

Development of Baseline Work Plan Templates for Transportation Projects

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ABSTRACT

A good resource planning is essential to budget allocation and programming in project management. To accurately estimate the number of labor hours needed for a transportation project has always been a challenge to management office, project managers as well as transportation engineers. A typical method for estimating the number of hours needed is mainly based on the experience of the estimator. Different engineers may have different estimates even for the same project. To minimize the variation of estimates and provide a fair baseline work plan, a work plan template is often utilized. However, how to develop the template itself is also a challenge. This article proposes a work plan template development procedure that could be employed by transportation agency to simply the complicate resource estimation procedure. Data collection, processing, analysis and modeling, as well as application are introduced. Limited numbers of regression models were obtained. Advantages and disadvantages are also discussed.

Keywords: Project Management, Work Plan, Templates, Prediction Model, Estimation, Schedule

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INTRODUCTION

Resource planning plays an important role in project management. Many Departments of Transportation (DOTs) employ a Work Breakdown Structure (WBS) to help resource planning. Potential activities necessary to complete a project are broken down into smaller tasks and activities at various levels. FIGURE 1 shows the work breakdown structure up to level 5. Levels 6, 7, and 8 contain tasks and activities when the Level 5 major work elements do not contain sufficient detail to plan, schedule and manage the work (1), which is beyond the scope of this effort.

Caltrans District 8 follows a statewide work plan development procedure, which requires a Project Manager (PM) to solicit work plan hours from each potential functional unit that may have involvement in a project. A work plan development team (WDT) is often assembled to develop the baseline work plan. This team may consist of people from different functional units, such as Design, Environmental, Right of Way, Engineering Services, Material, Traffic Operations, Maintenance, Construction, etc. A Task Manager (TM) is designated to be responsible for resource allocation for each unit. PM will review the work packages proposed by each TM and contact them in order to agree or disagree upon the task duration and resources for the development of the baseline work plan (2).

A challenge of the above procedure often is the estimated number of hours for an activity proposed by a TM is mainly based on individual experience, which could vary among task managers significantly. A PM needs to manually review each requested item and make a subjective judgment as approved or disapproved. If disapproved, the project manager needs to explain why the requested hours cannot be approved. Negotiation starts when this happens. The work plan is finalized when the TMs and the PM both agree on amount of resources and duration. There are several typical issues in the above procedure:

- Unnecessary functional unit involvement. Since the work plan request is sent to all potential functional units, it is very likely the unit will request for some hours for the subject project.
- Unnecessary task involvement. It is not unusual that a unit request for some hours for a task that does not belong to its duty.
- Excessive hours request. According to past experience, a unit tends to request for more hours to be on the safer side even they may not be able to use them up at the end. This might cause a programming issue - the unused budget cannot be allocated to other units that may actually need.

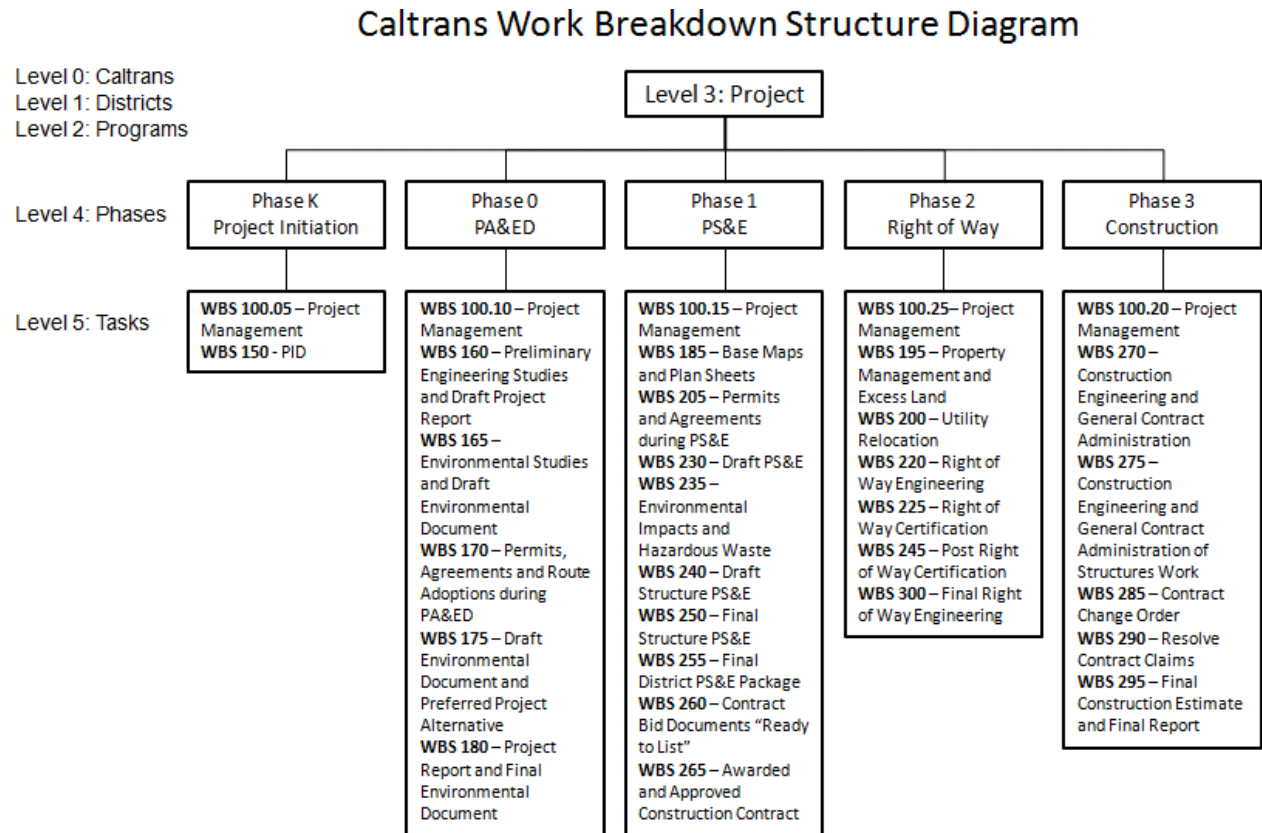


FIGURE 1 Caltrans Work Breakdown Structure Diagram

(Adapted from "Guide to Capital Project Delivery Workplan Standards" Release 10.2, 2012)

- Insufficient hours request. Although the major of units tends to request for more hours than less hours, it happens all the time that a unit did not request for enough hours due to not knowing the project scope well or lacking of experience. A project manager should not expect this to happen either since the work plan might look slim at the beginning but could turn into a program change request (PCR), which is a more complicated procedure.
- Conservative schedule. It's always safe to ask for a few more days to finish the assignment, isn't it? Such a typical thought could prolong the project schedule unnecessarily and significantly.
- Variation of estimates. It's common to see big variation of estimates between two similar projects just because different functional units provided the estimates.

To reduce the potential of over-budgeting or under-budgeting and minimize the variation of estimates, a PM needs to negotiate with task managers. However, according to Project Management Institute (PMI), Caltrans is a weak-matrix organization. Its project managers do not manage the manpower directly (3). This makes negotiation of hours even more challenge. Therefore, it's desirable to have some work plan templates that a PM or task manager can use as a baseline to develop a more realistic and reasonable work plan. The question now becomes can we have a baseline work plan if the project capital cost and type are given. Caltrans District 8 started this effort in February 2012. Massive work plan historical data had been collected, reviewed, categorized and further analyzed. Templates for most popular project types have been developed. Feedbacks from various functional units were collected and considered in the revised templates. FIGURE 2 shows the overall procedure of this effort. Details of each steps are further explained in the upcoming sections.

Work Plan Template Development Procedure

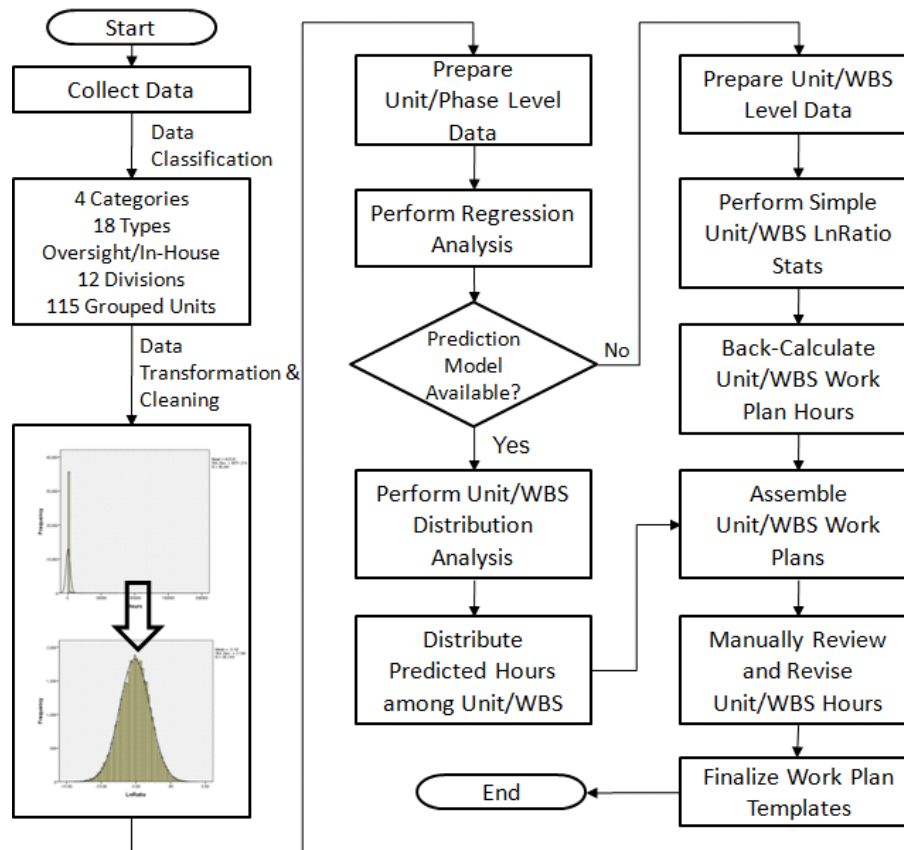


FIGURE 2 Work Plan Development Flowchart

DATA COLLECTION

A typical Caltrans project can be divided into five stages or phases: Project Initiation Document (PID), Project Approval and Environmental Document (PA&ED), Project Specifications and Estimate (PS&E), Right of Way (ROW), and Construction. A project phase can be further broken down into smaller tasks, i.e., WBS level 5 activities. A level 5 activity can be further broken down to level 6. The lowest level is Level 8. In this effort, only level 4 (phase level) and level 5 analysis were performed. For convenience, WBS level represents level 5 in this article.

Generally, the scope of work determines the need of effort. The more complicate a project the more hours it needs. It would be desirable if the all factors that have impact on support hours can be determined. In Caltrans, project information is stored in different systems, locally or centrally. District 8 used Work Plan Status (WPS) system backed by File Maker Pro (FMP) database to store and manage project information locally. Work plan hours were downloaded in December 1, 2011, which contains planned hours. The actual expenditure data are stored in Financial Data to Oracle (FIDO) before July 1, 2010, and in the Electronic Financial Information System (E-FIS) after. These data are on the servers in Caltrans headquarters, and are synchronized with District 8 WPS system once a week so the local can have a copy of all the actual expenditures. It is not unusual that a project may hire some consultant to help on some components. However, detailed consultant charges are not in WPS nor in FIDO/E-FIS. It is stored in another database operated by the Consultant Services Unit of District 8.

A project phase that had been finished will be considered a valid data entry. 1,620 projects corresponding to 5,810 project phases were collected, with earliest PA&ED date of November 26, 1990 and latest Construction Contract Acceptance (CCA) date of June 30, 2011. The following potential factors that may affect project support hours were collected:

TABLE 1 Project Type

ID	Project Type
01	Roadway
02	Maintenance
03	Mixed
04	Electrical
05	Drainage
06	Landscape
07	Barrier & Rails
08	Bridge
09	Building
10	Delineation
11	Retrofit
12	Relinquish
13	Bridge Maintenance
14	Walls
15	Study
16	Right of Way
17	Miscellaneous
18	Rail

Project Category

Projects were classified into four categories according to their cost and special nature: Major, Minor, Maintenance, and Streamlined Oversight Projects (SOP). A project does not belong to SOP or Maintenance was treated as either Major or Minor purely based on their construction capital cost. If the construction cost is over one million, it would be treated as Major; otherwise, it would be treated as Minor. Minor A (capital cost <\$250K) and Minor B (capital cost \$250K - \$1M) were not further distinguished in this analysis.

Project Type

Projects in each category can be further classified into types, such as Roadway, Bridge (Structure), Electrical, Landscape, Maintenance, or Mixed, etc. The scope of work of each candidate project was reviewed to determine the project type. Although it is desirable to have a project precisely classified into a type, there were challenges of doing so sometimes. TABLE 1 shows 18 project types suggested. If a project cannot fit in a specific type, Miscellaneous.

Oversight Status

A project can be either designed and managed in-house by Caltrans its own staff or by others, i.e. consultants. If a project is designed, managed by others and Caltrans only provided quality assurance and quality control (QA/QC), it is then called an oversight project. It is known there is a significant impact on work plan hours. In the analysis, 0 represents in-house, 1 represents oversight. In fact, oversight status should be specified for each project phase. Although in WPS, there is oversight status on the project list interface, it was found the information was not always complete. Most of the time it was due to an oversight project phase was not flagged. Design and/or construction cooperative agreement notes were reviewed to find and verify such information.

Agreements

1397 lines of project agreement were collected. The number of agreements was summarized for each candidate projects. Data were pulled out from agreements in WPS.

Remoteness

The distance between a project site and the District Office may affect the expense of a project and its schedule. Project sites 50 miles away from District 8 main office building located on 464 W 4th Street in the City of San Bernardino are considered remote. The remoteness of each project was manually assigned by reviewing the project jurisdiction and post miles.

Environmental Type

A project is supposed to have environmental clearance by default. Depending on if there is any federal involvement, a project might need California Environmental Quality Act (CEQA) clearance, or National Environmental Protection Act (NEPA) clearance, or both. Each level of CEQA and NEPA document represents a different level of effort, and was further coded to facilitate correlation analysis. Environmental Document (ED) information for 1,211 projects was collected from Statewide Environmental Evaluation System (STEVE) for analysis.

Storm Water Pollution Prevention Plan (SWPPP)

Generally, if a project needs a SWPPP during construction, more support hours will be expected. There are two types of Storm Water management plans: SWPPP, or Water Pollution Control Plan (WPCP). Such info was collected from Construction National Pollutant Discharge Elimination System (NPDES) group. 315 projects have WPCP and 189 projects have SWPPP.

Storm Water Data Report (SWDR)

SWDR is a design document for Storm Water management for a project. It may include permanent Best Management Practice (BMP) items. Such info was collected from District Storm Water unit. 747 Projects have prepared one or more SWDRs during various phases. 299 projects have a long-form SWDR, which is supposed to need more resource.

Right of Way

Right of Way info for 520 projects were collected from Right of Way unit. However, such data might not be considered complete. Most of the Right of Way data are still on the hard copies of Right of Way Data Sheets.

Construction Capital Cost

It is believed the more the capital the more the support cost will be. Final construction cost was collected from Caltrans headquarters and District 8 Construction Division. If HQ final authorized amount is available, it will be used as the capital cost. If HQ final authorized amount is not available, the winning bid amount will be used. If winning bid amount is not available, the cost estimate in WPS will be used.

Consultant Charges

If a project used consultant, the dollar amount spent will be captured in FIDO report. However, the hours may not be available. Consultant Service Units were contacted to obtain the consultant charges breakdown hours.

DATA PROCESSING AND CODING

Like most data analysis procedures, project data were preprocessed before they can be used for analysis. Grouping, summarizing, filtering, prioritizing, transformation, normalization, and coding techniques were employed to improve the data quality.

Due to limited amount of data for each functional unit, data were grouped for units with the same functionality. For example, individual PMs will be treated as a general PM group. The number of hours are summed up for phases and activities respectively for each project. More than 25,000 lines of consultant charges were obtained. Aggregated hours were added back to the in-house charges. Data were further reviewed to remove invalid entries. For capital costs, the final payment amount superseded contract bid amount, the contract bid amount supersedes the estimated amount. The number of hours were divided by project capital cost to get hour/capital ratio for further investigation of the distribution shape.

DATA ANALYSIS AND FINDINGS

The goal of this data analysis is to find out the relationship between the number of support hours and project capital cost associated with other potential influential factors such as project ED type, SWDR requirement, and so on. For this purpose, the project data collected are separated into 4 categories, 18 types, and two statuses (in-house or oversight). The development procedure is shown in FIGURE 1. The first step is to look at the distribution of all the parameters collected. A frequency analysis was performed. As shown in FIGURE 3, the support hour itself is skewed even after converted into ratio.

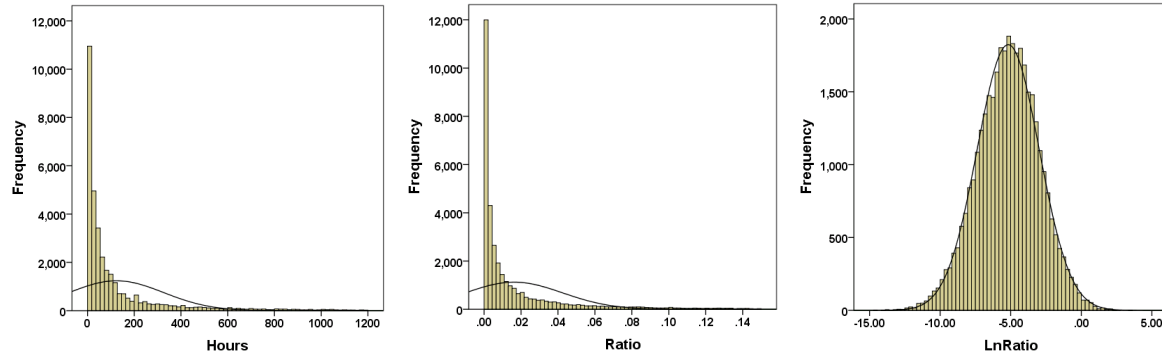


FIGURE 3 Distribution of Support Hours

However, the further natural logarithm transformation ($LnRatio$) indicates it approximately follows a normal distribution after conversion and transformation.

SPSS® software was employed during frequency, correlation, and modeling analysis. Various regression models, such as linear, quadratic, and loglinear, were tested. Unfortunately, none of the collected parameters other than the capital cost is significant in these models. One of the reasons could be the data were over categorized and the influential parameters no longer play important roles in these models.

It was further confirmed that the number of support hours is highly correlated to project capital cost, either directly or indirectly in a transformed format. Analysis indicated that $LnRatio$ follows a decent normal distribution, which makes it possible to employ simple statistic technique to estimate the expected support hours for the cases when no regression models can be obtained.

Regression Models

It is always desirable if the number of hours can be predicted given project scope of work and characteristics. To develop a regression model, a proper amount of data is needed. It was found there were not enough data points to develop a reliable model at WBS level 5. However, there are enough data points at phase level (level 4) for most units. Regression analysis was performed for the units that play important roles in project development and support. Analysis was conducted separately for projects in different categories and types, as well as in-house design or oversight. As an example, TABLE 2 shows the models for some of these units including project managers in project management (all phases), design senior in design (PS&E), and construction resident engineer during construction of major roadway in-house projects.

TABLE 2 Regression Models¹

Phase	Unit	Model Expressions	R^2	p -value	Sample Size
PS&E	Project Manager	$Hours = 79.2 + 0.105735 * \sqrt{Capital}$	0.216	0.000	87
Const.	Project Manager	$Hours = 44.6 + 0.002703 * \sqrt{Capital}$	0.567	0.000	71
PS&E	Design Senior	$Hours = 308.5 + 0.996857 * \sqrt{Capital}$	0.171	0.001	85
Const.	Resident Engineer	$Hours = -174.9 + 2.043172 * \sqrt{Capital}$	0.646	0.000	77

¹. Capital is the construction cost in dollars. "Const" stands for "Construction". Formula is only valid for projects with capital cost over \$1,000,000.

It is noticed that some models have a relatively lower R^2 values than others. Is such a model acceptable? This question will be discussed later.

Once the regression model is obtained, the hours can be easily distributed among level 5 WBS tasks. FIGURE 4 shows the average distribution percentages for the hours of design seniors among the tasks. For example, given a roadway project with a capital construction cost of \$10,000,000, if designed by Caltrans, the hours needed for the design senior during PS&E phase can be estimated as:

$$\text{Hours} = 308.5 + 0.996857 * \sqrt{10,000,000} \approx 3,461$$

The above number of hours is for roadway design unit only. It does not including the hours for other supporting units, such as electrical design, storm water, landscape, hydraulics, traffic design, traffic operations and so on.

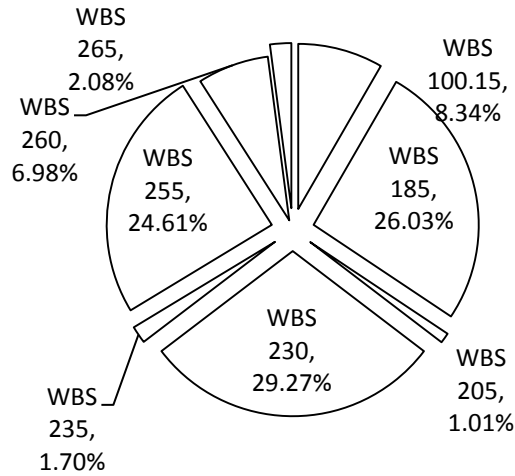


FIGURE 4 Resource Distribution

Simple Statistical Analysis

As mentioned earlier, regression model is not always approachable. A simple statistical analysis on the logarithm transformed support to capital ratio (LnRatio) was performed when this situation happens. Once the minimum, maximum, and average are obtained, the Program Evaluation and Review Technique (PERT) can be computed. PERT was developed in the Navy's Special Projects Office and first included the September 1959 issue of Operations Research (4). PERT uses the most pessimistic, most likely, and optimistic estimates to obtain an average estimate of a resource demand. It has been widely used in resource planning in project management. The standard deviation of the estimated PERT value can also be easily calculated. The number of hours is then back-calculated from the estimated LnRatio given the construction capital cost in dollars using the following formula:

$$\text{Hours} = \exp(\text{LnRatio}) * \text{Capital},$$

where Capital is in \$1,000. TABLE 3 shows the statistical results of traffic design for major roadway in-house projects since no regression model could be obtained:

TABLE 3 Statistical Results of LnRatio for Major Roadway In-House Project (Traffic Design)

WBS	LnRatio						Sample Size
	Min	Max	Average	Std. Dev.	Median	PERT	
100.15	-8.4710201	-6.3133324	-7.3723805	0.6289134	-7.3038886	-7.3333178	20
185	-7.8359547	-3.7480324	-5.8864358	1.5458101	-5.7569769	-5.7686491	12
230	-4.6509176	-1.4991615	-2.9554278	0.8810723	-2.8997053	-2.9581501	44
255	-6.7479784	-3.6116824	-5.18851	0.8345558	-5.1791977	-5.1794086	33

For example, for the same roadway project with a construction capital of \$10,000,000, the hours needed for traffic design would approximately be 7 hours for WBS 100.15 (Project Management), 31 hours for WBS 185 (30% PS&E), 519 hours for WBS 230 (60% PS&E), and 56 hours for WBS 255 (95% PS&E). If preferred, a range of hours can be calculated too.

WORK PLAN TEMPLATES

Assembling Work Plan

After the number of hours are obtained either from regression models or from simple statistical analysis, work plan templates can be preliminarily assembled. Given a project category, type, construction cost,

and oversight status, the hours need for each unit involved in the project can be estimated from either the regression equations or the statistical numbers.

Refining

The template is further reviewed to remove unnecessary unit/WBS combinations. Interview with each unit is recommended to further refine the templates. Once the template is agreed by all the units, it can be upload to Caltrans Project Resource and Schedule Management (PRSM) system as a project baseline work plan. The overall procedure was shown in FIGURE 1.

Verification

The template was compared with similar projects to identify abnormal cases. Such a two-way comparison indicated the templates developed look reasonable to most of the experienced project managers. Meanwhile, project managers also found that the template is a tool to help them identify issues in their project work plans.

Application

One of the applications is to provide a baseline work plan for each existing project already having a work plan so the PM can identify abnormal resource planning cases. A baseline work plan review report was generated for each project and was sent to its PM for review and comparison. Excessively over or under planned resources were flagged and further reviewed by PM. TM was contacted to provide justifications. Project work plans were revised if necessary. A work plan reviewing tool was also developed in WPS to let the user estimate the PERT hours that a level 5 task may need. These tools were welcomed by PMs.

The other application and the major application of this effort to provide a work plan template for new projects that have no work plans yet. Given project category, type, oversight status, and construction capital cost, a baseline work plan can be estimated. A PM and TM can further tweak the work plan according to project specific features. It could save a lot of time for the PM and TM in resource estimating.

Updating

It is suggested to repeat the analysis once a year to obtain an updated statistical results. Since the procedure has been established and the shape of the data has been determined, it will be much easier than this effort.

CONCLUSIONS AND DISCUSSION

Analysis indicated the support hours to capital cost ratio approximately follows a normal distribution. Regression models are available for some units at phase level only. Support hours obtained from the classical statistical analysis at level 5 are reasonable and acceptable when regression models are not available. Work plans obtained could help PMs and TMs in two ways. One can either compare the existing work plan hours versus the expected hours or one can draft a baseline work plan based on the project scope and capital cost.

Influential Factors

Although it is desirable to develop a prediction model with all influential factors included for work plan and schedule development, it is not always practical in reality. It is noticed that only the capital cost has a significant impact on support hours and schedules. This seems to contradict with our intuition. In fact, because projects are classified into very specific small groups, most of the impact a factor has on a project is taken into account.

Validity

As shown in TABLE 2, it is noticed that some models have a relatively lower R^2 values than others. Is such a model acceptable? R^2 is the percent of variation in the dependent variable explained by the

independent variables included in the model (5). In this effort, the dependent variable is the number of support hours and the independent variable is the construction capital cost. That is to say, for a major roadway project designed and managed by Caltrans, 17.1% of the variation in design hours can be explained by the construction capital cost. This means there are other factors that influence this relationship. Although the remaining variation in design hours cannot be explained by construction capital cost, it is the most important factor in estimating the design support hours. Since the model is not a time series and the p -value test is significant at 0.001 level the model can still be considered acceptable. The other contributing factors might have been accounted for in categorizations and classifications.

Schedule Analysis

Resource planning is not only about how much money will be spent but also about how fast the money will be spent. Time management or schedule management is part of the overall cost management in project management. To better estimate the duration of an activity, a schedule historical analysis was performed. This effort is to analyze historical schedule data at WBS Level 5 and find the pattern in project schedules. The other purpose is to compare a project schedule with the schedule of another project.

To perform this analysis, schedule data were downloaded from WBS. Duration in calendars was calculated using the start and end dates of each WBS Level 5 activity. Oversight and in-house projects were separated. Preliminary analysis indicated the duration to capital cost does not follow a normal distribution. Fortunately, the logarithm transformation worked again here. In fact, the logarithm of the ratio of duration to capital forms a bell curve in a pretty good shape as shown in FIGURE 4.

Improvements and Recommendation

It was noticed that the data collected ranged from 1990 to 2011. The construction capital cost was not normalized according to the construction price index (CPI). It can be expected that the regression model might be improved when CPI is considered. It is recommended to repeat the analysis annually using more updated data and consider CPI.

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