

A WEB-BASED APPROACH FOR CONSTRUCTION MANAGEMENT INFORMATION SYSTEM

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ABSTRACT

Technical advancements in construction over the years have allowed us to build faster, safer and bigger. But the goal remains the same- completion of a quality product on time and within budget. To achieve this goal, the management needs to know the progress of the project in a timely and accurate manner. That is how the project progresses, where they are currently in comparison to the initially set plans, whether the deadlines are met, budgets are respected etc. Managing a major project is almost impossible without a comprehensive management plan and a functional Construction Management Information System (CMIS), which is dynamic in nature. The present paper aims to develop a system for the project personnel in construction projects to collaborate on Web to improve the management of the exchanged information. CMIS is a tool to help the project manager as the decision maker in the project site. This system will provide the information needed by project manager to execute his job. CMIS is based on database. The scope of this dissertation is to analyze and systemize the information needs of project personnel in Building Construction Department and apply CMIS to enhance the problem solving and information management abilities of construction site management personnel. The project planning and scheduling has been analysed using the commercial software package Primavera Project Planner. A web based approach has been chosen for CMIS implementation. This approach allows the user to access CMIS from anywhere with user name and password through the internet. It provides several user interfaces which are not new for the construction personnel. CMIS just transfers these user interfaces into an online system. Finally CMIS is applied to a live project, as a case study.

Keywords: Project Management, Planning and Scheduling, CMIS, Web Based.

INTRODUCTION

A project is a temporary endeavour undertaken to create a unique product or service. Resources, such as people and equipment, work to achieve this objective. Project Management has been a recognized profession since 1950s, but Project management work in some form has been going on as long as people have been doing complex work. When the Great Pyramids in Egypt were built, somebody somewhere was tracking resources, schedule, and the specifications for the final deliverable.

Project management has broken away from the tag of a management philosophy restricted to a few functional areas and has evolved to have an Enterprise Project Management System affecting every functional unit of the company. More and more companies are now considering project management as mandatory for the

survival of the firm. Projects are undertaken with different objectives in order to fulfill some requirement or to improve the performance of the system. The higher objective the project fulfills, the more critical it becomes.

1. Project Management and Management Information

There is a clear distinction between the management of the information for a project and the management of the project itself. The management of information is not project management, but project management requires efficient information management [Gurley and McManus, 1998].

2. Motivation for Present Study

The need for improved project communication is a widely documented issue in construction industry. To facilitate the management of project information and address project communication requirements, a number of IT tools have been used with the aim to maximize benefits and reduce

cost for the entire project. The key to project information management, though, consists of the information flows associated with intra-organizational communications [Laufer et al, 1997]. The Indian construction industry has been found lagging in implementation of proper information transfer and management system for many years. There are very few companies and organizations, which have a proper Construction Management Information System and are implementing it. In recent years, a great deal of research has been carried out all over the world into the creation of automated Management Information System tools that enable organizations to automate systems for progress reporting.

3. Objectives and Scope

The main objective of the paper is to introduce one prototype for online system to handle management information on construction projects in Building Construction Department (BCD) called Construction Management Information System (CMIS). A web site has been developed for CMIS implementation. The planning and scheduling phase of the project has been developed on Software Primavera Project Planner.

The reporting system will be capable of monitoring the schedule, cost and funding components in a dynamic user-friendly environment for multi-task decisions. Provisions are made in the user interface to review the project. Necessary reports are generated in the specified format. [Jack R. Meredith and Samuel J. Mantel Jr., 1989] Scope of work can be summarized as:

- Studying the existing framework of project planning and management information system.
- Defining the structure of a progress reporting system to reflect actual project status at any period.
- Selecting the appropriate project management software package to document project information including schedule and cost.
- Designing custom report formats.
- Collection of field data from actual projects.
- Recording the updated project data in the applications.
- Producing the final report based on the updated data.

The salient features of CMIS are as given under.

- Introduce database system for CMIS using Relational Database Management System (RDBMS).
- Introduce one web site to access CMIS. This Web site can be accessed via <http://cmisravish.in>.
- Build time schedule and bar chart of new project using software "Primavera".
- Introduce online time scheduling, bill of quantities system.
- Introduce online reports; daily progress report, monthly report, monthly project invoicing with comparison of planned and actual value, cumulative invoicing with S-curve.
- Introduce the online control and monitoring system such as Milestone Schedule, Resource (P&M) Schedule, Resource (Staff) Schedule, Direct Labour Schedule, Monthly SC Labour Schedule, Monthly Material Schedule, Monthly Special Agency Schedule, Monthly Direct Cost Schedule, Monthly Indirect Cost Schedule, Monthly Liquidity Forecast Schedule, Task Completion, Job Cost Report and project Performance Parameter.
- Introduce news feature as online notice board, calendar and weather forecast information for all construction project personnel.
- Introduce Hypertext Processor (PHP) as server side scripts and HTML, CSS and JavaScript as user side scripting to build Dynamic Hypertext Markup Language (DHTML) that will allow the user to interact with CMIS.

4. Overview of Management Information Problems

This section introduces and examines a number of issues central to management information problems and puts forward some key concepts essential for the assurance of quality and value in the development of construction management information system.

5. Information Management and Construction Projects

Several papers have pointed out the shortcomings of traditional tools to provide information for construction projects control. These tools have been cost and progress

reports comparing expended cost to the budget, and actual progress against scheduled activities, which evolve from accounting practices and planning techniques. These reports focus only on one aspect of the process, namely the end product - they rarely identify the cause of problem when the problem occurs. Further, present day projects are complex in nature due to the involvement of a large number of individuals, firms, and organizations, and above all more complex building systems [Zapalac R., Karen K., Malagon T. (January/February, 2003)]. Hence, information required from management systems has increased.

For contractor, the management of project information begins from the day when the decision is made to bid on a contract and continues until the closeout phase. The construction industry is information intensive. It needs accurate, reliable, and timely information regarding legal requirements, building codes and standards, manufacturer's specification, site-specific data, and past projects, etc [S. Rizki, 2003].

6. Data sources

In construction industry, data comes from numerous sources, including contract documents and agreements, project manuals, the master schedule, building codes, test data, survey reports, bid tabulation forms, estimates, cost records, quantity take-offs, value engineering studies, request for proposal, request for information, change orders, field reports, meeting minutes, RFI (Request For Information) logs, shop-drawing submittal logs, and so on [Shahid S, 1996].

7. Information Users and Routing of Information

The term "information users" refers to who needs the information, or to whom information is sent to. In this category the users are: individual managers, departments within the organization, other project participants, etc. Control information spans across functional disciplines; for example, materials will be dealt with by estimator, buyers, planners, site managers, and surveyors.

8. Information Generator

As mentioned earlier, a construction project involves a number of individuals, disciplines or departments within the

organization, and other participants. Each one is a generator of information within the scope of his responsibilities. [Hazem Elzarka 2001].

9. Construction Field Computing

Construction field computing is the use of handheld devices that augment the construction superintendent's ability to manage the operations on a construction site. These Information Appliances (IA) must be portable devices which can be carried by the user, and have computational and connectivity capacity to perform the tasks of communication management. Data entry and retrieval must be simple so that the user can manipulate the device while simultaneously moving, observing events, studying materials, checking quality, or performing other tasks required. Examples of these devices are the PDA, tablet PC and the smart phone [Smith L., Mills J. 2005].

10. Usage of Information Appliances in Construction

Their responsibilities cover a wide variety of tasks such as:

- Comparing planned to constructed conditions.
- Coordinating and scheduling events and material delivery.
- Monitoring jobsite conditions and correcting safety deficiencies, improving efficiency, and ensuring quality.
- Recording and documenting work progress, labor, inspections, compliance to specifications, etc.
- Communicating direction to speciality contractors, laborers, suppliers, etc.
- Clarifying plans and specifications, resolving differing conditions, adapting methods and materials to site-specific requirements.

These tasks require that information is readily accessible and easily communicated to others and the company database. Since construction sites are unique, the device and system must be adaptable and flexible. Durability, predictability, and perceived value by the field management will determine the system's acceptance and thus it will have a proper use [Hendrickson C., Tung Au, 1989].

11. General Structure of Proposed Model

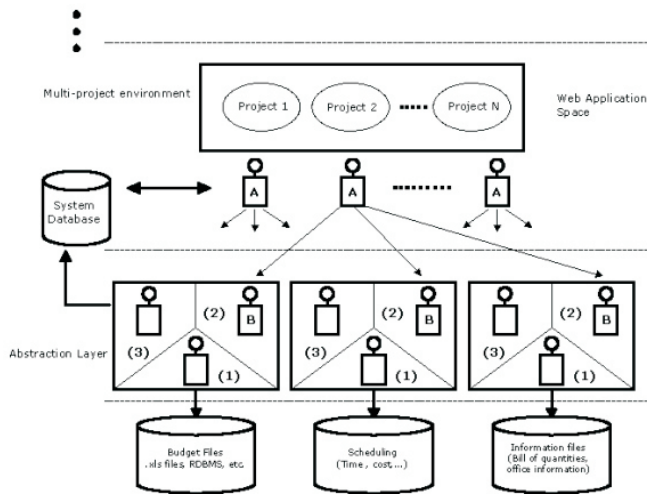


Figure 1. General Work Structure

In this model, the applications are integrated within the system through independent interfaces.

Each interface consists of three main functions:

- To mark the application's specific component that allows access to the application database.
- Provides the most important function of the interface in that it allows each application to be used independently as well as jointly.
- Saves the accessed and processed data on the system's database and also sends to the reporting system.

Online Construction Reporting System is designed to be easy to use, to have access to all data and analysis procedures. The menu driven approach was designed with the assumption that the user might not have a strong computer background. The user needs to have the capability to direct the flow of information towards a desired goal [Malcolm Murray and Angela, L., 2000].

In multiple project environments, shown in Figure 1, each project is displayed through different A-Type components. Each A-Type component is responsible for providing all information concerning the project it is linked with. For example, when the user wants to access budget information concerning a specific project, the related A-Type component communicates with the B-Type component it is linked to obtain the desired information from the relevant application's database. The application (or version of the application) containing budget data may

vary from one project to another. The system may therefore contain different information of B-Type components to accommodate such differences. A-Type components are functionally capable of utilizing as many different B-Type components as necessary in gathering the required data. In order to provide fast access to previously converted data, B-Type components save status information on the system's database. If the status information shows that the converted data is still current, this data can be rapidly accessed through the system's database without going through the conversion process. B-Type components perform a status control on the data requested by the A-Type component. Based on this information, A-Type components either attain the required data from the system database, or wait for the B-Type components to perform the necessary conversions in forwarding the required data. The main components of the Online Reporting System comprise the general information about the projects in both single and multi-project environments. [Dikbas, Yitmen and Morten, 2007].

12. Logic Flow

This will be basically divided into four different types of fields as

- Planned
- Actuals / Work Done
- Estimate To Complete (ETC)
- Revised Estimate

Planned start and finish dates are input at the start of the project (Table 2). Planned quantity, cost and rate are extracted from the Accepted Cost Estimate (ACE) prepared at the start of the project. These details are saved as baseline for future reference. These quantities are

Logic	Planned	ETC	Actual	Revised Estimate
Quantity	=ETC Qty (when Act. Qty. =0)	User input (Dynamic)	From Site Database	=ETC Qty. +Act. Qty.
Amount	=ETC Amt. (when Act. Amt. =0)	User input through resource allocation	From Site Database	=ETC Amt. +Act. Amt.
Rate	=Planned Amt. /Planned Qty.	=ETC Amt. / ETC Qty.	=Act. Amt. / Act. Qty.	=Rev. Est. Amt. / Rev. Est. Qty.

Table 1. Logic Definition to Compute Revised Estimate

Logic	Planned	ETC	Actual	Revised Estimate
Start Date	=ETC St. Date (when Act. St. is Nil)	User input (Dynamic)	From Site Database	=Earliest between ETC St. and Act. St. Date
Finish Date	= ETC St. Finish (when Act. Finish date is Nil)	Calculated based on the Duration Input given	User Input	=Latest between ETC finish and Act. Finish Date

Table 2. Table Definition to compute Activity Start & Finish Dates updated into planned invoicing schedule for client billing. Actual executed quantity details are extracted from the site database management system. Revised Estimate Quantity and Cost is the sum total of Actual + ETC (Table 1).

13. Database Concept

Programming Languages

1. HTML – Hypertext Markup Language, CSS-Cascading style sheet, JavaScript
2. PHP - Hypertext Processor
3. SQL – Structure Query Language

Hardware Required

1. Processor Pentium 100 Hz or above
2. Ethernet Card (for LAN)

Software Required

1. Windows 98 or above
2. Microsoft Internet Explorer 5.0 or Modem or above.

Figure 2 shows the Concept of Hybrid Database.

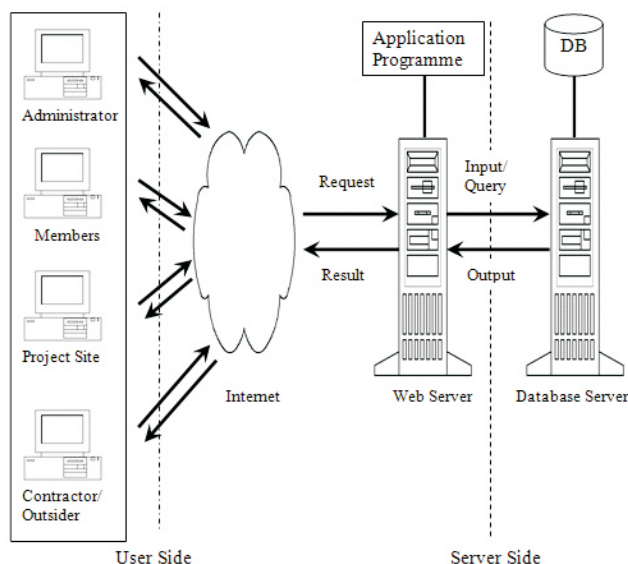


Figure 2. Concept of the Hybrid Database

14. Project Identified For Data Collection

A live project is identified for the development of the information system based on the literature search and field study on construction projects in BCD (Building Construction Department). The main project identified for data collection is Convention Center.

15. System Implementation in World Wide Web (WWW) Environment

The next step in the research involved is the implementation of information system in World Wide Web (WWW) Environment based on information, framework and methodology is adopted.

16. User Views

Based on information identification, 22 user views have been decided as user interface for gathering data from CMIS. These user views represent the views of the members of construction team.

16.1 Project Overview

User can get the information about all on-going projects in BCD with the user view. The information shown in the view are; overview of the project, the owner, location, number of activities, assistant engineer, junior engineer in charge, contractor, contractor's contact person, project start date, project finish date based on schedule, and type of calendar used for the project. This overview can also be shown to an unauthorized user who access this web site without password as shown in Figure 3.

16.2 Time Schedule

Time schedule view will show all the activities with their

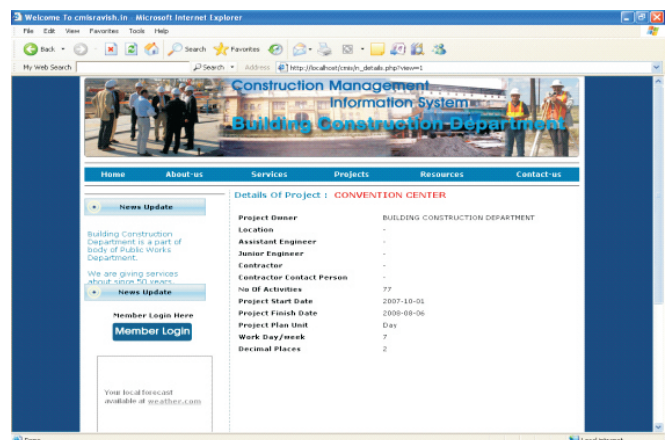


Figure 3. Details of new project user view

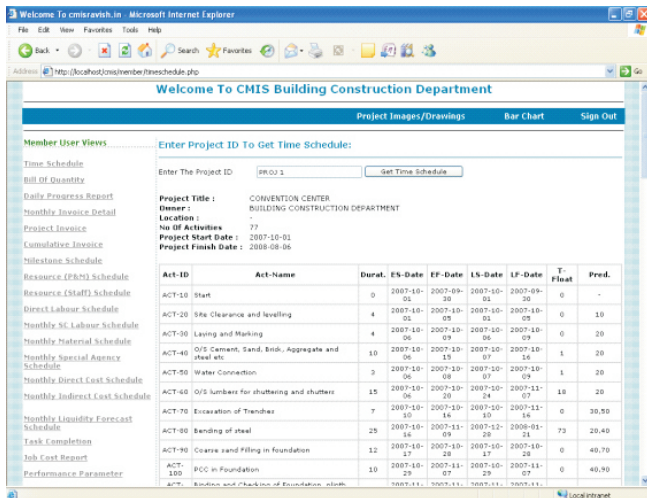


Figure 4. Project Time Schedule user View

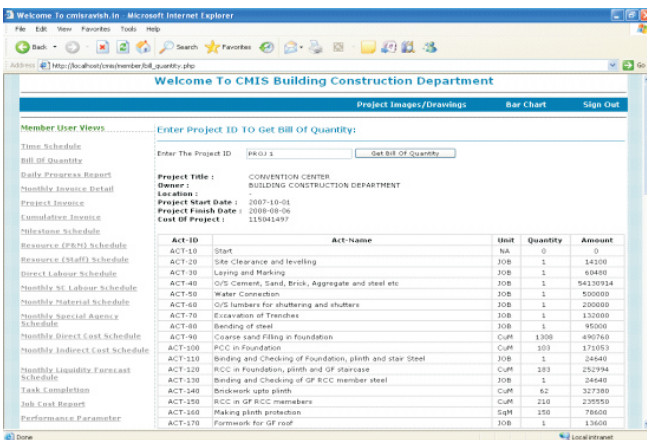


Figure 5. Project Bill of Quantity user View

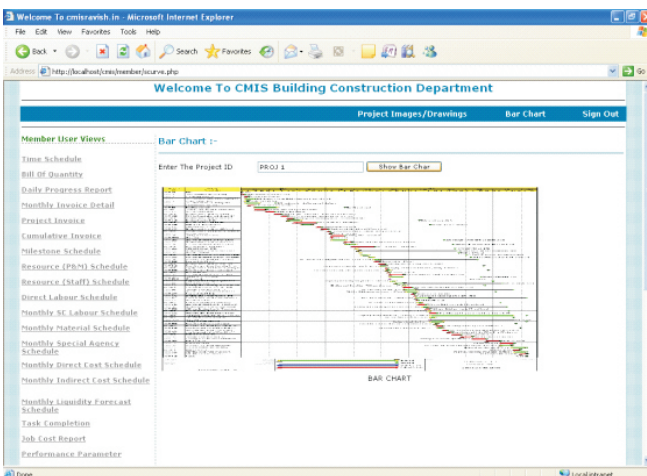


Figure 6. Bar Chart user View

activity ID, activity name, duration, early start date, early finish date, late start date, late finish date, total float and the precedence activity shown in Figure 4.

16.3 Bill of Quantity

Bill of quantity view will show the activity ID, activity name, unit of measurement, quantities and amount in rupees for each activity of construction as shown in Figure 5.

16.4 Bar Chart

Bar chart is a conventional and common tool that is used in the construction project, but it has powerful ability to know the progress of the each activity timely manner. The progress shown in the bar chart is the activity in a progress regarding activity scheduled and it will be available on user interface as shown in Figure 6.

16.5 Daily Progress Reporting

A customized form shown in Figure 7 is created so that, daily progress in terms of actual quantity finished is entered in respective field. In this user view, project base plan is updated in terms of cumulative work completed and also percentage of work completed.

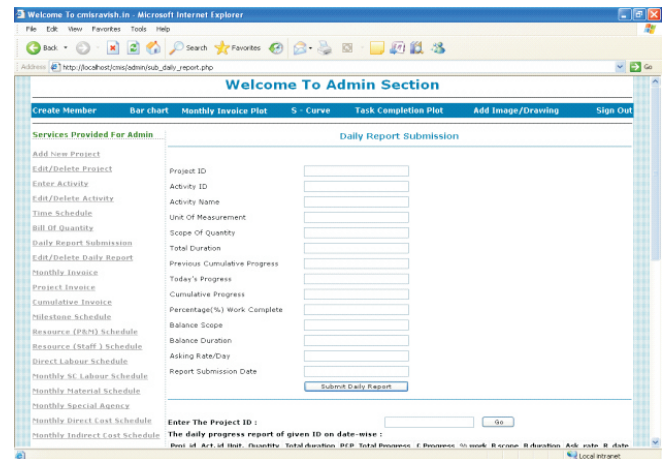


Figure 7. Daily Report Submission user View

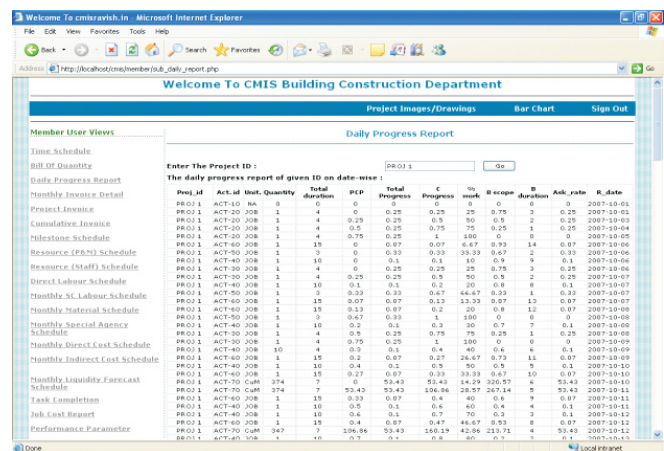


Figure 8. Daily Progress Report user View

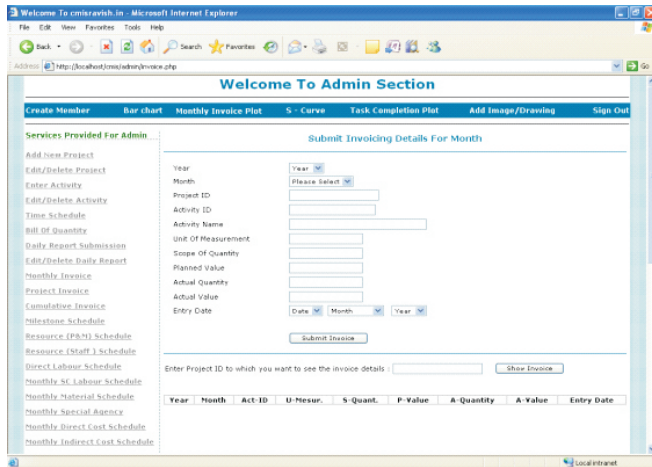


Figure 9. Monthly Invoice Submission user View

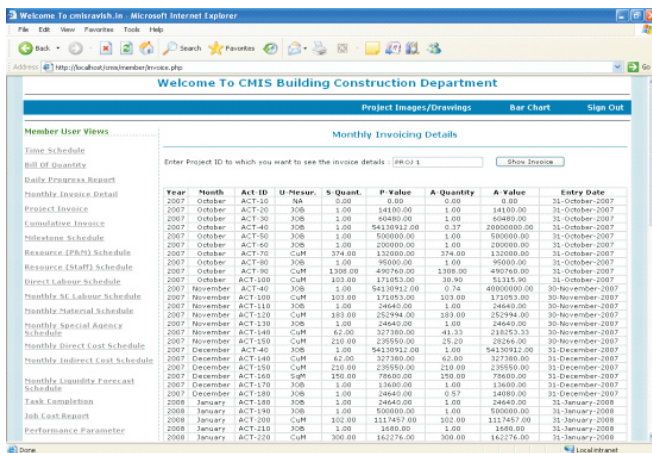


Figure 10. Monthly Invoice Detail user View

The actual scope quantity is obtained from ACE prepared at the start of the project. The form facilitates the user to visualize the required rate of work progress to achieve desired target. After daily report submission the date wise

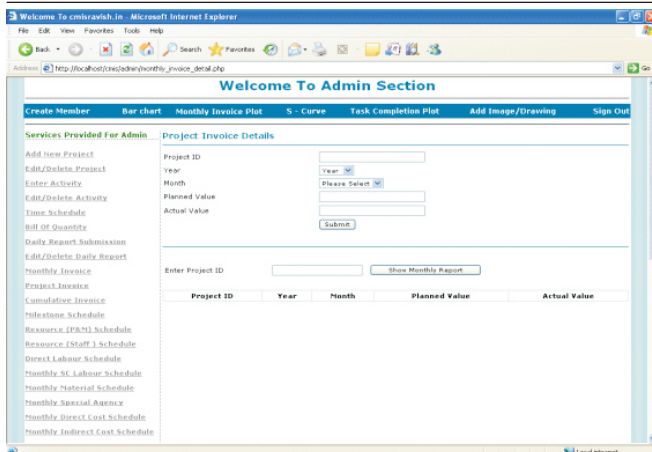


Figure 11. Project Invoice Submission user View

updated form will be as shown in Figure 8.

16.6 Invoicing Schedule

This user view allows the user to input monthly invoice details. It needs details of activity performed in that month; its unit of measurement, scope of quantity, planned value, actual quantity and actual value spend for the month. This user view is shown in Figure 9 and 10.

16.7 Project Invoice Detail and Plot

In this user view, user has to input monthly planned and actual cost in the user view to get the project invoice as shown in Figure 11. It will generate monthly comparative table between planned and actual cost with a plot among them. This user view is plotted separately in another form as shown in Figure 12.

16.8 Cumulative Project Invoice Detail and S-Curve

In this user view, user has to input cumulative monthly

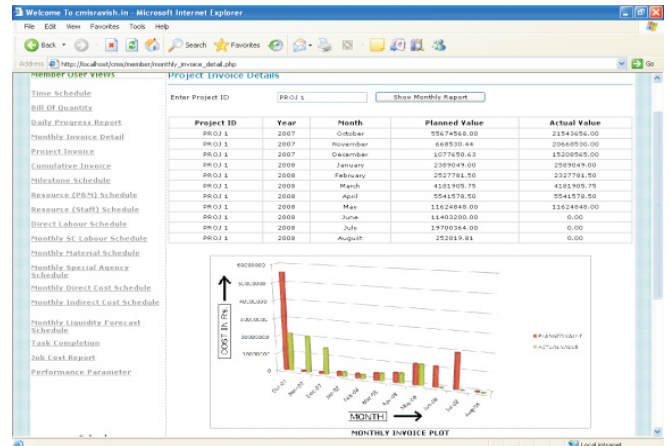


Figure 12. Project Invoice Detail and plot user View

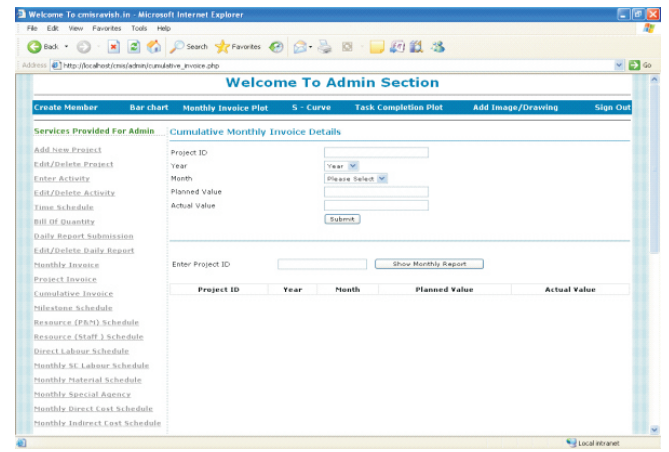


Figure 13. Cumulative Project Invoice Submission user View

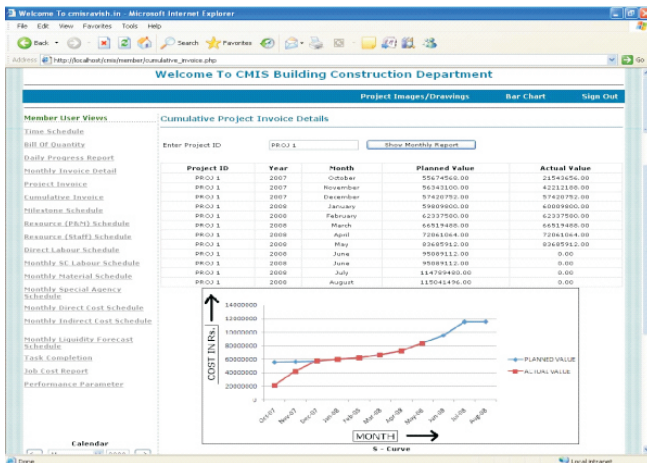


Figure 14. Cumulative Project Invoice with S-Curve user View

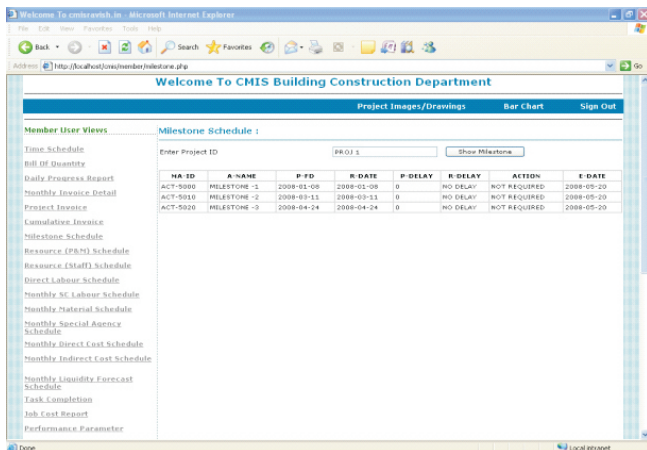


Figure 15:- Milestone Schedule user View

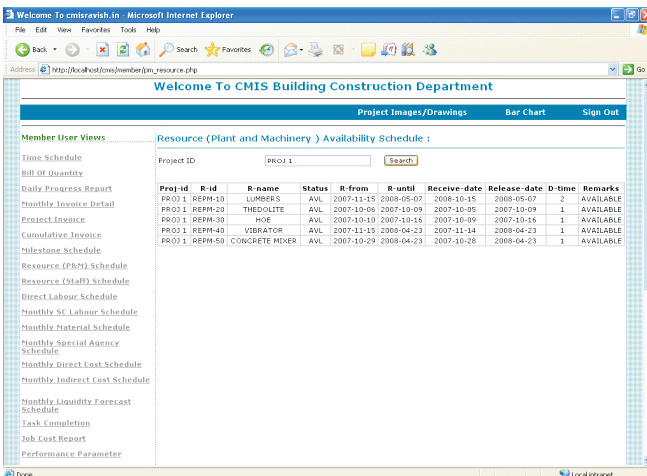


Figure 16. Resource (Plant and Machinery) Schedule user View

planned and actual cost in the user view as shown in Figure 13 to get the cumulative project invoice. It will generate cumulative monthly comparative table between planned

and actual cost with S-Curve. This S-Curve is shown in Figure 14.

16.9 Milestone Schedule

In the user view, user will be directed to user form for reviewing status of milestone events as shown in Figure 15.

16.10 Plant and Machinery Schedule

In this user view, user will be directed to user form for reviewing the availability status of plant and machinery available or required at the site as shown in Figure 16.

16.11 Staff Schedule

In this user view, user will be directed to user form for reviewing the availability and requirement status of staff at the site as shown in Figure 17.

16.12 Direct Labour Schedule

In this user view, user will be directed to the user form for

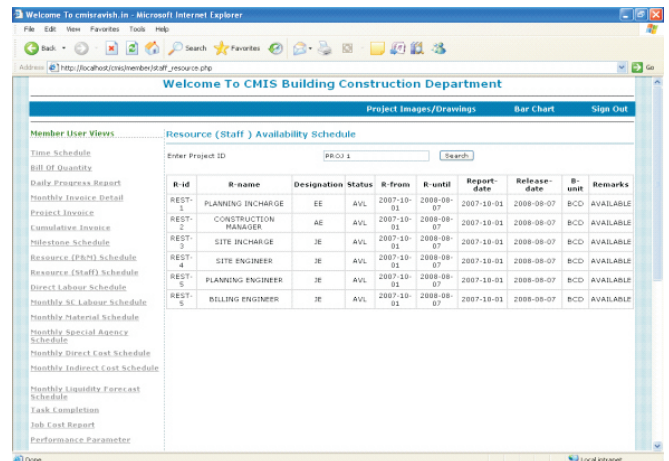


Figure 17. Resource (Staff) Schedule user View

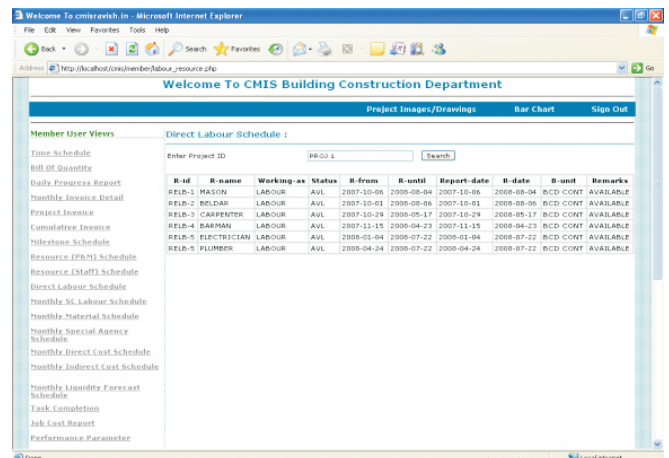


Figure 18. Direct labour Schedule user View

Figure 19. Subcontractor labour Schedule user View

reviewing the availability and requirement status of labor employed by the organization as shown in Figure 18.

16.13 Subcontractor Labour Schedule

In this user view, details of man hours in terms of planned, actual, ETC and revised required for each activity are extracted from the project database and also monthly details of planned and actual work are updated in the standard report format as shown in Figure 19.

16.14 Material Schedule

In this user view, details of quantity in terms of planned, actual, ETC and revised required for each activity are extracted from the project database and also monthly details of planned and actual quantities are updated in standard report format as shown in Figure 20.

16.15 Special Agencies Schedule

In this user view, details of quantity of work that has to be executed by specialized agencies in terms of planned,

Figure 20. Material Schedule user View

Figure 21. Special Agencies Schedule user View

Figure 22. Direct cost Schedule user View

actual, ETC and revised, required for each activity are extracted from the project database and also monthly details of planned and actual quantities are updated in standard report format as shown in Figure 21.

16.16 Direct Cost Schedule

In this user view, details of quantities and cost incurred for each activity based on resource consumption details in terms of planned, actual, ETC and revised, is extracted from the project database and also monthly details of planned and actual costs are updated in standard report format as shown in Figure 22.

16.17 Indirect Cost Schedule

In this user view, details of cost incurred for each overhead activity like rents, temporary structures etc in terms of planned, actual, ETC and revised, is extracted from the project database and also monthly details of planned and

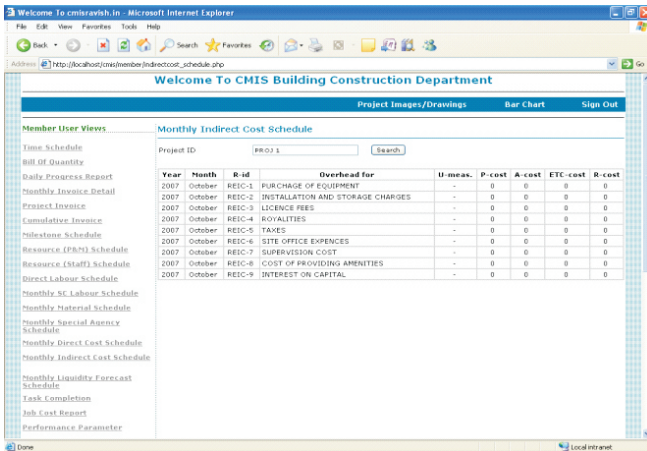


Figure 23. Indirect cost Schedule user View

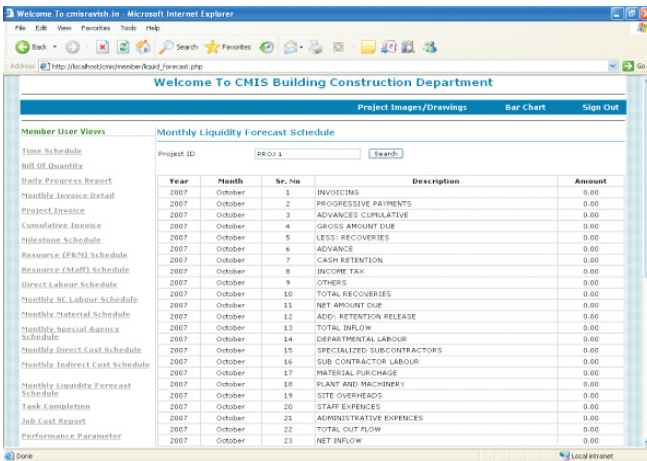


Figure 24. Liquidity Forecast Schedule user View

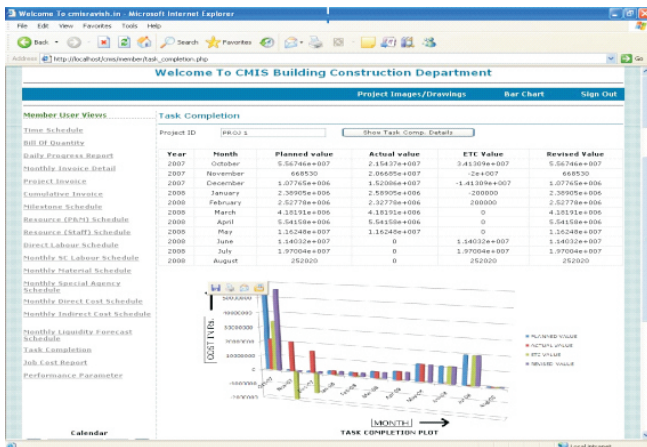


Figure 25. Task Completion user View

actual costs are updated in standard report format as shown in Figure 23.

16.18 Liquidity Forecast Schedule

In this user view, details of invoicing for that particular month

and activity cost details including overhead costs are exported to the reporting system and detailed cash flow computations have been done as shown in Figure 24.

16.19. Graphical Representation of Task Completion

This user view allows the user to generate monthly details of cost with graphical representation in terms of planned, actual, ETC, revised values as shown in Figure 25.

16.20 Job Cost Report

In this user view, cost incurred on the project till date is computed and ETC is prepared based on those figures. Other details of Job Cost Report include revised estimate, original estimate for revised quantities if there is any change in quantities. Also variance is found between revised estimate and the actual estimate for taking corrective action. Detailed Job Cost Report is shown in Figure 26.

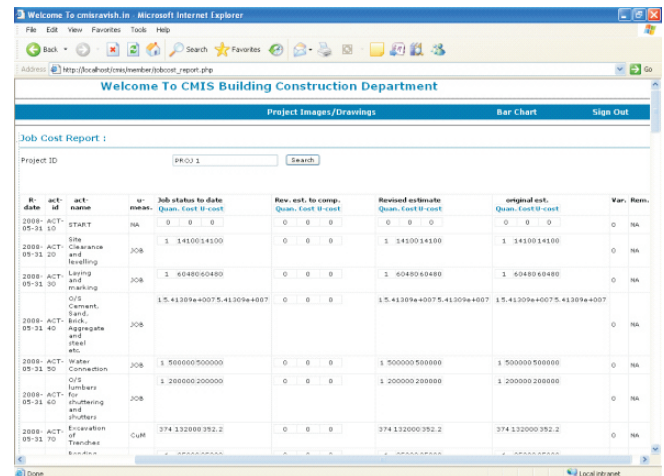


Figure 26. Job Cost Report user View

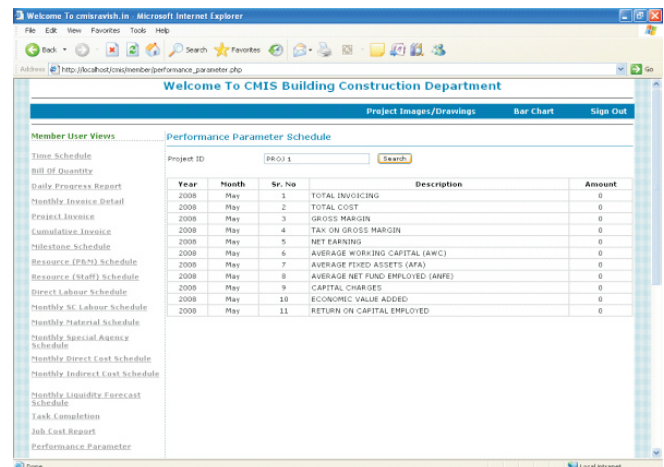


Figure 27. Performance Parameter user View

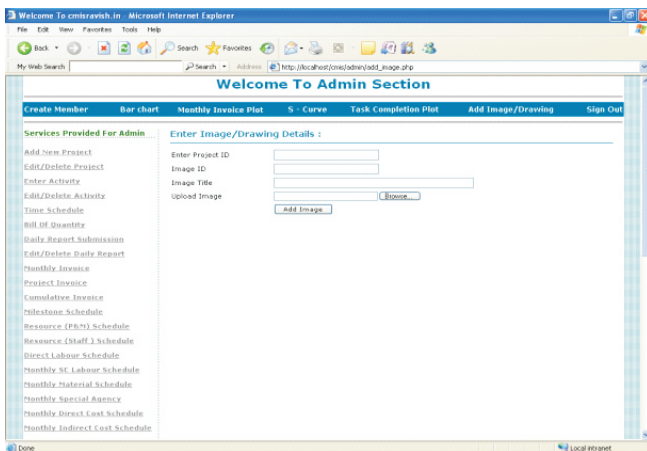


Figure 28. Project Image/Drawing upload user View

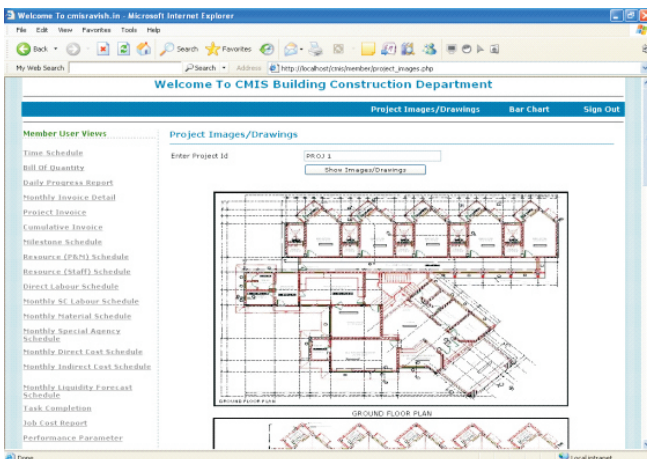


Figure 29. Project Image/Drawing user View

16.21 Project Performance Report

In this user view as shown in Figure 27, the report consisting project parameters are computed. This report narrates the performance of the project for that particular month. Invoice details and cost details are exported from the project template and the details of advances and retention money are extracted from site database.

16.22 Project Image and Drawing

This user view gives the information about the drawings, details and progress of work in visual form. All these information available in the user view are in image form. The project image and drawing upload user view is shown in Figure 28 and project image and drawing user view is shown in Figure 29.

17. Benefits and limitations of CMIS application

The benefits of CMIS application are as follows:

- Easy availability of internet facilities in the construction industry helps the applications of CMIS.
- CMIS needs no special training for any construction personnel. So, one can easily utilize this system. Moreover, with the availability of internet in the construction industry, the online system is easy to handle by all the users.
- Tools introduced in CMIS are not difficult. A person who has experience in the construction industry can utilize these tools easily, since CMIS provides common tool like bar chart and S-curve.
- Since CMIS is a web based technology, it can be easily accessed from anywhere with unique user name and password.
- Besides the above, CMIS improves efficiency as under:-
 - Reducing response time
 - Coordination between construction personnel and executive
 - Improves execution due to active involvement and faster decision making by concerned personnel in a project.

The limitations of CMIS application are as follows:

- CMIS is a comprehensive project management system, which is useful for user's construction personnel. This cannot be used by contractors.
- CMIS adds on to existing facilities, but it still requires hard copy of all data as backup.
- Data for scheduling, report formats etc should be updated manually.

18. The future development of CMIS

- CMIS is an owner oriented system. Presently, it cannot be used by contractor. So, this system can be further extended for the need of contractors.
- Presently, Primavera Project Planner package has been used for planning and scheduling. However, these packages are generally standalone version and not easy for web based applications. Hence, it requires further development for, CMIS to incorporate the automatic generation of planning and scheduling.

- In addition, reporting parameters like Earned Value Analysis, Safety and Quality Monitoring etc can also be included to make the reporting structure complete.
- Besides the above, 'What' if Simulation Reporting, Risk Analysis Module can also be incorporated in the present module to increase its efficiency.

Conclusion

- A prototype for CMIS has been developed for construction project environment in Building Construction Department as a tool to control all construction projects.
- Although, the prototype developed has simple functions, it is capable to handle small and medium construction projects. It uses simple and common tools for project controlling like bar chart and S-curve.
- There is a need for an administrator, who can handle the system, update, modify data and hence coordinate between construction personnel and CMIS. So that this CMIS can be a single window solution to complex building construction projects.

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