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WEB-BASED INTEGRATED PROGRESS MONITORING AND REPORTING

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Abstract: Web-based progress reporting systems are powerful tool in the pursuit of improving efficiency and enhancing the flow of information within construction projects. Executive management of real estate developers need an easy means and a near-real-time project information that describes project status to take immediate corrective actions as well as to know the exact overall status of corporation projects. This paper presents an integrated web-based progress monitoring and reporting model for real estate developers. It utilizes Primavera P6 as a scheduling tool, while progress visualization capabilities are achieved through project progress photos. The application main development tool is ORACLE Business Intelligence Enterprise (BIE). Specially designed relational database was used to be the main repository for scheduling and progress captured photos beside its customized web-based application. The developed application and methods constitute a practical integration between time reporting and progress visualization. The application 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 m^2 built up area. The analyzed case study demonstrates how the developed model can assist real estate developers in taking corrective actions based on the near-real-time actual data captured and processed to enhance project controls and progress reporting in construction industry.

1 Introduction

Construction companies currently are progressively managing their activities and projects to monitor performance more thoroughly to make better business decisions about their projects and portfolios. They are trying to develop tools that could support in monitoring through generating various reports to assist in speedy assessment, analysis and to take suitable actions in timely manner (Hassanein, 2002 and Montaser and Moselhi 2015). Construction managers struggle with huge amount of data during construction, which is caused by the lack of adequate visual representation. That can result in costly errors and/or lead to delays, which eventually will cause projects failure (Moselhi and Xiao, 2011 and Montaser, 2013). It is crucial to utilize visual representations to explain the complex structure of information, eliminate unclear issues, and recognize key data (John et al., 2005, Mani and Feniosky, 2007 and Montaser and Moselhi 2014). Web-based construction reporting systems can make use of browsers, data handling devices and other internet technologies to generate a network for sharing and deploying business information in a system. It will contribute in construction manager's decisions to complete work on timeframe and within the allocated budget (Moselhi et al., 2001and Moselhi et al., 2004).

Web-based reports common features are easiness of accessibility to project data, which can be achieved from anywhere and at any time through the Internet browsers. Furthermore, updated progress information is available immediately to all and shared as soon as it is obtainable with high quality and reliable timing

(Abdelsayed and Navon, 1999). Historical information for current and past projects is available for retrieval for any purposes, such as for project maintenance needs, new project planning etc. Web-based systems users have increased their competitive advantages and opportunities because of data integration and application capabilities (Scott et al, 2003 and Ji, 2004). Researchers have developed more effective methods of progress automated data acquisition and report development (Cheng and Chen 2002, El-Omari and Moselhi, 2009, Bosche, 2010 and Turkan et al., 2012). However, limited researches have been conducted on automating progress report generation process for construction projects (Li et al., 2015).

Currently, many construction companies use Primavera P6 as the implementation software for the overall project controls process. Primavera P6 is considered an outstanding application for planning, scheduling and forecasting of project activities performance (Blodgett and Criss, 2015). It provides a database platform by which projects schedules are preserved and updated regularly. An ORACLE Business Intelligence Enterprise (BIE) application usually consists of prebuilt, industry-specific interactive dashboards and reports that address key functional areas within an organization. Dashboards and reports are tailored for each end user's role in an organization (ORACLE, 2013). ORACLE BIE applications are integrated with operational applications to provide business metrics in reports, in context with an organization's business function and industry. It includes rich visualization, interactive dashboards, a vast range of animated charting options, Online Analytical Processing (OLAP) style interactions and innovative search, and actionable collaboration capabilities to increase user adoption (ORACLE, 2015).

The developed model integrates time information and progress visualization to assess the current progress rate and forecast project completion date, which assists stakeholders in making immediate corrective actions if needed. Moreover, progress photos are provided to represent the actual progress on the project for any selected WBS level, which provides visualization capabilities. A ware-house central database was created to be the main storage for all reporting components. Through the interaction between the scheduling tool and database, time and photos data are reported. A supporting web-based application is developed to import progress photos, which is transferred automatically to ware-house database upon importing. Web-based reporting application is used to integrate time and photos reports in one integrated web-based report model. Aside from data integration, the web-based application is providing user with visualization capabilities through interactive dashboards. The developed model allows users to understand visually and textually the reporting information and project status in easy manner as soon as the data is updated in supporting systems.

2 Proposed Model

The main steps of the proposed model are following the regular reporting steps, as shown in Figure 1. First step is developing the time schedule for the project after clear understanding of work scope and contractual constraints using a scheduling tool. Baseline time schedule is the approved plan for work in scope and is the major reference for any planned scheduling data. After finalizing the baseline, it is used to track project progress and compare actual and planned works through regular updates cycles. To update time schedule, project progress information is collected through the appropriate performance measurement technique, which was selected during project planning. Progress forms is updated and transferred to scheduling tool to produce the update time schedule. Scheduling tool database stores all time project information either planned or actual information. All the data is transferred to the ware-house database to be part of the integrated report.

Project photos is a vital component of progress reporting especially for non-specialized report viewers as they need to know the actual progress on site physically. The developed web-based model is integrated with the schedule to import and export photos based on reporting requirements and Work Breakdown Structure (WBS) used in planning stage. The photo session should be in sequence with the sorting of time schedule components for each level of time schedule to automate data transfer to assure that the correct photo in the suitable WBS. After taking the updated photos, it is imported to the developed model, which uses ware-house database as a main storage for photos updates. The model allows all stakeholders to view the photos through changing image name to schedule WBS name. Integrated report is issued automatically after updating data from time and photos database. Web-based application is utilized to issue the integrated report after collecting all information. 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.

First stage in developing the progress report is the reporting level of detail, which could be Enterprise Project Structure (EPS), WBS or activities, as shown in figure 2. Developing baseline time schedule during project planning stage is very critical to project success as it is the roadmap for the project completion. Regular updates are done for the project based on predetermined updates cycle to get actual progress from site. Scheduling tool database contains all schedule baseline and update parameters that are utilized in reporting project status. Data is imported from scheduling tool database to ware-house database. The extracted data contains complete project information while the presented data is limited to forecast or actual finish, planned finish, baseline and updated finish date variance, which shows the delay in project finish date from the planned date. Actual and planned percent complete are shown with Schedule Performance Index (SPI), which highlights project progress. These parameters are selected by project owner and can be easily extended to show any scheduling tool parameters to enhance reporting capabilities. User Defined Fields (UDF) in the scheduling tool is used in project and EPS level to allow the user to write any text summary to be mentioned in the report such as progress summary, project issues or project summary as a text format. Reporting application extracts this data from ware-house database and present it based on report levels and dashboard design. Also it calculates numbers of completed, in progress and not started activities, WBS or EPS based on the selected reporting level.

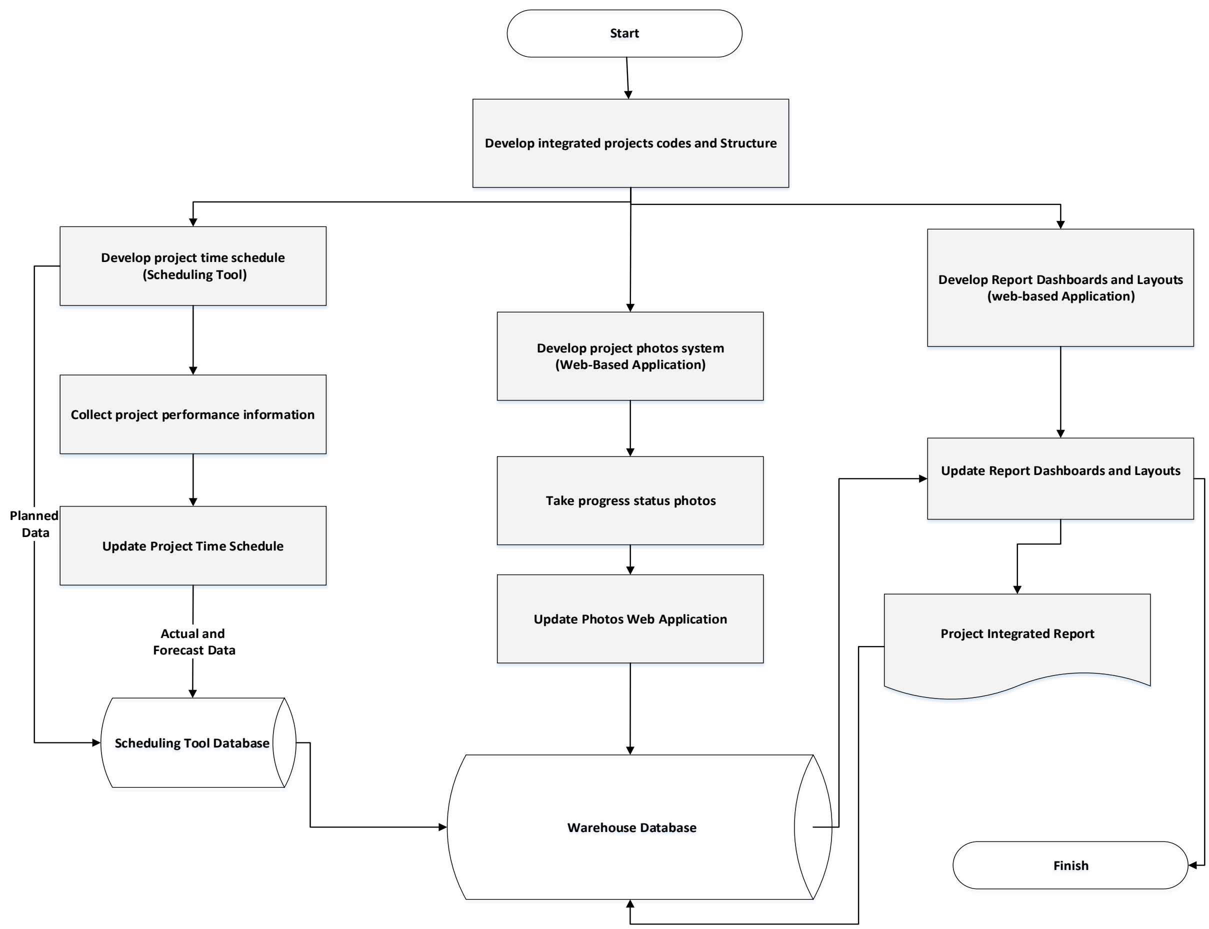


Figure 1- Proposed model

The development of the required sequence of photos to be presented and the number of photos and direction is the major step while reporting. Some projects already automated the process of taking progress photos through closed-circuit television (CCTV) camera systems installed on site. However, due to project budget constraint, manual process is applied during this stage. The process start with identifying photo report requirements, the sequence for the photo session and EPS, WBS or activities photos that is reported. It is essential while deciding those processes to take inconsideration EPS, WBS and activities sorting and organization to automate the process of recognizing photos in easy manner. A sample is shown in figure 3 illustrating the direction and sequence of photos that are given to photo responsible person to take photos based on it. After finalizing the photo sequence and levels that is imported, the web-based application is programmed to process the photos for each level and import a list of organized EPS, WBS and activities from the scheduling tool. The updated photos are imported to the application for each level as per the agreed sequence. Photos is renamed automatically inside the web-based model to match its name on scheduling tool. All photos are stored in same sorting and for each level inside the ware-house database to be used as a part of the integrated report. This serves as photo historical presentation for the progress on site since initiation till handing over and can be used to serve as a database in estimating production rates, reviewing sequence of work or settling down claims. The whole process is illustrated in figure 4. 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.

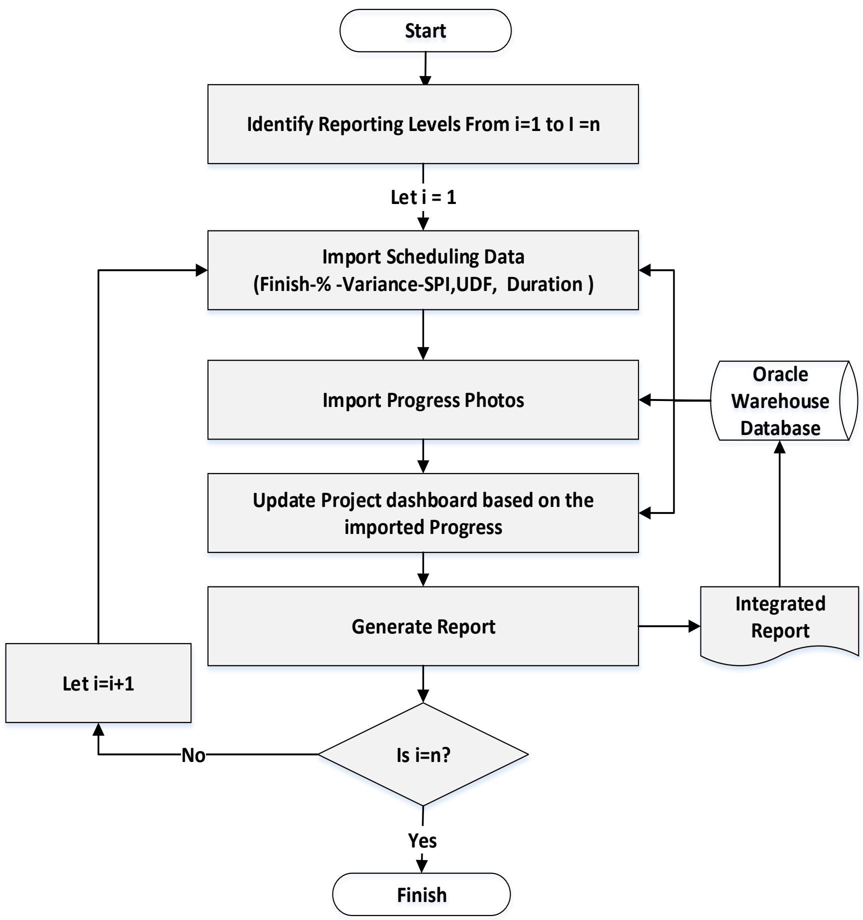


Figure 2- Report Development Process

Figure 3- Progress Photos sequence and directions

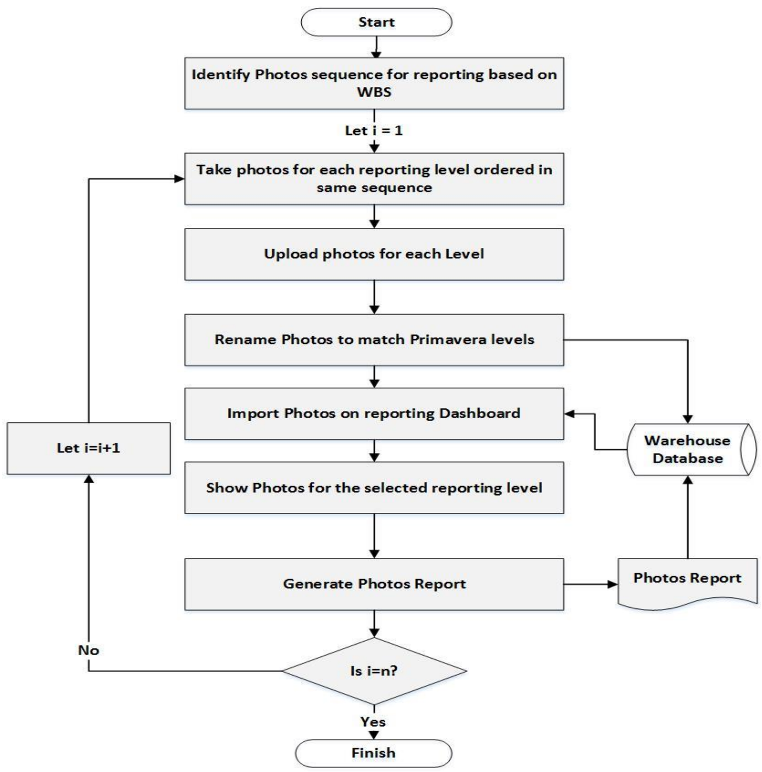


Figure 4- Progress Photos process

Ware-house database is the central storage area for the reporting model. The database consists of forty-three entities such as WBS, EPS and activities. Activities ID along with their features (name, type, status, float, dates, duration, WBS, codes, UDF …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 scheduling and progress photos. Every WBS has a unique identifier based on its level on the project and type of work done to facilitate date transfer to the integrated report from other reporting tools. Each WBS has its reporting photos extracted from web-based photos software. WBS UDF and codes are used to report certain parameters such as contractors, another system for progress summarization or static information. Database retrieves the stored data based on the level ID, which is unified for all tools. Portfolio, program, project, WBS and activities history entities are 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 and the details of the database are not included.

3 Model Implementation & Case Study

The Reporting progress is a complex process to integrate all project information in suitable time to take the correct decisions. The developed model is implemented in a web-based application, which has similar structure to the illustrated methodology. Primavera P6 Enterprise Project Portfolio Management (EPPM) was used in performing scheduling calculations to develop bassline and updated schedules. The application main coding language is Structured Query Language (SQL), while the main development tool is ORACLE Business Intelligence Enterprise (BIE). It uses ORACLE data integrator to support Extract, Load and Transform (ELT) technology that improves performance and maintain data integration. Also, the application utilizes ORACLE ware-house database to store tabular data, for integration with primavera and photos information. The database stores current and historical data and is used for creating report dashboards. Three-tier standalone architecture was chosen for the developed application and other reporting systems as shown in figure 5. Primavera P6 EPPM represents, the presentation tier, which is mainly a web-based interface for the system with optional desktop interface that saves data automatically to the cloud database. 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 scheduling calculations.

Tier two is primavera logic, where all scheduling algorithms and procedures in the data analysis and processing are implemented. ORACLE P6 EPPM database resides in tier three, where all the schedule planned and actual data is stored in it. Primavera application programming interface is the programming process, which enables storing and returning data inside and from database to do scheduling calculations during primavera processing. Ware-house database is the main database for photos developed application to be stored and used during report. The application utilizes ORACLE ETL tool built in the system to process data to processing tier to implement photos processing and return it to user interface and to be used as a part of the report. Photos UI is where the user import, view and track progress photos updates. ORACLE BIE 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. Reporting processing is the main logic for the application, which resides in tier two that processing utilize 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 two, which collect data from primavera and transfer it to ware-house database to be processed during report generation.

The developed web-based application 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 villas and 20 apartments are 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. The project is composed of four different types of villas type A, B, C, and type D, recreation center and infrastructure works. Activities for each trade was decomposed based on in scope of work to be updated based on work progress. WBS, activities and codes was approved and was developed based on company standard level of details. The hierarchy was developed to suit company business, which is real estate industry but the system can be applied to any industry. Activity duration estimating and sequencing process were done by project planner with respect to internal and external constraints. Recourses were loaded in the baseline time schedule and budget to be able to assess the project progress financially and produce S-curves. Activity codes was created to report progress by another grouping layout such as contractor activity code. UDF and codes were created as required by reporting templates to enable static data reporting. The baseline was in accordance with the approved project master schedule and it was approved by all concerned parties.

Planner developed a detailed progress forms to gather progress performance information to update project activity list. Project site team updated the progress form and returned it back to planner for review and updating the project schedule to assess actual performance against the plan. After ensuring information creditability, planner updated primavera P6 EPPM through export and import function. Updated schedule maintenance and review were carried out to report accurate project status against the plan. The developed web-based application was also created for managing site progress photos update to be reported as part of the integrated report in addition to working as a database for progress photo records through project stages.

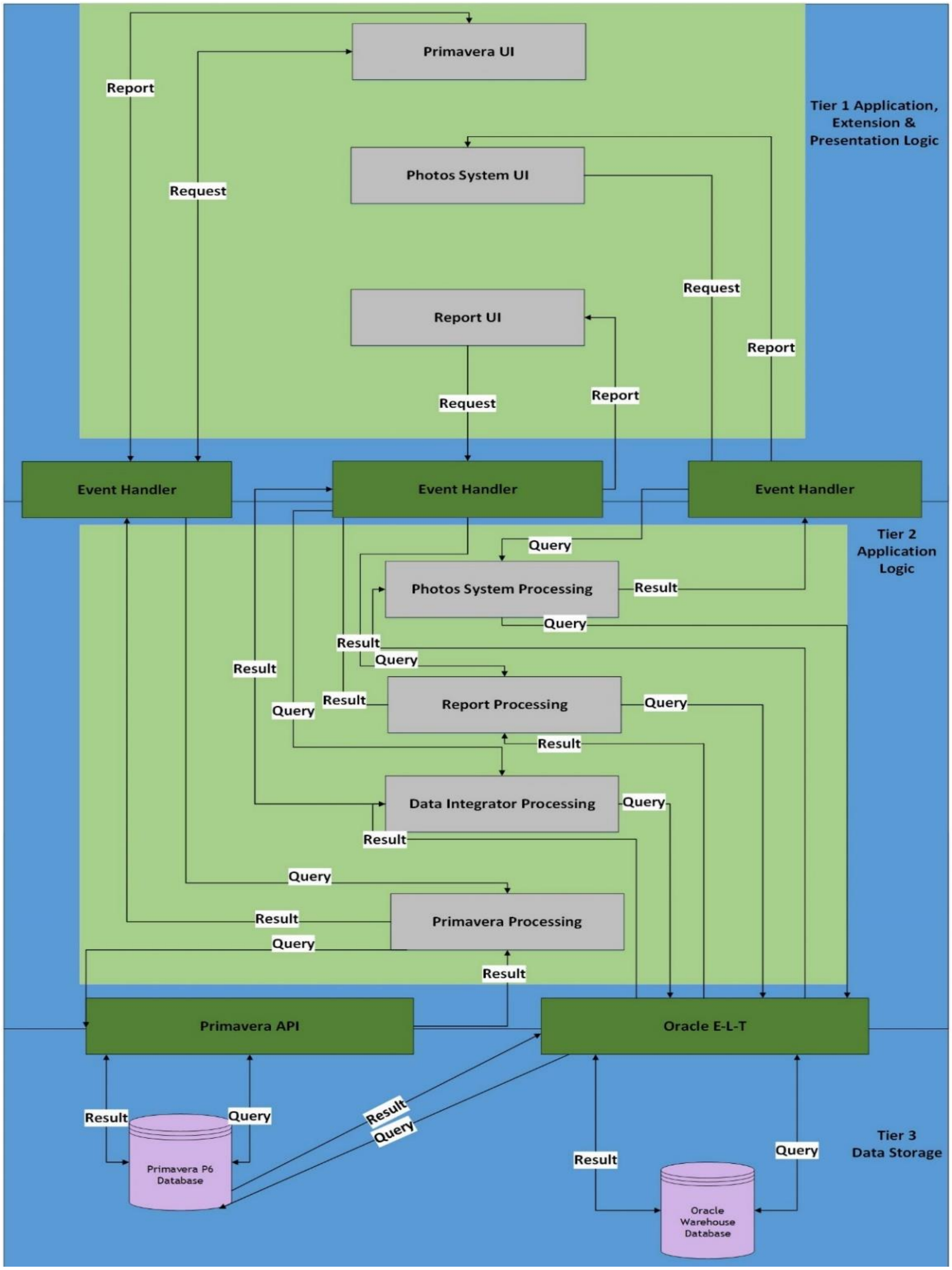


Figure 5- Reporting systems architecture

The application is programmed to extract primavera WBS levels for all projects from ware-house database upon creation. List of sorted WBS levels is the main factor of recognizing photo. User selects which layer to be updated through multi-selection pane. After selecting the layer, user is able to select which WBS level to be updated accordingly. User selected unit layer to be updated then chose all groups and all phases of LIMAS project zone 1 construction works. The application automatically gave a list for 111 units under that level sorted in same primavera order. After successful uploading of photos, uploaded photos were renamed automatically to match its WBS level and application show log for uploaded photos after renaming, as shown in Figure 7. All photos were exported and stored inside ware-house database to be used as part of the integrated report.

Project dashboard contains time status and static information for all WBS levels and each level dashboard contains its progress data and two levels summarized progress. Each dashboard contains general project information, counting of units in progress, completed or not started, planned finish date, expected or actual finish date, finish dates variance, planned %, actual % and SPI. It should be highlighted that that information in all dashboards are changed automatically based on the specified parameters chosen in the multi selection pane as shown in figure 8. It should be noted that all the reports described above are based on WBS levels except contractor level, which is activity code to allow summarization of contractor progress information. Contractor dashboard contains same information for specific contractor in addition to packages and groups assigned to that contractor. Progress photos is part of unit report, which are imported from ware-house database after updating photo application. Figure 9 shows the contents of unit report which are static information, time information, unit, unit trades and unit activities actual status, key milestones and unit photos. The selection of data in the report is based on units' owner requirements to be able to track the progress of their units.

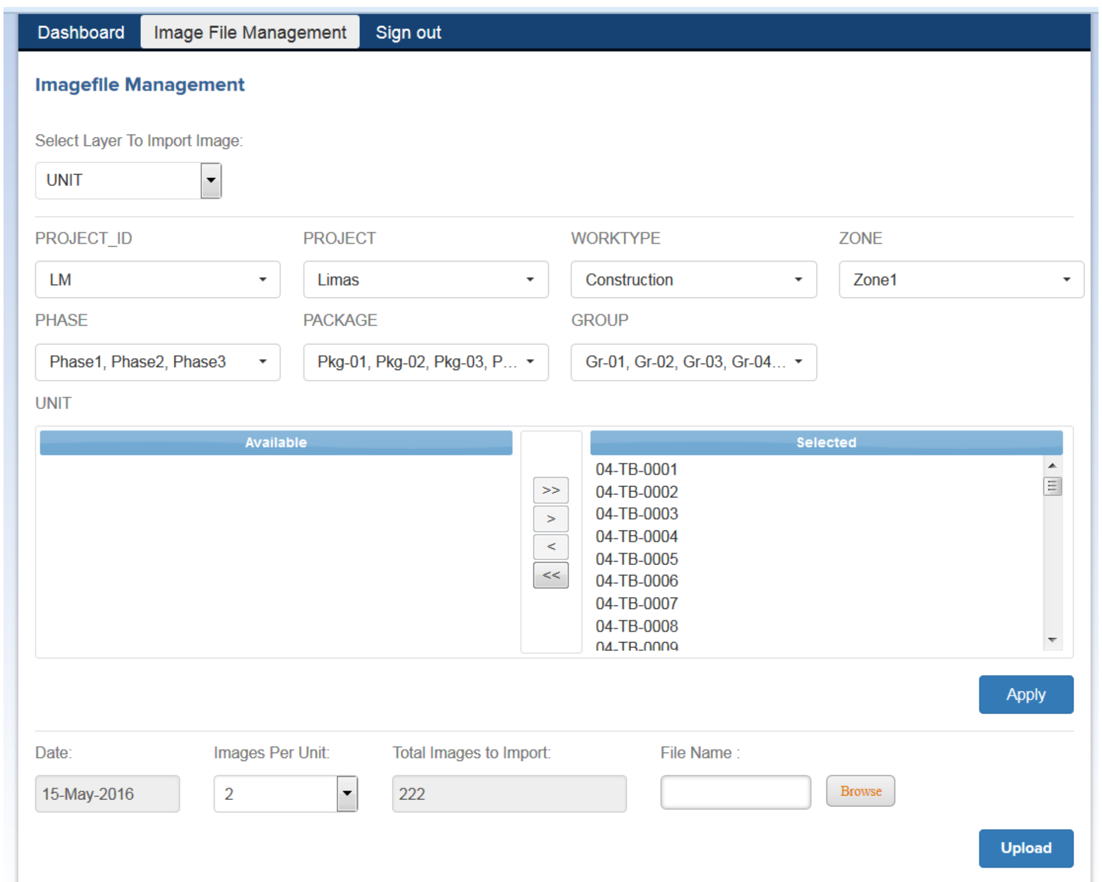
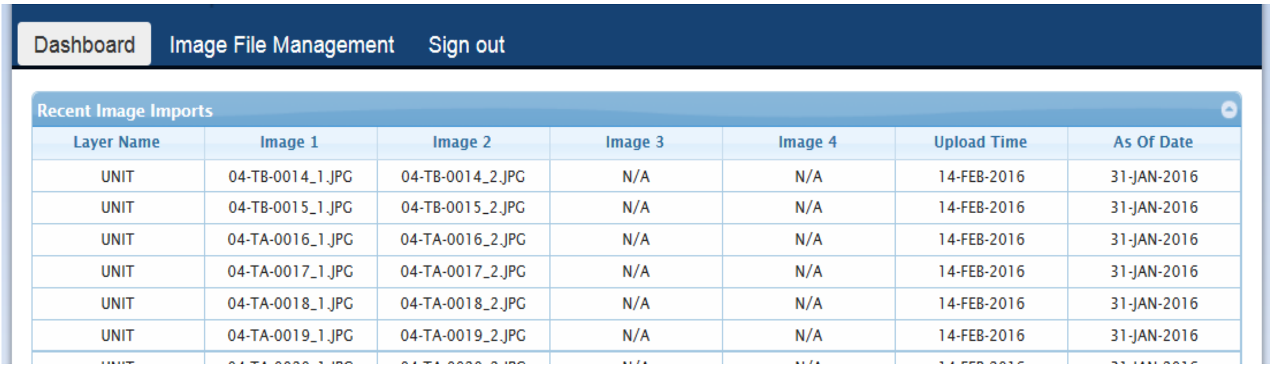


Figure 6- Web-based application uploading Window



Layer Name	Image 1	Image 2	Image 3	Image 4	Upload Time	As Of Date
UNIT	04-TB-0014_1.JPG	04-TB-0014_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016
UNIT	04-TB-0015_1.JPG	04-TB-0015_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016
UNIT	04-TA-0016_1.JPG	04-TA-0016_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016
UNIT	04-TA-0017_1.JPG	04-TA-0017_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016
UNIT	04-TA-0018_1.JPG	04-TA-0018_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016
UNIT	04-TA-0019_1.JPG	04-TA-0019_2.JPG	N/A	N/A	14-FEB-2016	31-JAN-2016

Figure 7- Uploaded photos log Window

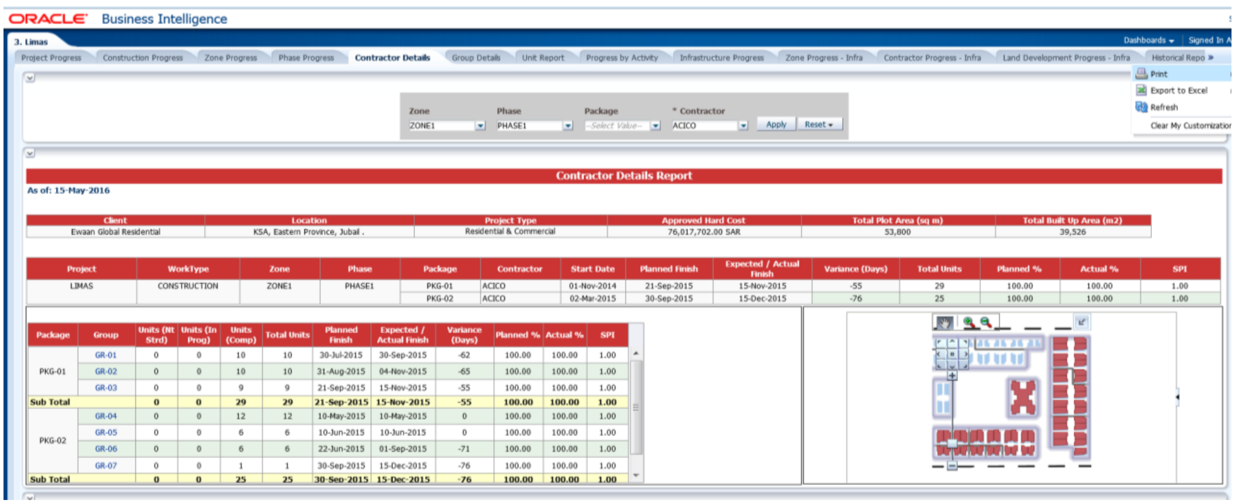


Figure 7- sample for multi selection pane for package dashboard

4 Conclusion

This paper represents design and implementation of automated integrated web-based reporting model for construction projects. The developed model integrates project time and visualization capabilities through progress photos. The report goes through 3 main stages for achieving the final output, which web-based integrated report. First stage is related to time information where baseline time schedule is created, progress information collected and baseline time schedule is updated. This process is done by project planners utilizing primavera P6 EPPM as a scheduling tool. Web-based application was developed to store progress photos 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 Primavera P6 EPPM and photos applications through ware-house database and reporting application capabilities. The developed model facilitates data reporting in visualized 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.

Figure 8- Unit dashboard

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