Management of Engineering/Design Phase

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Abstract: This paper critiques the common practice in managing and tracking the engineering/design phase of major projects and presents an alternative integrated approach. It addresses in detail the development of control budget, project schedule, progress measurement procedure, and project data base to accomplish full cost and scheduling integration. Cost/schedule integration is achieved by: (1) Developing control budget based on the project work breakdown structure (WBS); (2) identifying all project documents on the project WBS; (3) grouping the project documents in work packages; (4) making reference to the work packages on the project schedule; (5) determining distinguishable events (control points) for each package; and (6) using the earned value concept as the means for progress measurement. The procedure is capable of objectively determining the progress of the scheduling activities, performance indices, and budget forecasts. A numerical example and a case study are provided to illustrate the implementation and computational procedure of the presented approach.

Introduction

A survey of the literature suggests that researchers have focused their attention on addressing the management of the construction phase more than the management of the engineering phase of a project. The reason, perhaps, is that the cost associated with the engineering phase is only 3–10% of the total project cost. However, this relatively small percentage of the total cost can amount to a large sum of money on a megaproject. Regardless of the actual dollar figures, the cost of the engineering phase is a major source of income for architecture/engineering (A/E) firms. The management approach during the engineering phase may determine the gains and losses for these firms. The fact that a good portion of the engineering services are done under a term contract, a service order, or a similar contractual arrangement obliging the owner to pay for all man-hours used, should not lead to ineffective management of engineering services.

The objective of this paper is to provide a practical guide to cost and scheduling integration approach for managing the engineering phase of major projects. Such an approach should benefit the engineering/design professionals and owners by maximizing the output of each dollar spent for engineering services.

Current Practice

The common practice of depending, almost solely, on the drawing control log (DCL) as a control tool should be reevaluated. The DCL is a project document listing the project drawings by number and title. It usually includes information such as man-hours budgeted, man-hours used, forecast of man-hours to completion, percent complete, planned start and finish dates, and

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Drawing No./ Description	Budget Used (Mhr)	Percent Complete	Forecast (Mhr)	Planned Dates Start	Finish	Actual Dates Start	Finish

FIG. 1. **Drawing Control Log**

actual start and finish dates for each drawing, as shown in Fig. 1. This information is certainly needed to track the engineering activities in an A/E firm, but it should be realized that the DCL is only a reporting tool and not an information-generating tool. For instance, key data such as man-hour forecasts and percent complete are input data that are often determined subjectively and entered on the DCL. Planned dates also are often subjective input to the DCL. These dates usually reflect the judgement of the person in charge of developing the DCL or in charge of managing the engineering activities. It is sufficient to assign a drawing number and a title to show an actual start date on a drawing. With a start date, subjective data can be entered on the DCL.

Even if the planned dates are generated by some scheduling techniques (a bar chart or a scheduling network), the impact of actual progress, actual expenditures, and actual dates for each drawing on the project's milestones, the project's completion date, and the criticality of the project's activities are not apparent from the DCL.

In current practice, the budget for a drawing is frequently consumed before a drawing is declared over budget. Because the additional budget (man-hours) required to complete such a drawing at this stage is often relatively small, nothing may look too alarming. Man-hour forecasts, therefore, are usually inaccurate and are adjusted after the fact.

The current practice treats every drawing as an independent task without systematic integration with other project documents in terms of budget, schedule, progress, performance, and forecasts. The current use of the DCL gives a false impression of controlling the engineering activities, while in reality the DCL is a historical record for each drawing. We get back only what we subjectively entered on the DCL and thus no real project control exists over the development of the project documents.

Proposed Management System

It is important to note that man-hours in an A/E firm, during the engineering phase of a project, are typically used to produce four types of project documents. These are drawings, specifications, material documents, and manuals (project books). The material documents refer to material take-off sheets (MTOs), data sheets, purchase requisitions (PRs), and purchase orders (POs). The project books refer to operation manuals, maintenance manuals, welding procedures, piling procedures, and like items.

Although the development of project drawings may typically require 50–60% of the total budgeted man-hours, the other documents must be adequately addressed to ensure effective project management and successful project completion. A complete control budget has to include the budget required

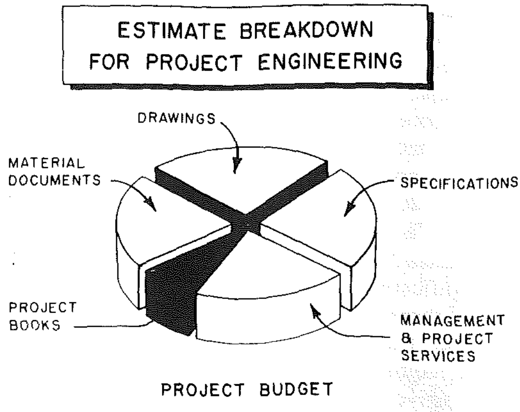

FIG. 2. Components of Control Budget

for the development of the four types of project documents as well as the budget required for the project management and services, as indicated in Fig. 2. Management and project services include engineering analysis, calculations, quality control, supervision, project management, and similar activities.

An effective management system integrates the project's budget, schedule, and progress measurements. This can be accomplished by observing the following points:

1. The control budget is based on a work breakdown structure (WBS) similar to that shown in Fig. 3. In this manner, the project is viewed in terms of its facilities, engineering disciplines, and engineering documents.
2. All four types of engineering documents are referenced on the project's schedule.
3. A quantitative method for progress measurement is adopted as an integral part of the management scheme.

Control Budget

The project management team (PMT) should be able to identify the number of documents (i.e., drawings, specifications, material documents, and

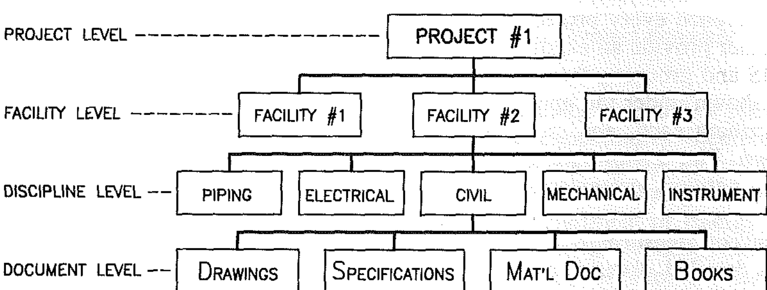

FIG. 3. Work Breakdown Structure for Engineering/Design Phase

project books) needed to describe the work required in each discipline for every facility. By identifying the number of documents at this level of detail on the WBS, the PMT can generate a definitive estimate detailing the man-hours needed by type of personnel (i.e., design/engineering, drafting, purchasing, supporting services) required for the identified documents. This also makes it feasible to check and verify the accuracy of the man-hours estimated for each discipline because of the limited number of documents involved at this level of detail and their association with a particular facility. Further, this approach facilitates the identification of certain documents that can be used as a "parent" model that needs to be copied for other facilities with or without modification.

The summation of these man-hour components, determines the budget for what we may call the "direct costs" for the engineering phase of a project. Add on the budget requirements for general project supervision and supporting services to arrive at a complete control budget. The add-on component of the budget may be estimated as a percentage of the direct costs. Based on limited data, the writer found this percentage to vary from 18% to 35%. More data is needed to correlate the percentage with project size, type, complexity, repetition, and project environment among other possible variables.

Identifying the budget components with a specific facility, discipline, document, and type of effort (i.e., drafting, design, procurement, supporting services, etc.) is advantageous not only for project tracking but also for other reasons. It creates a more accurate data base for estimating future projects, determines the type of personnel requirements, and provides a tool for allocating design phase costs to specific facilitates for depreciation and tax purposes.

In this paper, reference to engineering documents will always mean reference to drawings (D), specifications (S), material documents (M), and manuals/books (B). The term *drawing control log* (DCL) will be replaced by *control log* (CL) to indicate the inclusion of the engineering documents other than just drawings. Each document, therefore, has to be identified with a package number and a scheduling activity number as will be discussed later in structuring the data-base file.

Scheduling of Engineering Documents

In the presented system, the engineering documents have to be identified, organized, and grouped in several packages that can be easily referenced on the project's schedule. This is necessary because it is not practically feasible to reference every project document on the project schedule. Figs. 4 and 5 together provide an example for organizing the engineering documents using WBS and grouping them on a scheduling network. In Fig. 4, the documents are shown under the appropriate types, assigned a numerical code uniquely describing each, and grouped in packages based on the logic of their execution. Fig. 5 shows pictorially the sequencing of these packages in a scheduling network presentation. The packages constitute the network activities.

Progress Measurement

A detailed discussion of the basic requirements for establishing a quantitative measurement of work progress is provided elsewhere (Eldin 1989). In the system presented, the earned value concept is used as the basis for

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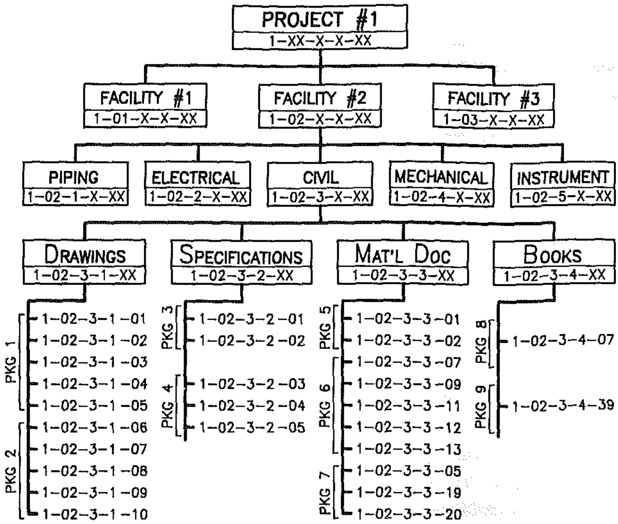

FIG. 4. Identification of Engineering Documents on Project WBS

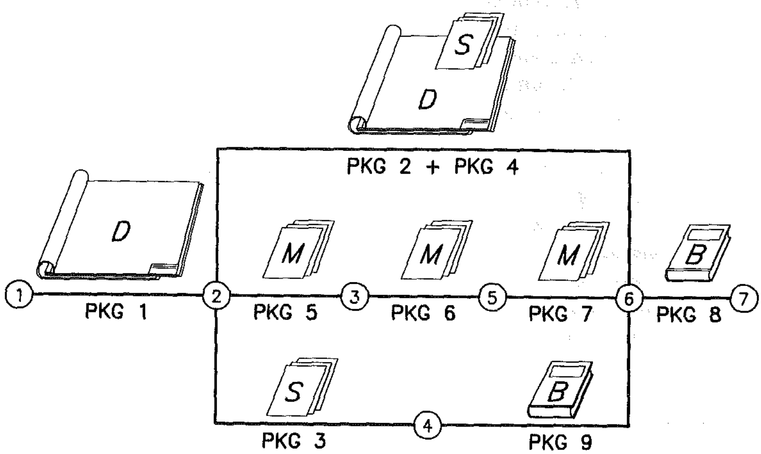

FIG. 5. Reference of Engineering Documents on Project Schedule

progress evaluation. The earned value (EV) is the amount budgeted or planned to reach a specific goal regardless of the actual expenditures incurred in reaching that goal. This concept was first implemented in the early 1950s by the Energy Research and Development Agency (ERDA) on government projects, and its use has been continued by The Department of Energy and several other government agencies (Rogers, 1979). The EV concept has also gained popularity in the private industry in the last decade ("Project Control" 1988). However, applications of this concept were mostly performed at a summary level and little have been published to date to assist engineering

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TABLE 1. Control Points and Earning Rules

Control point number (1)	Earning percentage (%) (2)	Description of control point (3)
1	5	Drawing started (title block complete)
2	45	Issued for engineering review
3	20	Checked and signed by engineer
4	5	Checked and signed by project manager
5	20	Client comments incorporated
6	5	Issued for bid/construction
Total	100	

firms in implementing the EV concept throughout the engineering/design phase.

The earned value concept can be successfully implemented in the engineering/design phase by identifying distinguishable events (control points) throughout the life cycle of the engineering documents and by developing earning rules for reaching these events. For example, the control points for a drawing may include: drawing started (drawing number assigned and title block complete); issued for engineering review; checked and signed by the responsible engineer; checked and signed by project manager, client comments incorporated; and issued for bid/construction. The earning rules assign a value to each control point. The earning values can be expressed as percentages of the document's budget, duration, or another arbitrary work unit. The control points and earning rules for this example can be demonstrated in Table 1.

Different control points and earning rules need to be developed for each type of engineering document. Typical sets of control points and earning percentages will soon develop once a firm adopts this technique and obtains feedback from completed projects. Standardized control points and earning percentages may become available when this technique receives wide application in the industry.

The status of each control point is determined by examining whether the control point was accomplished. A document earns fully the percentage assigned to a control point only when that portion is completed. Partial credit may also be allowed if appropriate. The work progress (percentage of completion) and the earned value for a document are determined by the following equations:

$$\text{percent complete } (PC) = \Sigma(CP_i) \cdot (A_i) \quad (1)$$

$$\text{earned value } (EV) = PC \times \text{current budget of subject work item} \quad (2)$$

where PC = the percent complete for the document under consideration; (CP_i) = the earning percentage associated with control point number i; and (A_i) = the actual progress accomplished on control point number i expressed in percent.

The use of this procedure is appreciated once an attempt is made to determine work progress at higher levels on the project hierarchy. For instance, if one attempts to determine the progress of a particular package, one adds the earned value of all documents included in that package and divides this

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total by the total budget for the package. This computation is expressed by the following equation:

$$\text{percent complete } (PC) = \frac{\Sigma\, EV \text{ for all documents in a package}}{\text{total budget for the package}} \quad \ldots\ldots\ldots\ldots \quad (3)$$

It should be noted that Eq. 3, which is only another form of Eq. 2, is applicable at all levels of control on the WBS. To determine the progress of a discipline, the summation of the EV for all documents making such a discipline is divided by the budget of the discipline. Similarly, the progress of an entire facility is determined by dividing the EV for all disciplines making the facility by the budget of the facility. Eq. 3 simplifies the computations of the PC at any level on the WBS, and makes the use of this procedure advantageous.

Data Base

Fig. 6 depicts the categories of data (document identification, scheduling reference, budget data, percentages for control points, and status of control points) required to establish the data base for the proposed system. Document identification numbers should be designed to facilitate data retrieval at any level on the project's WBS by describing systematically each document that exists on the control log. As shown in Fig. 6, each digit or a group of digits address a certain level on the WBS hierarchy. An illustration of the numbering scheme is shown in Fig. 4. A full title of each document can also be provided to improve the input and retrieval of project data. The second category of data addresses the reference of each document to its scheduling package and scheduling activity number. The third category contains the budget and the actual cumulative to-date expenditure for each document. Budget data can be expressed in terms of man-hours, dollars, or any other work units depending on the user's setup and preference. The fourth consists of the earning rules expressed in percentages of the budget assigned to each control point as explained previously. The fifth category of data involves the actual status of each control point.

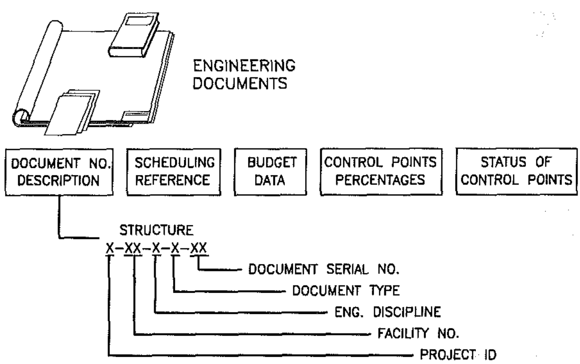

FIG. 6. Layout of Data Base

NUMERICAL EXAMPLE

Fig. 7 provides a numerical illustration for a data-base file for an example project having the WBS shown in Fig. 4. All categories of data shown in Fig. 7 are input data. Column 1 contains the identification number assigned to each document, structured in the manner described. Column 2 provides the document's scheduling references in terms of its package number and scheduling activity number. Columns 3 and 4 list, respectively, the budget and the cumulative to-date expenditures for each document. Column 5 provides the number of control points used for each document and their earning percentages. Column 6 shows the actual status of each control point.

Fig. 8 shows the type of management information that can be computed from the data base. As shown in Fig. 8, it includes:

1. Percent complete (PC) for each document, package, discipline, facility, and the entire project (column 7).
2. Earned value (EV) on each document, discipline, facility, and the entire project (column 8).
3. Performance (PI) for each document, package, discipline, facility, and the entire project (column 9).
4. Budget forecast to complete each document, package, discipline, facility, and the entire project (column 10).

COL #1	COL #2		COL#3	COL#4	COL #5						COL #6					
Document	Reference		Item's	Todate	-----Assigned % to CP-----						---Actual % Compl on CP---					
Number	Pkg	Schd	Budget	Actual	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6
1-02-3-D-01	1	1-2	140	128	5	45	20	5	20	5	100	100	100	100	100	100
1-02-3-D-02	1	1-2	70	100	5	45	20	5	20	5	100	100	100	100	100	100
1-02-3-D-03	1	1-2	70	70	5	45	20	5	20	5	100	100	100	100	50	0
1-02-3-D-04	1	1-2	50	55	5	45	20	5	20	5	100	100	100	100	100	100
1-02-3-D-05	1	1-2	40	30	5	45	20	5	20	5	100	100	100	100	100	0
1-02-3-D-12	2	2-6	60	46	5	45	20	5	20	5	100	100	100	0	0	0
1-02-3-D-15	2	2-6	40	33	5	45	20	5	20	5	100	100	100	100	50	0
1-02-3-D-26	2	2-6	40	15	5	45	20	5	20	5	100	100	100	100	100	100
1-02-3-S-01	3	2-4	80	8	20	15	40	5	10	-	100	100	0	0	0	-
1-02-3-S-03	3	2-4	65	24	20	15	40	5	10	-	100	0	0	0	0	-
1-02-3-S-07	4	2-6	25	15	20	15	40	5	10	10	100	100	100	100	0	0
1-02-3-S-08	4	2-6	15	6	20	15	40	5	10	10	100	100	0	0	0	0
1-02-3-S-10	4	2-6	40	22	20	15	40	5	10	10	100	100	100	100	80	0
1-02-3-M-01	5	2-3	15	15	25	25	20	30	-	-	100	100	100	100	-	-
1-02-3-M-02	5	2-3	15	10	25	25	20	30	-	-	100	100	100	100	-	-
1-02-3-M-03	5	2-3	50	8	25	25	20	30	-	-	100	0	0	0	-	-
1-02-3-M-04	6	3-5	20	28	5	30	20	25	20	-	100	100	100	100	50	-
1-02-3-M-05	6	3-5	15	18	5	45	20	25	20	-	100	100	100	100	100	-
1-02-3-M-07	6	3-5	20	20	5	45	20	25	20	-	100	100	100	100	100	-
1-02-3-M-10	6	3-5	40	38	5	45	20	25	20	-	100	100	100	100	100	-
1-02-3-M-11	7	5-6	20	18	25	25	20	30	-	-	100	100	100	100	-	-
1-02-3-M-12	7	5-6	20	10	25	25	20	30	-	-	100	30	0	0	-	-
1-02-3-M-15	7	5-6	20	18	25	25	20	30	-	-	100	100	100	100	-	-
1-02-3-B-01	8	6-7	160	100	25	25	25	25	-	-	100	100	100	100	-	-
1-02-3-B-02	9	4-6	40	5	25	25	25	25	-	-	100	0	0	0	-	-

FIG. 7. Layout of Data Base

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INPUT DATA					COMPUTED INFORMATION				
COL #1	COL #2		COL #3	COL #4	COL #7	COL #8	COL #9	COL #10	COL #11
Document Number	Reference Pkg	Schd	Item's Budget	Todate Actual	Percent Complete	Earned Value	Per.Ind. (PI)	Current Forecast	Current Variance
1-02-3-D-01	1	1-2	140	128	100	140	1.09	100	12
1-02-3-D-02	1	1-2	70	100	100	70	0.70	100	-30
1-02-3-D-03	1	1-2	70	70	85	60	0.86	82	-12
1-02-3-D-04	1	1-2	50	55	100	50	0.91	55	- 5
1-02-3-D-05	1	1-2	40	30	95	38	1.27	32	8
PKG 1 (SCHED.ACTIV 1-2)			370	383	97	358	0.93	397	-27
1-02-3-D-12	2	2-6	60	46	70	42	0.91	66	- 6
1-02-3-D-15	2	2-6	40	33	85	34	1.00	39	1
1-02-3-D-26	2	2-6	40	15	100	40	2.67	15	25
PKG 2			140	94	83	116	1.23	120	20
1-02-3-S-01	3	2-4	80	8	35	28	3.5	23	57
1-02-3-S-03	3	2-4	65	24	20	13	0.54	120	-55
PKG 3 (SCHED.ACTIV 2-4)			145	32	28	41	1.28	143	2
1-02-3-S-07	4	2-6	25	15	80	20	1.3	19	6
1-02-3-S-08	4	2-6	15	6	35	5	0.9	17	- 2
1-02-3-S-10	4	2-6	40	22	88	35	1.6	25	15
PKG 4			80	43	75	60	1.4	61	19
(SCHED.ACTIV 2-6)			220	137	80	176	1.28	180	40
1-02-3-M-01	5	2-3	15	15	100	15	1.00	15	0
1-02-3-M-02	5	2-3	15	10	100	15	1.5	10	5
1-02-3-M-03	5	2-3	50	8	25	13	1.6	32	18
PKG 5 (SCHED.ACTIV 2-3)			80	46	53	43	1.3	57	23
1-02-3-M-04	6	3-5	20	28	90	18	0.64	31	-11
1-02-3-M-05	6	3-5	15	18	100	15	0.83	18	- 3
1-02-3-M-07	6	3-5	20	20	100	20	1.00	20	0
1-02-3-M-10	6	3-5	40	38	100	40	1.05	38	2
PKG 6 (SCHED.ACTIV 3-5)			95	104	97	93	0.89	107	-12
1-02-3-M-11	7	5-6	20	18	100	20	1.11	18	2
1-02-3-M-12	7	5-6	20	10	33	7	0.65	31	-11
1-02-3-M-15	7	5-6	20	18	100	20	1.11	18	2
PKG 7 (SCHED.ACTIV 5-6)			60	46	77	47	1.01	67	- 7
1-02-3-B-01	8	6-7	160	100	100	160	1.6	100	60
1-02-3-B-02	9	4-6	40	5	25	10	2.0	20	20
All Drawings			510	477	93	474	0.99	517	- 7
All Specifications			225	75	45	101	1.35	204	21
All Material Documents			235	196	78	183	0.93	231	4
All Project Books			200	105	85	170	1.62	120	80
Entire Project			1170	853	79	928	1.09	10712	98

FIG. 8. Information Generated

5. Budget variance to complete each document, package, discipline, facility, and the entire project (column 11).

The computations are simple, but the use of a computer is recommended. The computation procedure is a good application for electronic spread sheets and data bases. In reference to Figs. 7 and 8, the computation procedure is as follows:

1. Multiply the contents of columns 5 and 6 satisfying the expression: $\Sigma(CP_i)(A_i)$. The result is the progress measured (percent complete) on each document, which is placed in column 7.
2. Multiply the contents of columns 3 and 7. The product is the earned value, which is placed in column 8.
3. Divide the contents of column 7 by column 3. The product is the performance indices, which is placed in column 9.
4. Divide the contents of column 3 by column 9. The result is the budget forecast, based on the computed performance indices, which is placed in column 10.
5. Subtract the contents of column 10 from that of column 4 to determine current budget variance, which is placed in column 11.

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6. Subtotal the earned values (column 8) and the budgeted amounts (column 3) for the various levels of summary at which progress is to be measured. Divide the subtotals (column 8/column 3) to determine the work progress achieved at that level of summary.

7. Subtotal the earned value (column 8) and the actual expenditures (column 4) for the various levels of summary at which progress is to be measured. Divide the subtotals (column 8/column 4) to determine the performance indices at that level of summary.

8. Subtotal the budget (column 3) for the various levels of summary at which progress is to be measured by the PI calculated as shown in step 7 to determine the current forecast at that level of summary.

9. Subtotal current variance for the various levels of summary at which progress is to be measured to determine the current budget variance at that level of summary.

Advantages and Benefits

The presented approach provides an integrated and quantitative management-control approach for tracking the engineering phase of a project. The computed percent complete for the various packages form a more objective basis for updating the project schedule in contrast to the common practice of subjective assessment of work progress. In return, more meaningful scheduling dates can be reported on the CL from every schedule update. The system allows the designer or the draftsperson the desired flexibility in managing the detailed schedule for each document within a package. However, the system sets the basis for and controls the determination of the work progress, scheduling dates, performance, and budget forecast for each package.

The budget forecasts are also determined in an objective manner based on the actual performance. Performance indices are computed based on cumulative data that reduce the tendency of the forecast to be affected by a single bad period. In this systematic approach, the PMT will be able to determine quantitatively the impact of the computed man-hours variance (i.e., difference between original budget and current forecast) not only on project cost but also on project milestones and completion date. Performance indices at the document and package level can also be used in evaluating personnel performance and in creating a self-driven motivation for the highest possible performance.

The simplicity of the computations makes the procedure practical and justifiable even for small projects. With the availability of several data-base and spread-sheet programs, the system can be easily implemented on a microcomputer without a need for advanced programming skills. The system takes advantage of the spread-sheet layout where the user sees and easily accesses all data and information.

The use of this system provides a means for verifying the project budget and justifying budget modifications for owners and design professionals. It can also relieve senior project staff from routine tasks such as assessing work progress, and thus allows devotion of additional time to the more significant management activities. With this procedure, determination of work progress and assessment of project status can be delegated to a junior engineer. It should be noted that devotion of considerable time to routine tasks by senior project personnel is a recognized current problem (Russell 1982). Delegating such a time-consuming responsibility to a junior PMT member to free a senior staff member obviously enhances cost effectiveness and improves resource utilization.

Case Study

The described procedure was employed for tracking the engineering phase of an oil-production offshore project. The project involved the upgrading of existing tie-in platforms, production platforms, and an onshore receiving facility. It included upgrading the existing facilities to the current safety, environmental, maintenance, and operation standards, and providing a permanent, centralized well test capability at the tie-in platforms by utilizing a test barge.

The owner's PMT consisted of nine members and was intimately involved in managing the project with the A/E's PMT. There was apparent resistance from the A/E's PMT to the implementation of this procedure in the beginning. There was a concern of making things too visible for the owner and a fear of using the PI as a personnel evaluation criterion. However, the persistence of the owner's PMT with the promotion of the partnering and one-team attitude contributed to the success of the implementation and maintenance of the tracking system. The A/E's PMT showed strong commitment to the system once it became operational.

The control budget was developed based on the project WBS as shown in Figs. 9, 10, and 11. The project documents were detailed for the disciplines in each facility and the types of man-hours were determined accordingly. The budget, which amounted to little over 22,000 man-hours, was valued at approximately $1,000,000 and scheduled for completion in six months. A data base similar to that shown in Fig. 7 was developed using a coding system and a packaging scheme similar to that shown in Figs. 4 and 5. A program was written for a Mattier computer system to process the data as described in the procedure.

The additional cost of implementing and maintaining the procedure was approximately $14,000, and the system was operational about one month

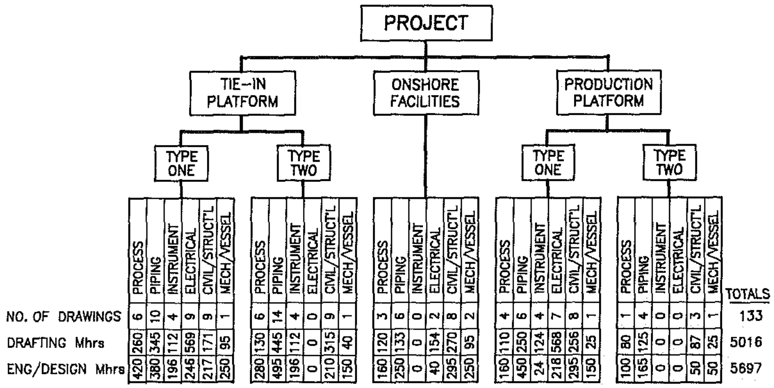
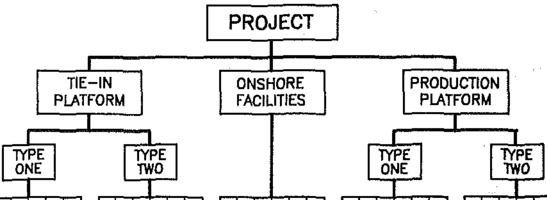


FIG. 9. Engineering and Drafting Man-Hours for Drawings



TIE-IN PLATFORM — TYPE ONE

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF MTOs	0	60	6	54	54	5
NO. OF DATA SHEETS	0	40	2	12	20	1
NO. OF PRs	0	20	4	10	18	9
PROCUREMENT Mhrs	0	200	40	100	180	90
DRAFTING Mhrs	0	400	20	120	200	10
ENG/DESIGN Mhrs	0	240	24	216	216	20

TIE-IN PLATFORM — TYPE TWO

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF MTOs	0	14	1	9	9	2
NO. OF DATA SHEETS	0	0	0	0	0	0
NO. OF PRs	0	6	4	10	8	9
PROCUREMENT Mhrs	0	60	40	100	80	90
DRAFTING Mhrs	0	0	0	0	0	0
ENG/DESIGN Mhrs	0	56	4	36	36	8

ONSHORE FACILITIES

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF MTOs	0	6	1	2	5	2
NO. OF DATA SHEETS	0	0	0	0	0	0
NO. OF PRs	0	15	5	9	9	8
PROCUREMENT Mhrs	0	150	50	90	90	80
DRAFTING Mhrs	0	0	0	0	0	0
ENG/DESIGN Mhrs	0	24	4	8	20	8

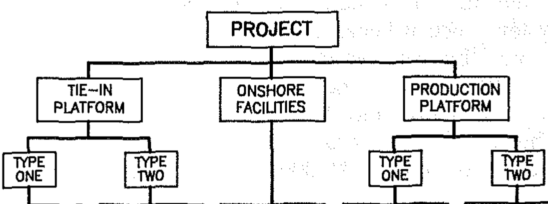
PRODUCTION PLATFORM — TYPE ONE

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF MTOs	0	65	11	55	53	11
NO. OF DATA SHEETS	0	20	0	10	50	0
NO. OF PRs	0	4	4	8	8	5
PROCUREMENT Mhrs	0	40	40	80	80	50
DRAFTING Mhrs	0	200	0	100	500	0
ENG/DESIGN Mhrs	0	260	44	220	212	44

PRODUCTION PLATFORM — TYPE TWO

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL	TOTALS
NO. OF MTOs	0	32	8	40	24	8	537
NO. OF DATA SHEETS	0	20	0	12	24	0	211
NO. OF PRs	0	8	2	8	10	5	206
PROCUREMENT Mhrs	0	80	20	80	100	50	2060
DRAFTING Mhrs	0	200	0	120	240	0	2110
ENG/DESIGN Mhrs	0	128	32	160	96	32	2148

FIG. 10. Engineering, Drafting, and Procurement Man-Hours for Material Documents



TIE-IN PLATFORM — TYPE ONE

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF SPECIFICATIONS	0	1	6	15	0	9
NO. OF BOOKS/MANUALS	2	5	2	7	1	3
SUPPORTING Mhrs	120	100	40	140	80	75
ENG/DESIGN Mhrs	80	140	280	210	20	300

TIE-IN PLATFORM — TYPE TWO

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF SPECIFICATIONS	7	0	6	16	0	9
NO. OF BOOKS/MANUALS	2	5	2	7	1	3
SUPPORTING Mhrs	120	100	40	140	80	75
ENG/DESIGN Mhrs	80	140	280	210	20	300

ONSHORE FACILITIES

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF SPECIFICATIONS	8	0	3	6	1	8
NO. OF BOOKS/MANUALS	2	1	1	3	1	4
SUPPORTING Mhrs	120	20	10	60	80	100
ENG/DESIGN Mhrs	200	80	100	90	50	200

PRODUCTION PLATFORM — TYPE ONE

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL
NO. OF SPECIFICATIONS	5	0	7	8	0	8
NO. OF BOOKS/MANUALS	2	5	2	7	1	3
SUPPORTING Mhrs	120	100	40	140	80	75
ENG/DESIGN Mhrs	80	140	280	210	20	300

PRODUCTION PLATFORM — TYPE TWO

	PROCESS	PIPING	INSTRUMENT	ELECTRICAL	CIVIL/STRUCT'L	MECH/VESSEL	TOTALS
NO. OF SPECIFICATIONS	4	2	6	4	0	5	144
NO. OF BOOKS/MANUALS	2	5	2	7	1	3	92
SUPPORTING Mhrs	120	100	40	140	80	75	2610
ENG/DESIGN Mhrs	80	140	280	210	20	300	4840

FIG. 11. Engineering and Supporting Man-Hours for Specs and Manuals

from the start. This cost included the programming efforts, initial additional time devoted to structuring the control budget, data entry, and routine generation of the project reports. The system generated several useful reports furnishing the percent complete, EV, PI, forecasts, and variances at all levels of control on the project hierarchy.

Minor problems were encountered in keeping track of the man-hours charged to certain material documents when the expended efforts affected several purchase requisitions. Also, the association of a scheduling activity to its specific documents required some guidance, especially in the beginning, until the draftspersons got a better understanding of the relationship between the documents, packages, and scheduling activities. The system was rated

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highly by the PMT for its usefulness and practicality and was recommended for other projects.

Conclusion

Tracking of the engineering phase of a project deserves more attention from researchers. An integrated project tracking approach for managing the engineering phase of major projects was presented in this paper. The presented procedure uses the WBS and the earned value as a means for integrating cost and scheduling data. The procedure is practical because it only requires data that are available in the estimate (or control budget) and visual inspection of the project documents. The procedure is also a means for reducing the involvement of senior PMT individuals in a time-consuming routine task, such as determination of work progress. With this procedure, such a task can be delegated to less senior personnel. This will result in improving the management of design activities, resource utilization, cost effectiveness, and the quality of project documents.

The engineering/design phase has fewer variables to track than the construction phase, and its budget and progress is more directly related to man-hour expenditures. The writer believes that integrating cost and scheduling data is easier to achieve in the engineering/design phase than in the construction phase. Our success in developing effective integrated tracking systems for the engineering/design phase may improve our ability to move to a more challenging task, that is, development of true integrated systems for tracking the construction phase. It is the writer's intention to include this procedure in a comprehensive expert system for managing all project phases. Formulation of such an expert system is currently underway.

Appendix. References

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