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SIMULATION TOOL FOR MANPOWER FORECAST LOADING AND RESOURCE LEVELING

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ABSTRACT

Large scale / mega projects are lengthy complex endeavors that require significant planning by management, engineers and construction personnel to ensure the success of the project. When we examine the state of mega projects today, we are faced with a real crisis. Companies, both client and contractor, are reporting significant cost and schedule overruns. Lack of project scope definition and planning are the primary characteristics of this problem. Computer simulation is a powerful tool for analyzing complex and dynamic scenarios. It provides an appealing approach for the analysis of repetitive processes. Simulation helps decision makers identify different possible options by analyzing enormous amounts of data. Hence, computer simulation can be used effectively to analyze the resource loading and manpower requirements needed to complete a task in a given time frame, based on current progress levels. This paper discusses a special-purpose simulation (SPS) tool for optimization of manpower forecast loading and resource leveling. The simulation model is capable of optimizing resource requirements for a petrochemical project, based on standard discipline requirements and involvements. Tests of this simulation tool have produced exceptional results; currently, the system is being modified to incorporate historical data within the simulation.

1. INTRODUCTION

The purpose of manpower forecasting and leveling (MFL) is to provide an accurate and effective method of identifying current manpower availability, forecasting future manpower requirements, and maintaining the balance between demand and supply. MFL is used for manpower planning, space planning, business development and IT requirements. During the initial pre-qualification, or proposal phase of a project, management must determine its personnel resource requirements to complete the scope that is outlined in the contract. Requirements are determined using various sources, such as experience, historical data, project deliverable size, and availability of resources. Although the needs will change throughout the life of a project, it is important to establish a baseline to determine the current availability and future demands to minimize potential risks. MFL is also essential to ensure that sufficient space and computers are available for the appropriate manpower of each project.

The research explained in this paper is focused on the use of MFL for the purpose of manpower planning during the engineering phase of an engineering, procurement and construction (EPC) project in the petrochemical industry. The system proposed in the paper uses Monte Carlo simulation to establish resource requirement curves based on project man-hours and reported progress by discipline, in order to forecast project manpower needs. This system was used in forecasting the initial engineering manpower needs of an international mega project, which was executed in 2006 with exceptional success.

To increase the success probability of a project, a project manager's main objective is the completion of a project within the confines of the project management constraints triangle (Figure 1). A project manager relies on work processes to standardize the implementation of the project within the boundaries of the project management frame work. In EPC projects, close monitoring of the project performance against the plan is the key tool used in identifying and mitigating risks in the project execution plan. The establishment of a realistic baseline is essential for the success of the project (Heisler, 2001). Risk mitigation depends on the projected forecast of both the schedule and budget against the actual measured performance. Earned value analysis provides an indication of the actual progress of the project (Westney, 1997); however, a real-time simulation model, such as the one presented in this paper, allows for the early detection of risks, as well as providing an optimized recommendation regarding possible recovery plans.

The paper starts by highlighting key terminology used throughout the paper, including a brief introduction of a standard project progress framework. The simulation methodology used in this research is then introduced. Finally, the simulation module and its advantages are presented, along with current and future applications.

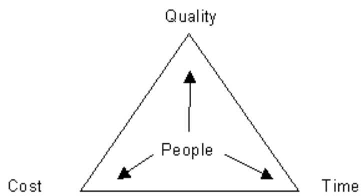

Figure 1: Project Management Constraint Triangle (Chapman, 1997)

2. DEFINITIONS AND THE PROJECT PROGRESS PROCESS

The following terms are used in the paper.

2.1 MFL: Manpower forecasting and leveling.

2.2 Manpower forecasting: The process of identifying and establishing the manpower needs for projects and of identifying the available resources.

2.2 Manpower leveling: The process of maintaining a balance in the manpower availability versus project requirement in all disciplines.

2.3 Project lead discipline engineer: The leader of a discipline in a project; responsible for professional expertise in leading the discipline in question and for effecting the work on the project by using project instructions, proper standards, procedures and systems.

2.4 Project Progress Process**:** The creation of a project plan is a unique exercise involving the input of many stakeholders (Wysocki et al., 2003). The accuracy of the input of these stakeholders creates a state of equilibrium inside the project management constraint triangle. The project manager, the project engineers and the project controls staff are responsible for identifying both the scope of the project, as outlined in the work breakdown structure (WBS), and the duration of the scope of the entities identified (Wysocki et al., 2003). The lead discipline engineer, under the direction of the project engineers, creates a detailed list of deliverables and the man-hour (MH) requirements for the completion of each deliverable.

The information provided by the discipline and project management teams can now be used to create a level 1 schedule, detailing the general workload needed to complete the project. Based on the deliverable list provided and the schedule associated with it, a graphical progress model that completes the defined scope of work can be developed (Heisler, 2001). The primary objective in the early stages of the project is to develop a road map for the logical mobilization of personnel, based on the deliverables and the associated schedule. Later stages require the development of a logical project framework that will permit monitoring and control of all aspects of the project. Both stages are fundamental elements of the simulation model presented.

3. LOGIC BEHIND THE SIMULATION

The simulation tool presented in this paper provides the user with the ability to:

- validate the proposed duration and man-hour consumption per discipline for the duration of the project; and,
- create a forecast model of the work to be completed, based on earned work completed by a discipline.

The simulation uses a number of critical input data elements at the beginning of the project to create a baseline forecast for each discipline and the overall project. These data elements are as follows:

3.1 Total Project Hours

Total project hours is the summation of all the hours identified by each discipline to complete the defined scope of work. This total also includes a dedicated percentage used by the project management team to manage and control the project. Risk and contingency are also factored into the total. The hours are based on the deliverables defined in the scope of work.

The simulation uses the total project hours as the basis of the baseline calculation for each of the seven engineering disciplines. Project change notices affects the agreed upon total project hours; and, the simulation model incorporates such changes and generates a new baseline based on the new additional hours and the completed project progress.

3.2 Discipline Total Percentage

The type of project to be executed, the scope of work and the list of deliverables are all used to identify the total hours of work required by a discipline. This is a best guess by the lead discipline engineers; therefore, the simulation assigns a percentage of the overall man-hours to each discipline. This percentage is used by the Monte Carlo analyzer to generate a discipline plan progress curve.

3.3 Total Project and Discipline Duration

Total project duration is the number of months proposed by the client to the contractor to complete the project scope of work. This duration acts as a primary constraint to most EPC projects.

Total discipline duration reflects the amount of months needed by a specific discipline to complete all their deliverables, as identified in the scope of work. This number is proposed by the discipline to the project management team. The discipline of project management/control is involved throughout the entire duration of the project. Other technical disciplines complete their work at different times during the life of the project.

Both durations can be changed by the client and/or the contractor, depending on the current project situation. The simulation model evaluates the baseline and forecast values based on these new duration parameters. The durations also determine if the hours allocated to the project are sufficient to complete the project.

3.4 Discipline Work Loading - Skew

As with the total discipline duration value, the work to be completed by a discipline will vary depending on the identified scope of work and the interdependency between each of the disciplines. There are six engineering disciplines in EPC projects in addition to project management discipline. They are the civil/structural, mechanical, electrical, process, piping and instrumentation disciplines. Work by each discipline will fall into one of three categories:

- **Front Loaded:** Work by the discipline must be completed early as other disciplines use the information provided to complete their work. This is typically true of both the process and mechanical disciplines (Figure 2).
- **Back Loaded:** Work needs to be completed by other disciplines for this discipline to start its work. This is true of the piping discipline and the creation of isometric drawings (Figure 3).
- **Uniformly Loaded:** Project management is a typical discipline that is uniformly loaded. This discipline contributes and supports the other disciplines from the start until the end of the project (Figure 4).

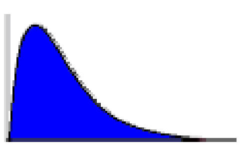

Figure 2: Front Load

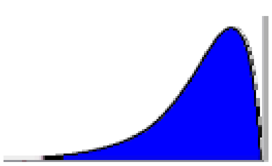

Figure 3: Back Load

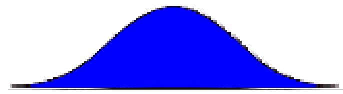

Figure 4: Uniform Load – Platykurtic

The simulation allows for the loading factor of each discipline to be varied at any point during the life of the project. This ability is necessary as scope changes, risk and other scenarios impact the progress of a specific discipline and, ultimately, the entire project (Figure 5).

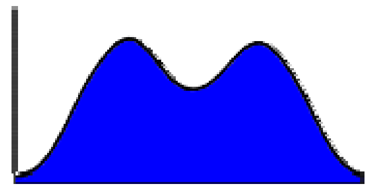

Figure 5: Modified Work Load

4. STRUCTURE OF THE SIMULATION TEMPLATE

The progress and trend simulation model presented in this paper is a special-purpose simulation (SPS) tool that is used to optimize the decision-making process regarding the viability of the project at the discipline level. The simulation was developed using Microsoft Access and Excel Visual Basic for Applications (VBA) 2000+. This allows the model to be easily exported into a variety of operating system environments.

4.1 Project Window

The project window is considered the parent element of the system. The following information is required as input (Figure 6):

- project duration,
- total project hours,
- discipline duration, and
- discipline consumption of overall hours.

The total discipline hours are automatically calculated by the system, based on the total project pours and the discipline percentage. The system uses a normal distribution of the discipline, with a ±2% variance to calculate the total discipline hours. The project ID and name are used to uniquely identify the project in the system.

4.2 Discipline Window

The system may have seven child elements, one for each discipline. The discipline work loading (front, back or uniform distribution) is required as input for each discipline selected in the discipline dropdown (Figure

7)The work loading factor percentage is computed using a normal distribution formula:

$$y = \frac{1}{\sqrt{2\Pi}} \ell^{-\frac{z^2}{2}} \qquad (1)$$

The above information are the minimum requirements for the system to generate a baseline progress curve for the project based on the discipline loading factor.

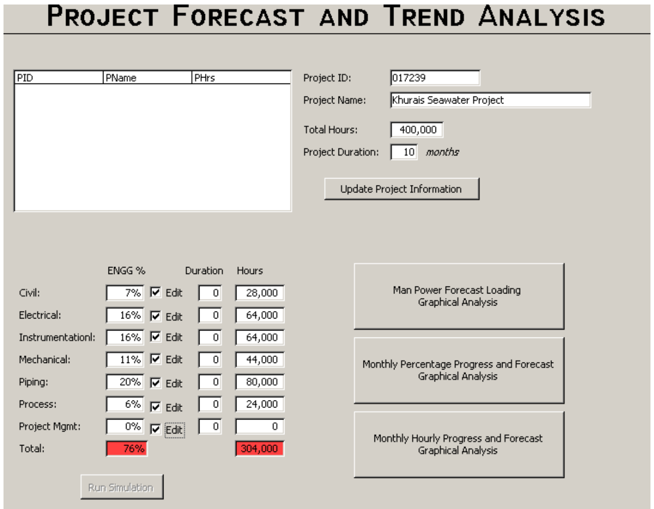

Figure 6: Project Window – Parent Element

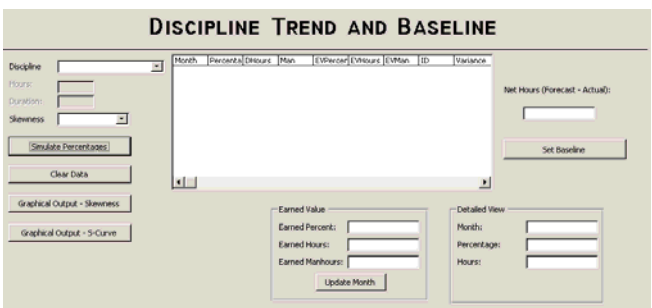

Figure 7*:* Discipline Window – Child Element

4.3 Earned Value Input

The SPS template was created as a real-time execution simulation tool. This allows the user of the system to input the actual earned progress versus planned. The template then recalculates the forecast progress based on the user input, in order to provide a new baseline and an accurate forecast of the current progress of the discipline (Figure 8).

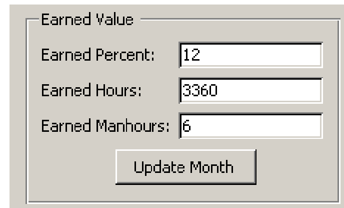

Figure 8: Earned Value Input

4.4 Simulation Output

Other than the monthly progress percentage, the system calculates the total monthly hours and the cumulative monthly hour variance for each discipline. This provides the user with an indicator of the hours required to accomplish a specific progress level. The system also calculates the number of human resources required to attain a specific progress level, based on a man-month calendar of 165 hours.

The simulation produces both numerical and graphical data for each of its outputs at the project and the discipline level (Figure 9). This allows the user to view the project progress in terms of total discipline progress. This aids the project manager in determining which disciplines are impacting the overall progress of the project, as well as determining the corrective actions to mitigate the problem.

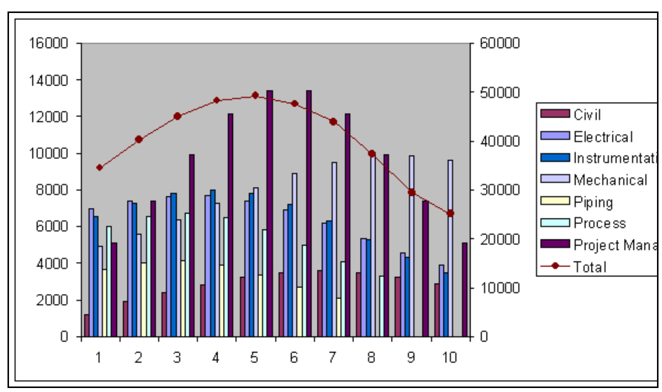

Figure 9: Monthly and Cumulative Hourly Progress Application and Benefits of the Simulation Template

5. APPLICATION OF SIMULATION TEMPLATE

The simulation template presented in this paper is primarily focused on the petrochemical EPC industry. The template can be used as early as the proposal phase of a project. The proposal team can simulate the hours, duration and manpower that will be needed for a project. This allows the proposal team to add necessary skill sets only when needed for a specific duration. This also enables the team to examine the validity and success of their bid from engineering, scheduling and cost perspectives.

The template can also be used by project managers, engineers and planners to better forecast the project progress. The true power of this template is in the detection of progress trends based on the earned value input of each discipline. The template can quickly provide a number of new baselines to mitigate any challenges present currently or in the future.

6. CONCLUSIONS AND FUTURE WORK

Planning a project includes the establishment of a framework for effective project control through the definition of project scope and logical sequencing of work to be performed. Simulation tools provide a mechanism for creation and monitoring of such a framework. The proposed SPS template uses current data to forecast the future requirements of a project. This template can be utilized throughout the life of a project to better control the project plan, as well as create new realistic baselines, if necessary.

One of the common barriers to the implementation of project management techniques is the large time commitment requirements necessary to create and validate the project plan. Simulation is a powerful and accurate cost-effective planning tool. The template presented in this paper can improve the quality of the project through the:

- reduction in project planning and costs;
- reduction of time and cost elements of proposals, and increasing a company's competitiveness;
- early detection of discipline progress challenges;
- optimization of human resource requirements for a project; and,
- reduction in staffing costs throughout the life of a project.

Future versions of this template will have the ability to:

- use different statistical distributions in calculating the discipline work load;
- add a cost component to determine the impact of the project duration being extended or an increase in the total manpower to increase progress; and,
- limit the monthly progress based on historical data value and adjust the durations to compensate accordingly.

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