

WEB-BASED INTEGRATED PROJECT CONTROLS SYSTEM

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Abstract –

The early detection of overruns in construction industry is essential for effective project management. Inefficient and wasteful project reporting systems contribute in project failure as it deprives project management team from taking immediate corrective actions. Reporting and dashboard tools allow multiple data source extraction and processing, which facilitate producing integrated web-based visualized report in near-real-time to be available for project parties. This paper presents a web-based platform that supports real estate developers through integrating cost data with visualized progress information. The platform development tool is ORACLE Business Intelligence Enterprise (BIE). A specially designed relational database was developed to store progress and cost data and to produce the visualized progress layout using mapping techniques and dashboard design. Cost data is imported from a customized cost reporting system with a distinct database. The developed platform creates a practical integration between cost reporting and facilitates data reporting in visualized and graphical representation. The platform has been tested and applied to actual case study to demonstrate and verify its ease of use and capabilities. The case study project is a residential community composed of villas, building and supporting infrastructure works in addition to community building in the Kingdom of Saudi Arabia with 53,800 m² land area and a 39,526 m² built up area. The developed model supports project controls more thoroughly to make better business decision.

Keywords –

Web-based reporting, integrated reporting, cost reporting, project control and ORACLE Business Intelligence.

1 Introduction

Project managers could utilize earned value management methodologies the most as it keeps them up-to-date with the early indicators and progress of a project's execution plans and alerts them to take corrective action when needed [17]. Many research studies have been dedicated to this area to enhance and to show its capabilities [3] [8]. Early finding of actual or

forecast cost overrun in the field of construction projects is vital to assist project managers [6]. It supports and gives the opportunity to develop remedial actions and rises the chance of controlling such issues or lessening their overall impacts on the project. Hence cost overruns reduce revenues of projects, it is very clear to understand why both project managers and project executives are sensitive to any data deviations. This necessitates the need of project manager's ability to plan, implement, and sustain an efficient and comprehensive methodology for progress monitoring to promptly recognize, process and communicate variations between actual and planned performances as early as possible [5] [6]. The main challenge for project managers and project controls managers alike is the essential desire to combine and integrate the information gathered and maintained by these various entities within the organization [10] [11] [16]. Project controls usually pursue to integrate variant tools and applications together so that they can get reliable information across those tools and applications. One main method in which this characteristic of effective project controls process may be achieved is through integrated reporting systems. Recording systems are a significant concept for integrated reporting module which means that all information distributed in the form of reports or interactive dashboards need to be reconciled to a single information's source [1].

Cost data is mainly the criteria which most companies evaluate the success or inadequacy of their project controls techniques. Project financial information has many unique features which aren't limited to simple budgeted amount presentation but also, the desire to track much more discreet information. This information is regularly contained within the system of record but this data should be addressed in the overall reporting of projects [9] [12]. Currently, most of organizations have a financial system of record is often a large Enterprise Resource Planning (ERP) application such as SAP or ORACLE. Integration of information from these systems of record involves that the required information to be exchanged easily between of these unique systems. ORACLE BIE applications include Extract Transform Load (ETL) routines to extract, transform, and load data into the ORACLE Business Analytics Ware-house. It connects to multiple data sources such as ORACLE DB & Exadata, QL Server,

DB/2, Teradata Essbase, ORACLE OLAP and MSAS and Integral part of ORACLE Fusion Middleware [13], [14] [15].

The developed model facilitates cost reporting based on Cost Break-down Structure (CBS) or Work Break-down Structure (WBS) hierarchy. Additionally, it visualizes the imported progress from scheduling tools to progress curves and bar charts. Colored progress layouts are used as a major part of the system to show the progress of each project component in a different color matching with its progress. The developed model facilitates data reporting in visualized and graphical representation. The developed model is very flexible to modification of data presentation and manipulation method and can show any data extracted from the supporting systems. Stakeholders can take immediate corrective actions based on the web based system output. A warehouse database is specially designed to gather information from scheduling and cost tools to produce the required visualized web based reports.

2 Proposed Methodology

The reporting system is developed to provide project stakeholders with integrated project reporting through logging in any internet browser. Cost information is provided to show budget of work and payments details and status. Visualization capabilities is a major consideration during developing the model consequently the model contains interactive mapping layouts which represents graphical representation for work progress based on color scheme. The web-based application is providing user with visualization capabilities through interactive dashboards. The dashboard allows user to draw interactive graphs and interactive progress layouts through transferring progress % to color schemes for any WBS/CBS level. The model allows users to understand tabularly, graphically, visually and textually the reporting information and project status in easy manner as soon as the data is updated in supporting systems.

The main steps of the proposed methodology are following the regular reporting steps, as shown in Figure 1. cost tool is used to develop the cost monitoring system and for following payments. Budget data is the baseline or the cost system and is used as the main guideline during project life cycle. Actual cost and payments incurred is gathered and stored in the cost system. After updating the system with the latest status, it stores all the cost information in cost tool database to be transferred to the ware-house database. Progress information will be imported directly to the databased through exporting it from the used scheduling tool. Integrated report is issued automatically after updating any data from cost, and importing the required data

from scheduling tool. Web-based application is utilized to issue the integrated report after collecting all information. The application should provide ease of usage in both creation and viewing project progress dashboards. The dashboard contains all imported data in addition to charts, curves and progress layouts through manipulating the imported information. Finally, the interactive dashboards and report are generated through the system and can be viewed by all users. Reports are saved inside the ware-house database to be used as a historical information for all project data to be used later if needed.

As shown in figure 2, First stage in developing the progress report is deciding which levels is going to be reported (EPS-WBS-activities) in addition to dashboard and report design that should consider Stakeholders requirements. Graphical representation of data is obtained through the report through progress status which is a bar chart showing planned and actual % while time status is a pie chart representing elapsed and remaining duration. Resource assignments which are exported from scheduling tool into ware-house database is utilized inside the reporting application to produce S-curve to show both cumulative and periodically planned and actual progress graphical presentation. The S curve is plotting work progress against time. Work progress may be expressed in terms of units of work, budget, man-hours, percent complete. It is a result of scheduling sequence and dates represented by units of work allocation through project period.

Budget data in the developed model is limited to budget at completion for the work which represents the cumulative value of budget cost work scheduled also the cumulative value of the performance measurement baseline MB. While the actual status of the project is reported through three numbers which are certified gross of work done, certified net amount and net paid to date. Certified gross to paid represents the amount that already certified without any deductions such as advance payment recovery and retention while the net certified amount represents the work amount after the contractual deductions. Net paid to date is the amount of money already spent to date. It is important to show both paid to date and net certified amount to show the variances between the two numbers which highlights any delayed amount due to any financial reason such as payments still not released by finance department or still under process. Cost reporting information is selected by project responsible to satisfy stakeholders requirement. The data is imported to all project and portfolios levels to be part of each level integrated report. The model could also be extended easily to include any cost data such as cost variance, cost performance index and estimate at completion, which enriches the process of cost reporting.

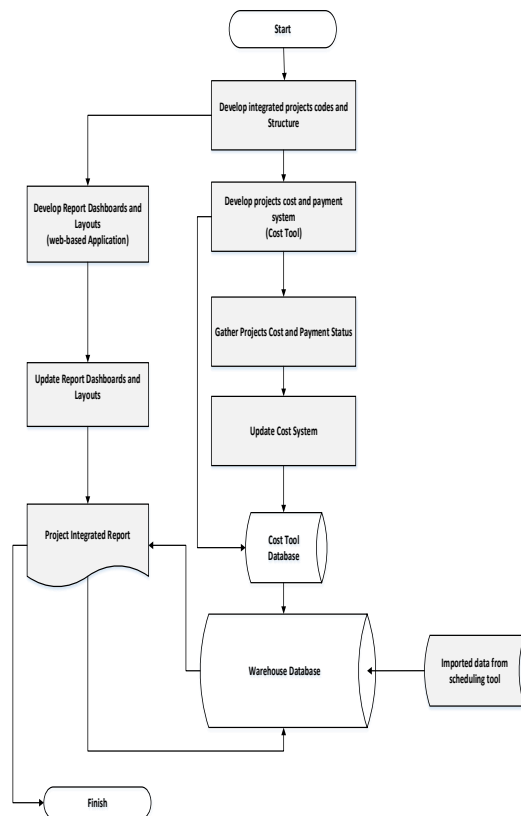


Figure 1- Proposed methodology

Progress Visualization is a requirement for reporting complex information for stakeholders in easy manner. Through colored progress status or highlighting a specific part of the project gives the report viewer the summarization of project status in a simple way. To prepare progress layouts, layers of progress should be defined which are matching with WBS and activities to ease the progress interpretation. Each layer has a specific code similar to the code used in scheduling tool. Programming logic is written to color the required components based on the imported progress from the scheduling tool. The color scheme is based on conditional formatting function to show similar progress percent in same color while lower in a different color to report progress %. Also, the selected WBS is highlighted in the overall project layout upon selection. Counting the WBS or activities based on their color gives the viewer overall progress status such as how many WBS started, completed or in progress beside the total number of WBS which contains a selected activity. As shown in figure 3, the coloring report is generated as a final step and stored inside the ware-house database to be used as a part integrated report. The used application for reporting should allow the mapping and presenting coloring schemes to be utilized in visual representation. Finally, the integrated report is saved in ware-house database after updating all reports to be kept for

recording purposes. Stakeholders can view report immediately and a customized notification is sent to them once an update occurs.

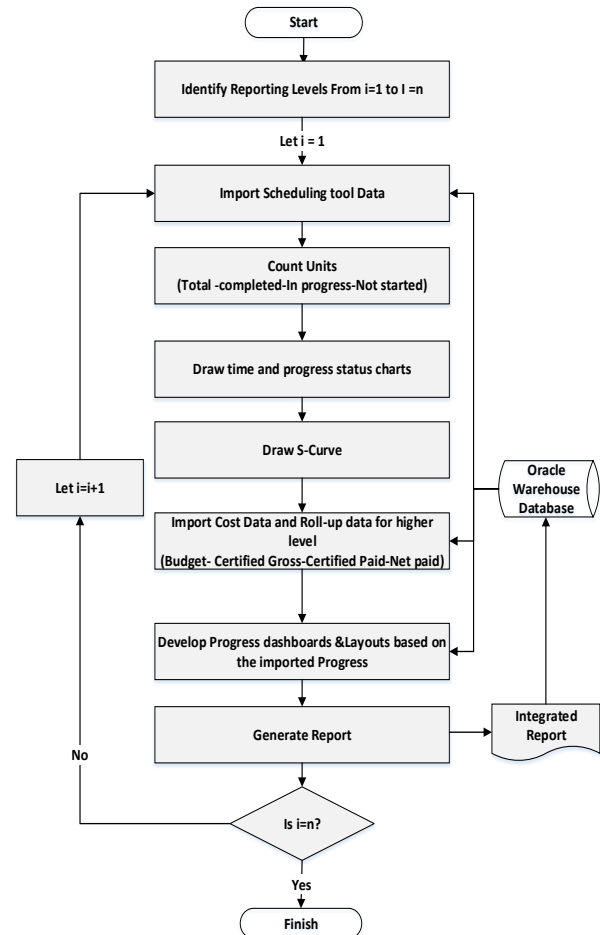


Figure 2- Report Development Process

Ware-house database is the central storage area for the reporting model. It is basically developed to integrate data from scheduling tool and cost tool to satisfy reporting requirements through providing requests to retrieve the information needed by reporting software beside being the main storage for reporting historical information. Activities ID along with their features (name, type, status, float, dates, duration, WBS, codes, etc.) are the main attributes which is exported from scheduling tool for the activity entity. The activity entity is the lowest level to measure project performance. WBS levels is the main source for reporting cost data beside scheduling and progress photos. Every WBS has a unique identifier based on its level on the project and type of work done to facilitate data transfer to the integrated report from other reporting tools. WBS has many attributes such as name, ID, dates, scheduled % and performance % which are imported from scheduling

tool while budget, certified gross value, certified net amount and paid to date is imported from scheduling tool. Each WBS has its reporting photos extracted from web-based photos software.

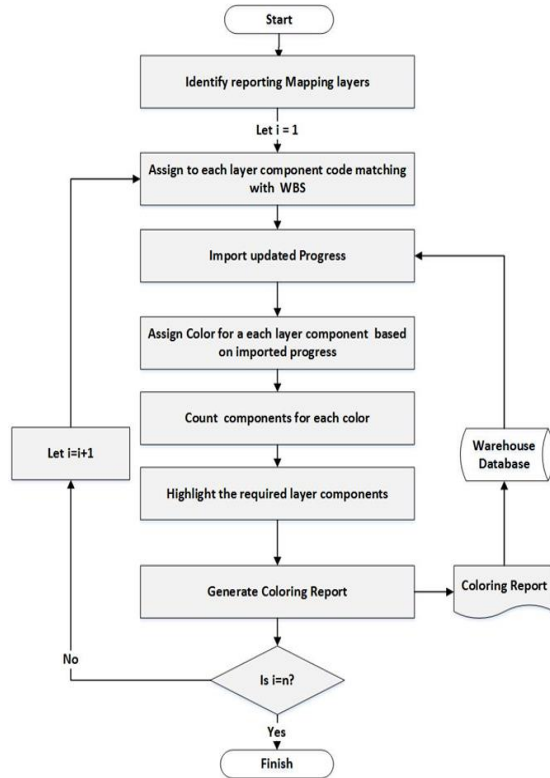


Figure 3- coloring layouts process

All imported attributes are presented in integrated way based on WBS ID matching. Activity spreadsheet and resources assignment are another entity that is extracted from scheduling tool to produce S-curves through manipulating the resources distribution for each period. It contains periodically and cumulative planned and actual activity resources assignments distribution. EPS is the highest level for reporting which divides the projects in portfolios and programs to summarize information to executive directors. Each tool has different tables for EPS, WBS, Activities to report the output for each level and the integration occurs inside the reporting module through requesting the data from the database based on the required reporting level and type of data required. Database retrieves the stored data based on the level ID which is unified for all tools. Portfolio, program, project, WBS and activities history entities is created inside the database to record all historical information for the reported data and to save the reports when created. Due to space limitation, the entity relationship diagram of the designed database will not be presented. Sample of relationship between entities are the relation (1:M) between WBS and

activities, EPS and WBS and WBS and photos while the relation M:N Between activity and resources and activity and activity codes.

3 Model Verification

The developed model is implemented in a web-based software, which has similar structure to the illustrated methodology model. In-House web-based cost reporting module has been used as a cost tool and it depend on ORACLE database which facilitates data transfer. A separate customized web-based application is developed to allow project reporting and viewing. Visualization and integration of reports data are a major advantage of the developed reporting module. The application main coding language is SQL (Structured Query Language) while the main development tool is ORACLE Business Intelligence Enterprise which is used to design reports and dashboards. It uses ORACLE data integrator to support Extract Load and Transform (E-LT) technology that improves performance and maintain data integration. It utilizes ORACLE warehouse database to store tabular data and for integration with cost and progress information to gather progress data. It is a central repository of integrated data from one or more disparate sources. It stores current and historical data and is used for creating report dashboards.

Three-tier standalone architecture was chosen for the developed software and other reporting systems as shown in figure 4. Tier one represents the presentation tier, which is mainly a web-based interface for the system. The user interacts with that interface through predesigned quires regarding project development and updates. There are two-way data flow between UI and event handler to get the required data and apply cost calculations. Tier two is cost logic where all cost algorithms and procedures in the data analysis and processing are implemented. Cost system uses ORACLE E-T-L tool built in the system to process data to processing tier to implement cost calculations and return it to user interface. Ware-house database is the main database for photos developed application to be stored and used during report generating. ORACLE Business Intelligence Enterprise Edition 11g(OBIEE) is the main system for developing the integrated report. It was chosen to be compatible with other used application in addition to mapping and reporting capabilities which produce interactive dashboards. User interface is the first tier of the system it allows user to select the required dashboard to be viewed through multi selection pane that enables him to filter report results. Reporting processing is the main logic for the application which resides in tier two that processing utilizes the stored data in the ware-house database to generate reports through data manipulation, filtration and graphical presentation.

Data integration process is another part of tier 2 which integrate data from cost database and transfer it to ware-house database to be processed during report generation. Ware-house databased stores all dispatched reports inside it to be used for recording purposes.

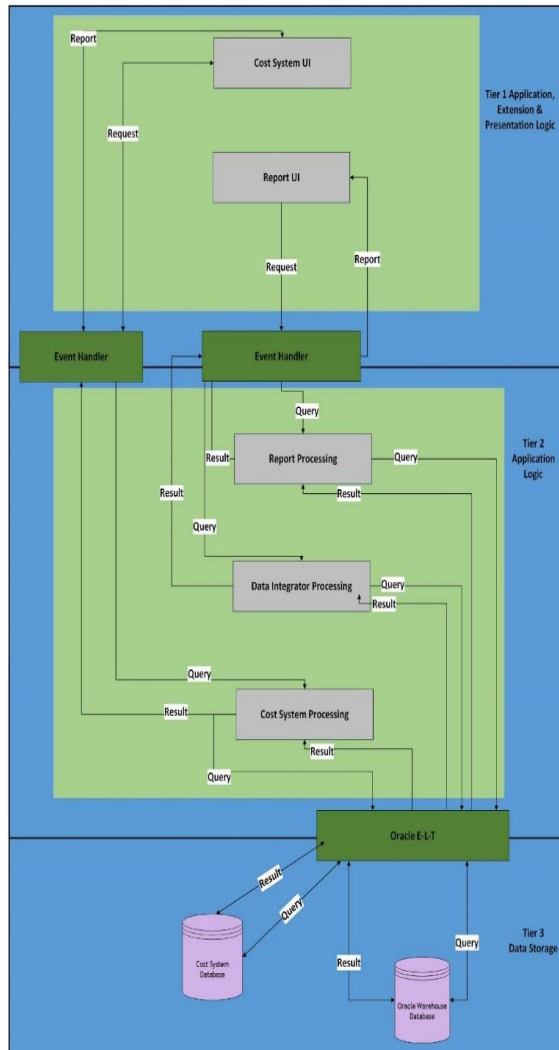


Figure 4- Reporting systems architecture

Use-case diagram is an illustration of a user's communication with the system. It describes the relationship between the user and the different users or systems. Figure 5 represents the use-case diagram for all the integrated components. There are four actors to generate the integrated report. First actor is cost engineer who is responsible for developing cost system, collecting cost updates and updating the system. Both planning engineers and cost engineers should use the same hierarchy during developing both systems beside developing the report and dashboard design which satisfies all stakeholders requirements. The concerned stakeholders, 2nd actor, including cost engineer are able

to log-in and view reporting system. The 3rd actor is the cost system which executes cost calculations to cost system in addition to importing all the data (planned, budget and Actual) to each system database. The last actor is the OBIEE which is the main reporting application which supports dashboard and report design, colored layouts based on visualized maps and support simple reporting calculations. Data is imported from ware-house database after manipulation and filtration to generate the integrated web-based report.

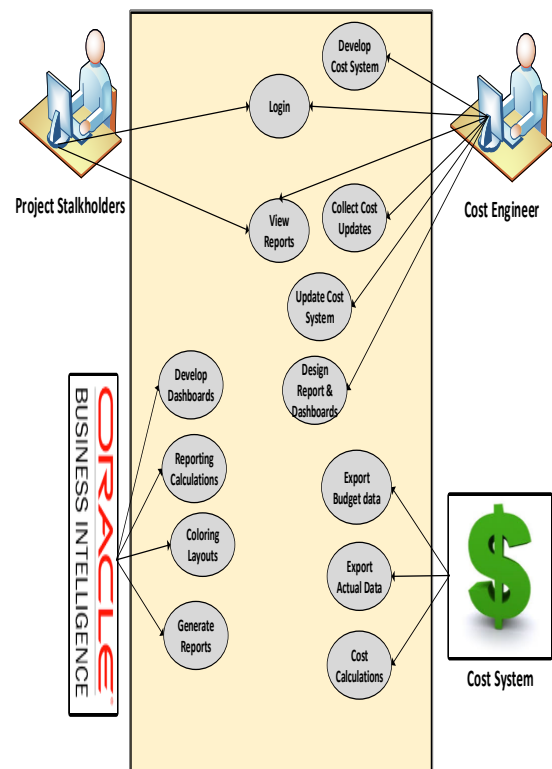


Figure 5- Use-Case diagram

The developed web-based system has been applied to real case study project to test and verify its capabilities. The project is LIMAS/ Jubail project at Alhamra district, Jubail City, Kingdom of Saudi Arabia. LIMAS project is a gated housing project (110 villa + 20 apartments) is being built on a 53,800 m² land area and a 39,526 m² built up area. The land is surrounded with plenty of houses and villas served with complete infrastructure as shown in Figure 6. The project is composed of four different types of villas type A, B, C, and type D, Amenities Building (recreation center) and infrastructure works. The project is composed of 26 villas type A with BUA=393 m²/ villa, 54 villa type B with BUA= 319 m²/ villa, 30 Villa type C with BUA= 266 m²/ villa ,1 building (20 apartments) with BUA= 2070 m² and recreation center with BUA=2032 m.



Figure 6- Project perspective

Cost process starts with developing CBS which should be matching with WBS levels. After budget decomposition and contractor creation. BOQ items were loaded in the system for each contract coded with its cost code based on cost hierarchy as shown in figure 7. For each item, description, unit of measurements quantity and rate were inserted while amount was calculated automatically inside the application. These parameters can be inserted manually or through exporting from excel or any other similar application. Allocation of all project budget is necessary in this stage to assure accuracy of cost report. Budget on the integrated report is extracted during this stage and stored in the ware-house database.

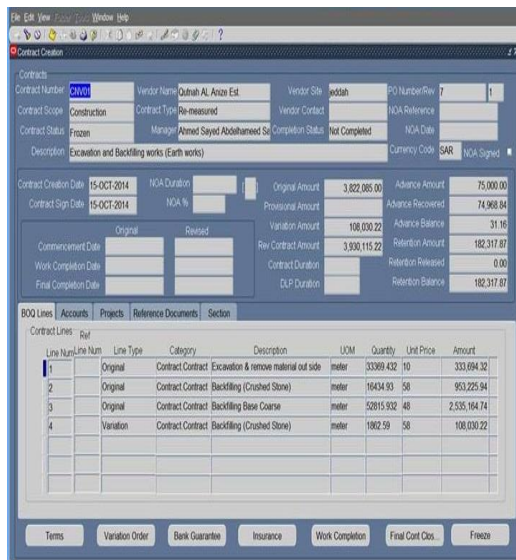


Figure 7- Contract Creation Process window

Regular updates for cost data occurs in case of any approved variation or change order. Figure 8 is illustrating the process of updating cost data based on

progress on site to issue payment certificates. Contractors submit progress per each BOQ item to consultant for review. After consultant review to check that the payment is matching with actual approved works on site, cost engineer update the system accordingly. Payment certificate are issued after approval form all concerned people as shown in figure 9. The payment certificate shows the gross value of work done and net amount of work done which are used as a part of the integrated report. payment issuance from finance department is part of the cost system. Based on finance approval and transferring amount to contractor's accounts, net paid amount is calculated inside the system and transferred to ware-house database for reporting purposes. ORACLE Cost systems contains many parameters and automated reports which are generated automatically inside the system upon sending queries.

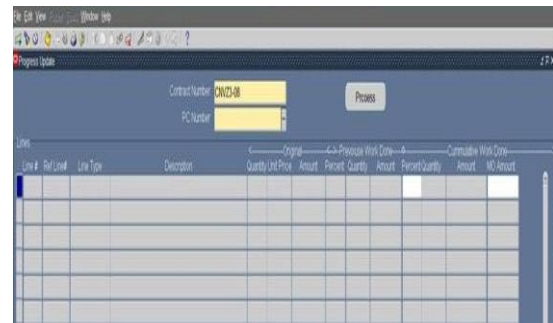


Figure 8- BOQ items Update Window

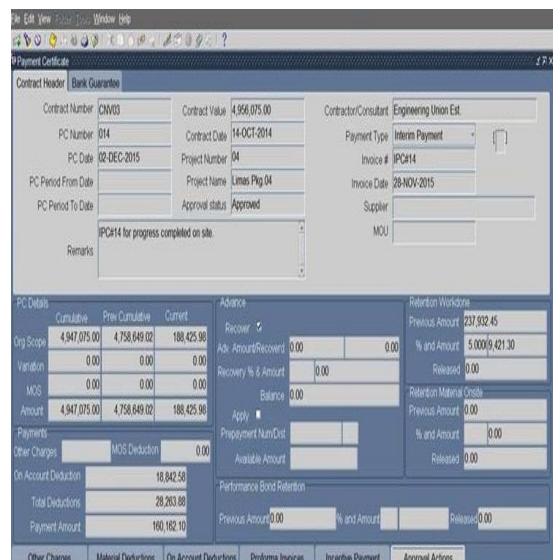


Figure 9- Payment Certificate Window

Dashboards design is the first stage for issuing the progress report. The executives have visualization

requirement to view the whole progress on colored layout based on units' progress for each activity and to highlight the selected area in the master plan based on selection. Master plan AutoCAD file was modified and layers were assigned to match with WBS hierarchy and conditional formatting was used to differentiate between unit's progress. Moreover, the selected part of reporting is shown in red color to add visualization effect to the report. Report dashboards were similar to the manual reporting which was reported before developing the new system. S-curves were created inside the reporting systems based on the extracted data from scheduling tool to simplify the numbers by using graphical presentations.

First dashboards were designed to show portfolio progress to assess the overall situation of company projects in summarized way. It contains map location of each project, progress status and time status charts for each project which were created using OBIEE capabilities and overall time and cost status for the projects as shown in figure 10. The second portfolio dashboard shows S-curve for contractors and projects based on multi selection pane to choose period, project or zone as shown in figure 11. This dashboard enables user to evaluate the overall situation of project or contractor during selected time period.

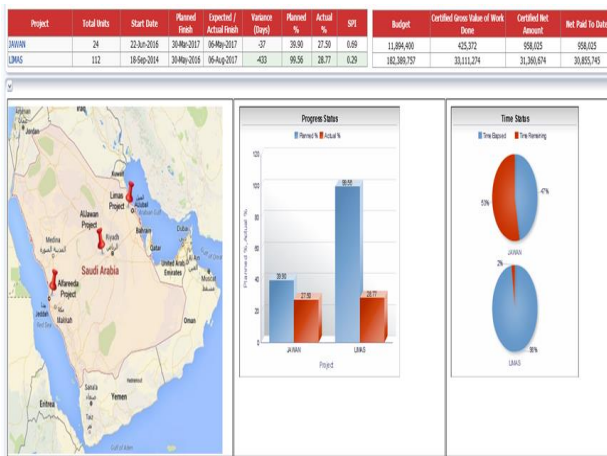


Figure 10- Portfolio dashboard

Project dashboards contain interactive map show units' color based on the actual progress for each unit as shown in figure 12 which is showing phase dashboard. This interactive colored layout is developed inside the OBIEE automatically to allow progress visualization. Activities progress layout is the last dashboard in the report showing the status of each activity in colored map in addition to legend showing the count of completed, in progress and not started units for that activity as shown in figure 13. Same dashboard was developed for infrastructure works with some modifications based on the nature of infrastructure

works. OBIEE provide flexibility in modifying dashboard contents and information presented based on user requirements.

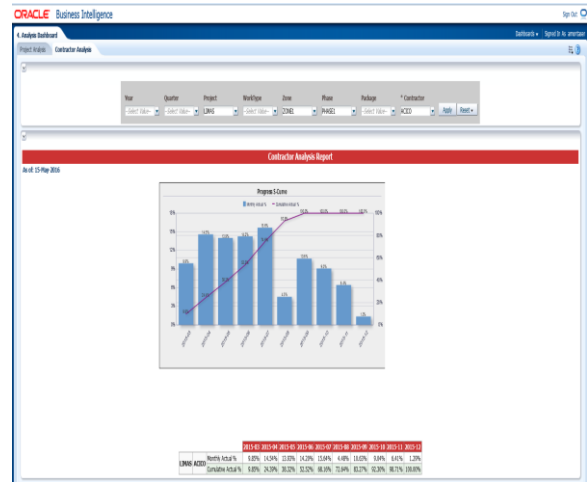


Figure 11- Portfolio S-curve dashboard



Figure 12- Phase dashboard

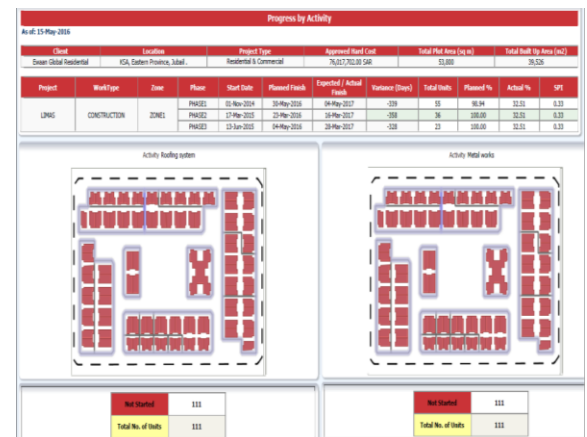


Figure 13- Activity dashboard

4 Conclusion

This paper represents design and implementation of automated integrated web-based reporting system for construction projects. The developed model integrates project time and cost data in addition to visualization capabilities through utilization of mapping techniques. The report goes through 3 main stages for achieving the final output, which is web-based integrated report. Cost reporting is the first stage of the process in which budget is created and actual costs and payments are recorded. Cost engineer is responsible for this process using customized ORACLE cost system. Web-based application was developed to store progress updates and store it to be used in creation of the developed reporting model. Web-based application was developed using OBIEE to support visualization and integration of data in addition to designing interactive dashboards. At the core of the developed model lies a data analysis and processing framework that stores, retrieves and processes the captured data from cost system. The developed model facilitates data reporting in visualized and graphical representation. The customized integrated web based module constitutes a step ahead of current market applications solution for integrated web-based reporting. The developed model supports monitoring performance more thoroughly and make better business decision through generating one simple integrated reports to assist in speedy assessment, analysis and to take suitable actions in timely manner. The updated progress information is available immediately to all concerned parties with high quality and reliable timing. The developed model is very flexible to modification of data presentation and manipulation method and can show any data extracted from the supporting systems.

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