of the drawbacks in the current practices of material management in the construction industries. As a result, incorporating Automation into the field of managing materials became the primary objective. Field studies were carried out to ascertain the same, as well as to get acquainted with the real site practices with respect to Material Management.

II. RELEVANCE

Researchers have continuously identified that efficient management of materials can result in substantial savings in project costs [3,4]. According to R. Navon and O. Berkovich, a computer integrated material management system can help in data collection, data organization, analysis and presentation to support real-time decision making[5]. The literature reports attempts to automate material management using automated data collection (ADC) technologies. The recommended technologies included Barcode, RFID, GPS and Handheld Computers.

All of the above have the potential to reduce manual involvement in the process, but they mostly relate to certain segments of the entire process. Thus this study describes the development of an automated model for the management and control of materials ordering, purchasing, supply and use.

Ahuja et al. (1994) describes the criteria for a software system in general as follows[6]:

- Relatively easy to install and operate.
- The input data must be easy to prepare, and the output reports must be understandable
- Data sorting
- A fully tested system and should have a proven record
- The program should be flexible and have capacity for handling many types of applications
- The database must contain all the necessary elements so it can be managed to generate the desired information reports
- The program should be compatible with other programs and systems in use in the company
- The system must be economical in terms of installation, operation, and maintenance

Salah Uddin. K.M. et al. (2015) dealt with inventory systems modelling and simulation to analysis the inventory cost of single item inventory in Bangladesh, by conducting a stochastic simulation and experimental study for reducing inventory cost and optimizing service levels in distribution of inventory. The research came into a conclusion that a real inventory system can fully be captured through a computer simulation [7]. Mathew. J. Liberatore et al. (2001) focused on future research and the use of project management software in the construction industry by drawing data from an empirical study of project management professionals. It was found that the number of activities in a typical project and the use of software for all active projects were the key determinants of the usage of specific analytical techniques. To maximize the impact on practice, development of new planning and control methods need to be integrated into project management software [8].

Mahdi Safa et al. (2014) defined and developed an integrated construction materials management (ICMM) model by deploying principles of virtual inventory management, feasible materials management networks, and a supplier selection process. The use of the supplier selection process was demonstrated through implementation on an industrial project and using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This process optimized and validated purchasing at each stage of fabrication for each construction package [9].

Automation increases the productivity of the construction project, reduces the duration and laborious work, and increases the construction safety, increases the quality of work as compared to manual work [10].

Due to its wide range of applications, there is a huge scope for incorporating Automation in monitoring as well as controlling of materials in construction sites.

All the studies carried out so far focus upon implementing automated tools in different facets of construction project management like supply chain management, etc. But they have not focussed solely upon managing materials real time at the construction sites, for their procurement, storage and dispatch. Reviewing through the market condition with respect to the availability of automated tools for project management, all of them come at a very high price, making their utilisation not feasible for the local builders and contractors. Thus it can be concluded that an automated tool for the management of material lacks in the field, especially one which would be really simple to use and cost effective.

A properly implemented material management system can lead to better control over material flow, more predictable project outcomes, reduced costs, improved productivity and quality to the whole of construction. A simple, user friendly and cost effective software thus developed can be useful for the construction companies, basically the small scale ones, for their managerial purposes.

III. OBJECTIVES

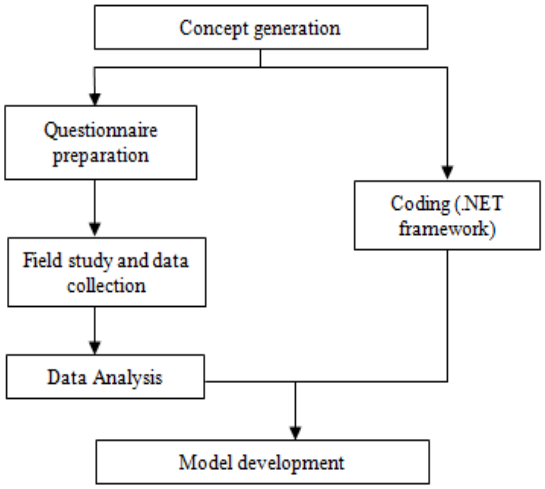
The study in this paper is carried out in order to satisfy the following goals:

- To identify the relevance of automation in construction project management, especially in the control and management of materials
- To develop a sample web application model based on automation in material management and control, which would be simple and cost effective, incorporating material management concepts and other features with the help of field studies

IV. METHODOLOGY

The workflow of the model application to be developed, was to be formed as the start of model development. As the logic is formulated, the application may be developed by using any of the coding packages. Meanwhile, questionnaires are to be prepared for intensive field studies, deriving out the factors from the literatures. Detailed analyses has to be carried out thereafter. From the field studies and comparisons with the field requirements, suitable changes can be made to the model.

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962



V. CURRENT APPROACH

The study was carried out in different phases. Formulating the flowchart for the workflow of the model, coding was carried out to develop the application. The programming was done using the .NET framework with SQL as the back end, thus developing the intended web application model. Questionnaire was also prepared to aid for the field surveys to be conducted simultaneously.

Based on the findings from the literature and field studies conducted prior the commencement of this study, an integrative model for materials purchasing, supply and use, as well as the control and monitoring of the entire process, was planned to be developed. The basic outline of the same was ruled out first.

The model has to deal with materials purchasing, their delivery to the site, and their dispensing for use in the building.

- The database should contain tables such as 'Materials', 'Inventory', 'Planned usage', 'Suppliers'.
  - 'Material table' will contain each material and its associated details
  - 'Inventory table' contains every material that has been procured, with the quantity and shipment date
  - 'Planned usage' contains all the associated materials required as per the plan, along with the quantity and the date to be despatched
  - 'Suppliers' contains the details of all the suppliers associated with each material
- Creates a Purchase Order (PO) by fetching the requisited materials and the corresponding quantity from the materials table of the database
- Sends the PO to the supplier
- Supplier has then to confirm the PO
- If supplier doesn't confirm, the PO within the required date, then trigger alerts that the supply is not in accordance with the order.
- If the supplier confirms PO, payment needs to be done to the supplier
- When the material is delivered, then:
  - The details of the shipment need to be fed to the inventory table of the database
  - Compare the materials and their quantity to the planned material and quantity
  - Trigger alerts if there are any mismatch with the details of the materials and the quantity
- If a material has been despatched for use, then:
  - The material and the quantity after despatch have to be updated in the database
  - The despatch has to be in accordance to the 'planned usage'.

The model should record historical data regarding suppliers, incoming materials and actual quantities. All problems with the suppliers, such as late supply, or deviations in quantities or quality should be logged in the historical database. The person in-charge of material ordering, say the Project Manager, may consult this database before issuing a new PO. Automatic recognition of data needed to be another feature: once a material is selected using its particular identity, the rest of the relevant data should be retrieved from the database and filled in the form. The database should be developed in such a way as to be built only once. These principles were formulated so as to form a basic guideline during the actual development of the tool.

The algorithm for software development is presented as a process workflow in figure 1:

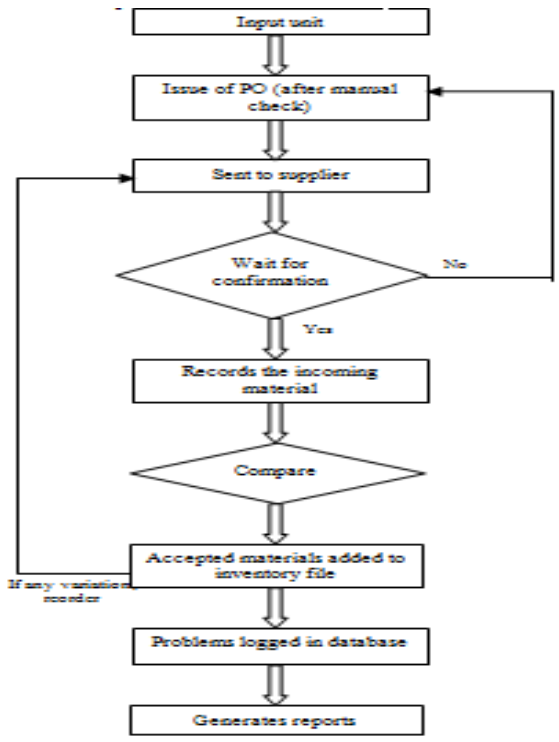


Figure 1: The workflow of the model

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

VI. DESIGN

The program is designed in such a way that the model web application developed may be accessed by the person in-charge of materials or project manager and suppliers. Each of these participants or users, has access to their respective modules. These two modules are further divided into various sub-modules viz., categories, items, suppliers, purchase orders, deliveries, inventories, works and payments. The user (admin) can log in with specific id and password and access these modules from the home page.

Provisions for admin are:

- Categories and sub-categories of materials can be added
- Specific items under each can be added along with descriptions and other details like minimum stock, unit, unit price, etc. There is also a provision to upload the image of the item to get displayed.
- In the 'suppliers' module, new suppliers can be added for each material. The distinctive feature in here is that, suppliers can be put with activated or deactivated status, with respect to their performance or any other criteria.
- Purchase orders can be sent for an item quickly as all the information with respect to that material will be automatically filled up in the respective fields, along with an option to select the supplier from the suitable ones. The quantity to be ordered is calculated manually with reference to the site conditions and work requirements, on the basis of the Just-In-Time (JIT) concept of material requirement planning.
- Once the purchase order gets approved or confirmed by the supplier, payment can be done, thus ensuring delivery.
- Once material is delivered, the same can be added to the inventory table, thus automatically updating the stock available. Material despatch can also be done, which in turn updates the available stock correspondingly. Also once the material gets delivered, the supplier can be rated on the basis of their performance, to aid for establishing future communication with them.
- Materials used with respect to each work can also be updated, along with schedule updation within the module itself.
- Payment records can be viewed. This information might be useful for the accounts section.

Provisions for user (supplier):

- The supplier can log in with the specific id and password provided to him by the admin
- Once logged in, can access different sub-modules, similar to the admin
- The supplier can view the purchase order sent to him. He can accept or reject the order and the corresponding response will be sent to the project manager.
- Payments obtained can also be viewed along with the delivery history.

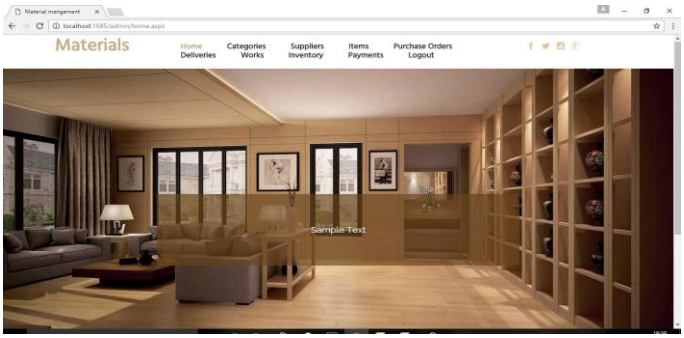


Figure 2: The home page

The access to the different modules are obtained from the home page once logged in (figure 2).

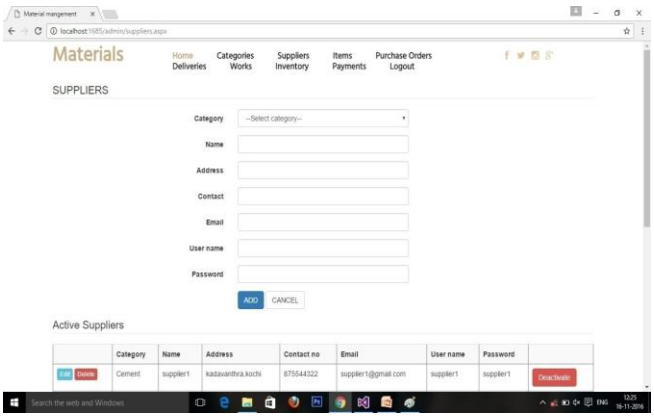


Figure 3: Suppliers' module

Facility to activate or deactivate the suppliers' status, on accordance with their performance or other criteria is also provided (figure 3).

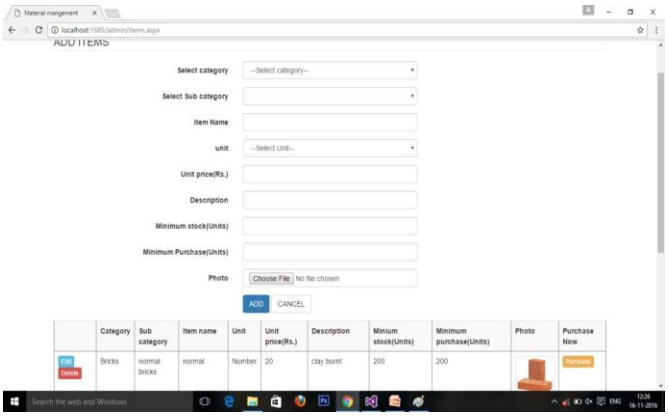


Figure 4: Adding individual items

In the 'Items' category, details of individual

materials under each category and its sub-categories can be input, which includes the item name, description, unit, unit price, minimum stock, etc along with images (if any).

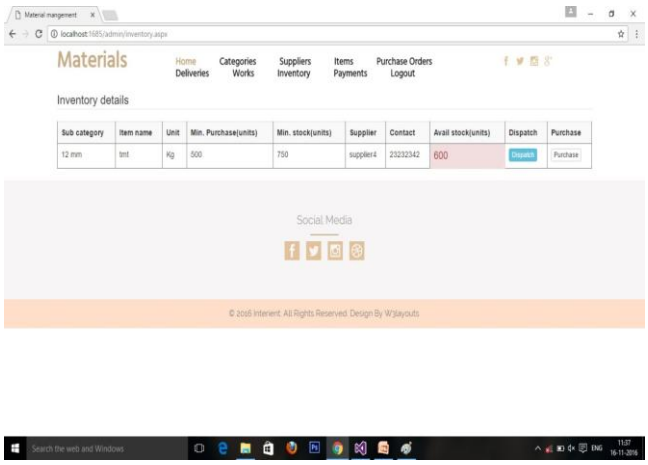


Figure 5: Inventory details

The updated stocks are added to the project inventory. Materials can be despatched as per the site requirement or the materials of low stock can be purchased within the 'Inventory' module. Stocks less than minimum stock level will be highlighted in order to aid in immediate purchase. Similarly, suppliers can also log in to view the POs received, and other details like payment details, etc.

VII. FIELD STUDIES

Field studies were carried out in the form of questionnaire survey in order to aid as a market study for the developed application model as well as to gain information about role of automation in project management.

The questionnaire consisted of different sections for the respondents to fill in. The factors considered were of two aspects: one dealing with the problems leading to the necessity of an automated system for materials and the next dealing with benefits of any automated material management software if developed. This section consisted of questions to be answered on a Likert scale, with five ratings.

Questionnaire survey was conducted and 51 respondents actively participated in it from the 100 builders approached. The builders undertaking residential projects alone were considered, from various parts of Kerala.

Detailed analyses were carried out to check the reliability of the questionnaire as well as to rank the factors according to their Relative Importance Index (RII). The value of Chronbach's alpha for the reliability analysis was found to be 0.78 (>0.70) which is an acceptable value. The RII values were obtained as follows:

TABLE I
RII VALUES OF MM PROBLEMS

SNo	Problems which may lead to the necessity of an automated system for MM	RII
1	Unavailability of materials	0.54
2	Variation in material qty ordered and delivered	0.725
3	Late material delivery to site	0.65
4	Improper supplier response	0.745
5	Delivery of incorrect materials	0.64
6	Unnecessary piling up of stock	0.7
7	Carelessness in placing material PO	0.805
8	Increased material wastage in sites	0.52
9	Incorrect material qty estimation to place order	0.67

TABLE II
RII VALUES OF BENEFITS OF AUTOMATED SYSTEM

SNo	Benefits of any automated MM software if developed	RII
1	Reducing the overall costs on project materials	0.58
2	Better handling of materials	0.795
3	Reducing duplication of materials orders	0.825
4	Timely availability of materials on site in the right qty	0.7
5	Improving labour productivity	0.385
6	Complying to time schedule	0.55
7	Enhancement of quality control	0.535
8	Improve follow up and monitoring of construction materials	0.77
9	Better relationship with suppliers	0.64
10	Waste reduction	0.41
11	Reduce space for materials on site	0.55
12	Obtain better price for materials	0.53
13	Help contractor to win better chance for tender	0.445
14	Effective, efficient and systematic control over materials	0.77
15	Reduce material transportation costs	0.425
16	Better use of computerized technologies	0.775
17	Considerable contribution in profit	0.575

The factors (the problems in procuring materials) which fall the most important were found to be: Carelessness in placing material PO on time, improper supplier response and Variation in material quantity ordered and delivered. These problems can be solved with

the help of the developed application model. Variation in material ordered and delivered can also be monitored via inspections and frequent updations to the model.

With the usage of this particular application, an effective, efficient and systematic control over materials can be obtained. Other distinct benefits in managerial level being: improved follow up and monitoring of construction materials and better supplier relationships.

VIII. CONCLUSION

The study examined material management practices on building construction sites. It described a study identifying the key material management techniques that reflect current and emerging practices in the construction project industry. A simple software application was developed for aiding in automatically controlling and managing materials. Some of the outstanding features of the model may include: provision for generation of payment and other reports on materials in printable format, supplier rating and management according to their performance, etc. The same is expected to eradicate the major drawbacks of the manual material management practices in the current industry. Even though automation has got demerits of its own, its advantages overwrite them.

Further developments and enhancements on technical and performance features of the tool may be developed like inclusion of more project participants with varying visibility levels, inclusion of e-tender concept, etc. Further research may also be carried out to gain in-depth knowledge on the concept of automation.

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