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کنترل پروژه برای شرکت‌های مهندسین مشاور
(بر اساس سندی از CII)

ارائه دهنده:

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What we will learn?

- Introduction
- Organizations for engineering
  - General
  - Functional organization
  - Task force organization
  - Matrix organization
  - The status of project controls in the organization

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What we will learn?

- Project control basics for engineering
  - Types of engineering contracts
  - The nature of engineering work
  - Planning and budgeting
  - Terminology
  - Breakdown structures and work packages
  - Schedules
  - Codes of accounts
  - Progress measurement
  - Procurement activity
  - Controlling
  - Historical data
  - System design and computer selection
  - DOE/DOD cost & schedule control system criteria

What we will learn?

- Other observations and findings
  - Obtaining project participant support
  - The key role of the project manager
  - How much should be spent on project controls?
  - Changes
  - What makes projects a success
  - The future

What we will learn?

- Appendix A: Progress measurement systems
- Appendix B: The DOE/DOD cost & schedule control systems criteria

Introduction

Project control

- Project control is concerned with resource quantities, time, and costs.
- Planning and controlling of resources is generally accomplished within the **cost control system.**
- **All resources**, whether they be personnel, material, equipment, supplies, or services, are quantifiable and can be converted to a dollar amount.
- During the **planning** of a project, quantity and dollar budgets for these are established.
  - During the **controlling** operation, actual quantity and dollar performance and rates of utilization are compared with **planned performance**.

Is the control of engineering activity more difficult?

Control of engineering activity

Is the control of engineering activity more difficult?

- Control of **engineering activity** is generally **more difficult** than control of **construction activity** because
  1. Engineering tasks are **more difficult** to quantify and track between start and completion
  2. Engineering tasks are **more** parallel and overlapping
  3. Responsibility for a given design often is shared **among various disciplines**

When the challenge is higher?

Control of engineering activity

When the challenge is higher?

- The **challenge** is particularly **great** on those projects in which engineering **overlaps** procurement and construction.

- Engineering work, however, **can be controlled**.

Succeeding sections of this publication provide details of a system for this control.

Organizations for Engineering

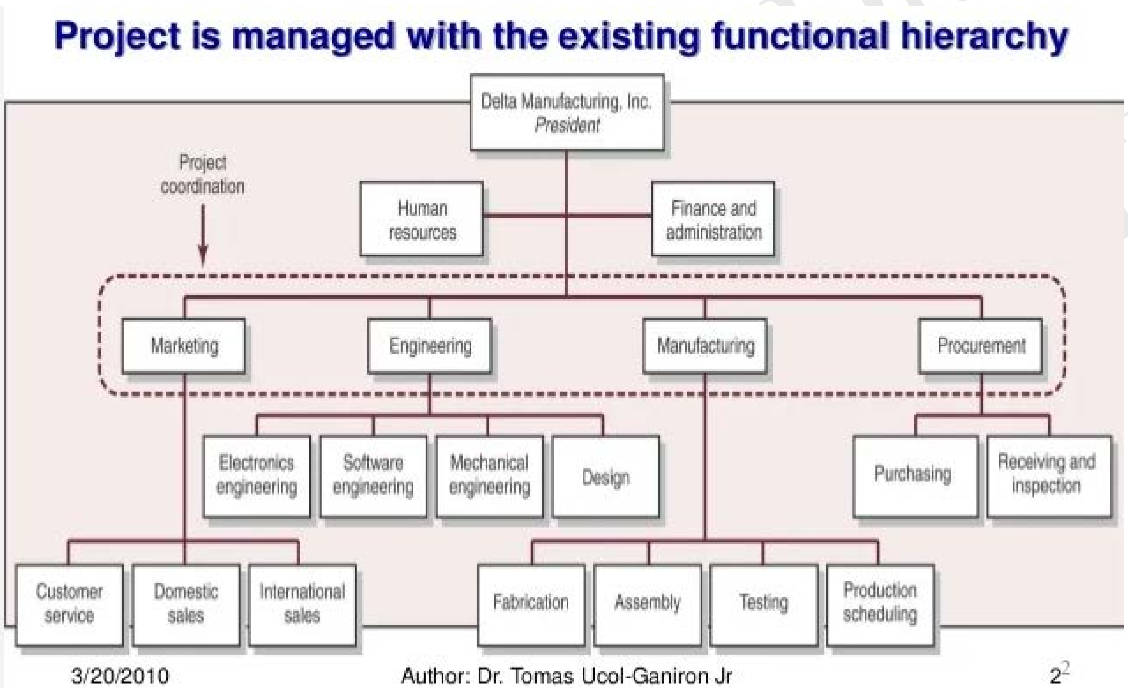
General

- **Three types of organizational structures** may be utilized for managing this work
  1. Functional organization
  2. Task force organization
  3. Matrix organization

Let’s look at each!

Functional organization

- A functional organization is the **traditional pyramidal organization** wherein **each functional department** (e.g., Engineering, Accounting, Construction) is organizationally **independent of the others** and **handles all work within its area** of expertise.



How the coordination is handled?

Functional organization

How the coordination is handled?

- **Coordination between departments** is handled on an informal basis and resolution of **conflicts**

  falls to the senior managers to whom the various departments ultimately report.

- This type of organization **works well**

  when a **minimal amount** of contact is needed between departments.

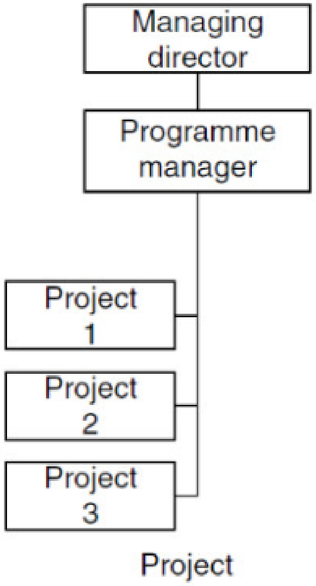
- Within a functional organization, project management

  becomes an **additional duty** of senior company managers.

- It is a **feasible**, though not particularly efficient, organizational arrangement for management of small projects; it is **not effective for large projects**.

Task force organization

- A **task force** is an organization **comprised** of **individuals** assigned from the **functional departments** to the **task force** for the purpose of **managing a project**.
- Individuals **assigned to the task force** are committed full time to the **project** during the period of their assignment.



How the team appointed here?

Task force organization

How the team appointed here?

- A **project manager** is appointed and

  other personnel are organized functionally **under** the project manager.

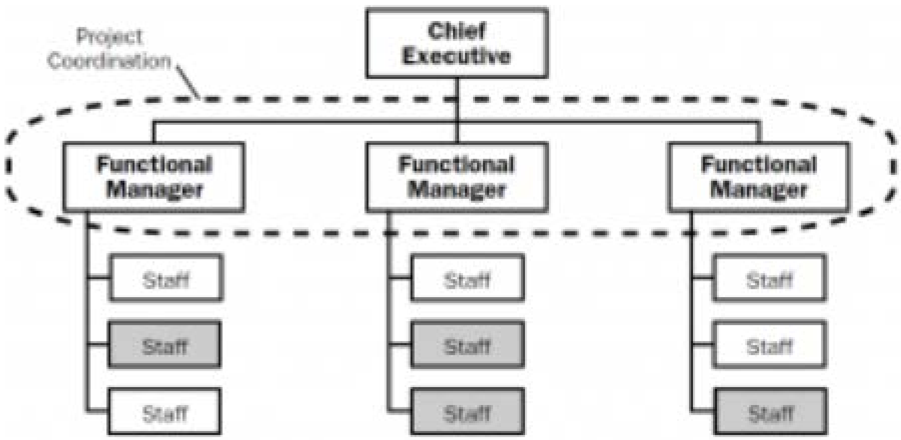
- The organization and personnel of the task force **may change** as the **project moves through various phases**.

  - The **major advantages** of a task force are that

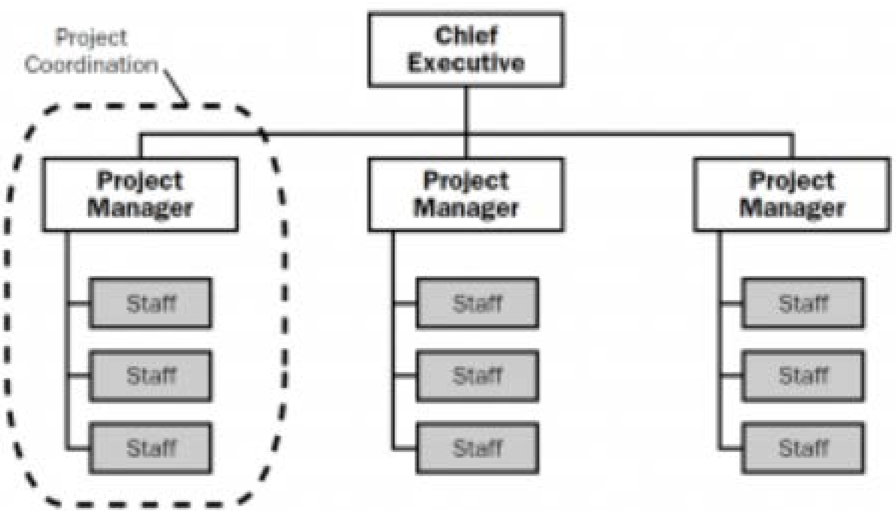
    1. It permits **concentration** of resources on a project
    2. Involves minimum management levels

This type of organization is particularly suited for large projects.

Functional vs. task force



- ❑ Functional



- ❑ Task force

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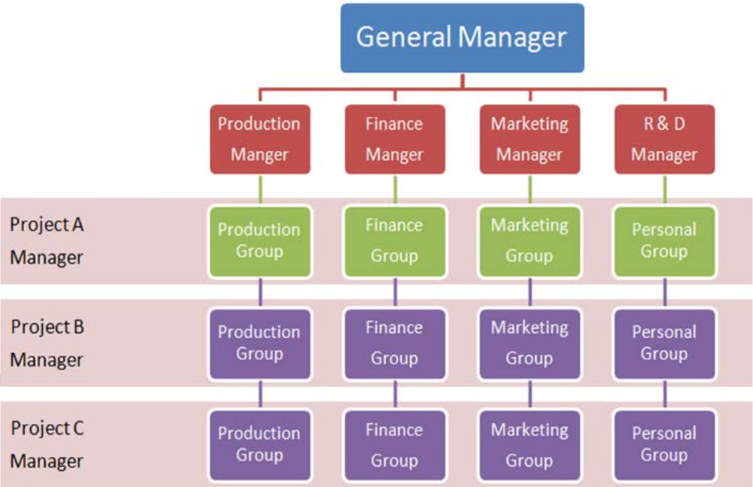
Matrix organization

- The **matrix organization** is a **combination** of a task force organization and a functional organization.
- In a matrix, there are **two chains** of command for each staff member,
  1. One along functional lines
  2. Other along project lines
- This is achieved by having the **staff report** to two managers simultaneously –
  1. A project manager for **project direction**
  2. A functional manager for **technical direction**

How the team appointed here?



Matrix organization

How the team appointed here?

- The **project team** within the matrix is a **group** whose members are **drawn from**
  1. Various <u>functional departments</u> of the organization
  2. Who are <u>committed to support</u> the project or task at hand

- **Project (team) managers** are normally drawn from a <u>pool of functional managers</u>.

- In some situations, <u>both project managers</u> and <u>team members</u> may **simultaneously serve** on **more than one** project team.

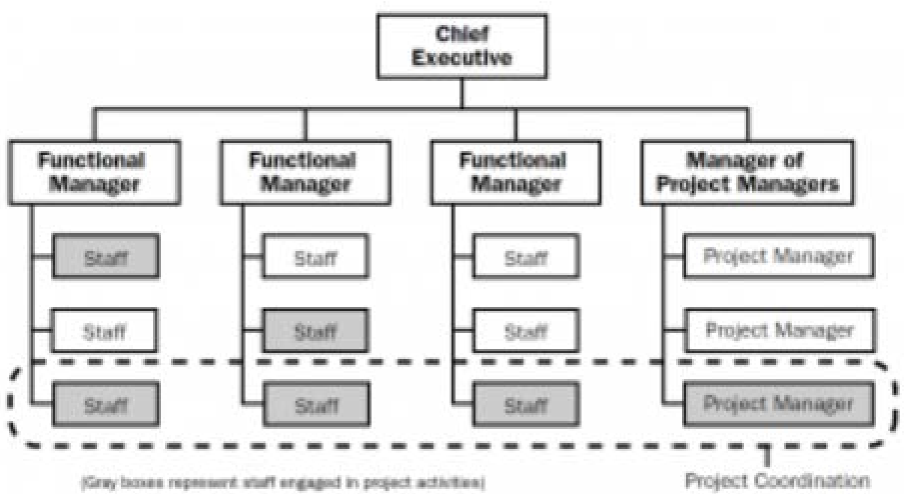
What types do we have here?

Matrix organization

- There are strong and weak matrix organizations.

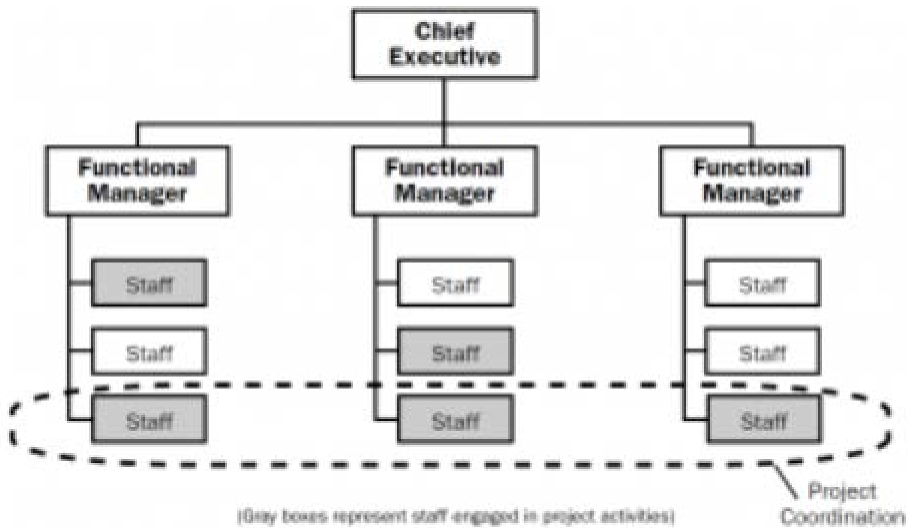
1. A **strong matrix** is one where the project team structure is separate and premier

   - i.e., the **project manager's authority** over the individuals on the project team exceeds that of the **functional managers.**



Matrix organization

- There are strong and weak matrix organizations.
  2. In a weak matrix, the **reverse is true**



How powerful and common for engineering companies?

Matrix organization

- Matrix organizations are the most common and also the most complex form of organization utilized for **management of engineering work**.
  - When **well managed**, they provide for **maximum**
    1. Coordination
    2. Information exchange
    3. Resource sharing

- **Matrix organizations** are also the most economical form for **management of multiple projects**

The strong matrix is the preferred form

When to start project control?

The status of project controls in the organization

- **Project control**, to be effective, **must begin** during the planning and budgeting of the work.
- It will **continue** during the conceptual and detailed engineering phases.
- If these **phases are a part** of a contract where engineering, procurement, and construction **overlap**,

  engineering project control will be integrated with procurement and construction project control.

Why is it important?

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The status of project controls in the organization

Why is it important?

- The project control function is the **"eyes and ears"** of management at all levels and the **source** of project **status information** for the client.
- It is also an **information center** for every professional on the staff.
  - Accordingly, it should be organizationally placed so that it **responds directly** to the project manager.
- It must **not be treated** as another accounting function, **nor should** its activity be decentralized among the **functional groups**.
- It must be recognized as an integral part of management, **not as a police force**!

Management must assess the information provided, then take the necessary steps to implement the action needed.

Project Control Basics for Engineering

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Types of engineering contracts

- In **industrial construction** it is **common** for engineering, procurement, and construction to be **handled in parallel** and

  with some overlap - these are called **Engineering-Procurement-Construction (E-P-C)** projects for purposes of this section.

- The **engineering portion** of the project **may be part of**
  1. Turnkey arrangement administered within a **single agency** or
  2. Handled as a separate contract that must tie-in with the **contracts of others**

What are the common types of engineering contracts

Types of engineering contracts

What are the common types of engineering contracts

- It is possible, however, for **engineering** to <u>precede completely</u> both **procurement and construction.**

- An **engineering contract** in this case is referred to in this section as **Engineering-Only (E-O).**

- The **E-P-C format** is the **more challenging** of the two from a project controls viewpoint.

What are the products of engineering work?

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The nature of engineering work

What are the products of engineering work?

- The **primary products** of engineering work are documents to **guide both**
  1. Construction of a facility
  2. Manufacture of **engineered equipment** for **installation** in such a facility

- Other products are studies, procedure and operating manuals, and various consulting services.

The nature of engineering work

- In performing its work, the **engineering group** is generally organized around
  1. **Engineering disciplines**
     - civil, architectural, structural, mechanical, electrical, etc.) or
  2. **Specialty services**
     - model shop, procurement, environmental studies, economic studies, etc.
- These **production units** of the organization have products such as
  - Drawings
  - Specifications
  - Models
  - Manuals
  - Studies
  - Procurements

✓ Supporting them are such functions as word processing, computer services, accounting, personnel, and others.

Do owners have in-house engineering firms?

The nature of engineering work

Do owners have in-house engineering firms?

- **Some owners** maintain internal organizations for accomplishment of **conceptual and/or detail engineering** of their facilities.
  - But **much if not most** of it is **handled under contract** with an engineering firm.

What are the most common contracts with them?

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The nature of engineering work

What are the most common contracts with them?

- **Many contracts** in the latter case are reimbursable, although
  1. Fixed-price contracts are becoming more common,
  2. There are reimbursable contracts with ceilings, targets, or incentives

How reimbursable contracts handled in engineering?

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The nature of engineering work

How reimbursable contracts handled in engineering?

- The **typical reimbursable contract** is handled in this fashion:
  - Professionals within the **production units** are identified as reimbursable.
    - ✓ The **client** agrees to **pay for each hour** of work of those reimbursable individuals

      in an **amount equal** to the base hourly pay of **each individual times** a **multiplier**.
    - ✓ This multiplier is in the range of **1.5-2.5.**

How about other items other than professionals?

The nature of engineering work

How about other items other than professionals?

- The typical reimbursable contract is handled in this fashion:
  - Other items are identified as **"reimbursable directs."**
  - These are items such as
    - ✓ travel,
    - ✓ reproduction,
    - ✓ computer services, and
    - ✓ communications

In most cases, **their costs** are passed **through to the client** without markup.

How about items such as general management?

The nature of engineering work

How about items such as general management?

- The typical reimbursable contract is handled in this fashion:
  - Items such as general management, accounting, personnel services, and secretarial services are **"non-reimbursable directs and indirects,"** and are **not charged directly** to the client.
    - These costs are **accounted** for within the multiplier noted before.
      - That **multiplier** also accounts for
        1. Profit (unless the project is cost-plus)
        2. Personnel fringe benefit costs (burden) such as vacation, medical, and retirement.

How about fixed-price contracts?

The nature of engineering work

How about fixed-price contracts?

- If the contract form is fixed-price or **other than the reimbursable** described before, engineering agency still must account fully for

  1. Direct costs
  2. Project level indirects
  3. General overhead
  4. Any contingency
  5. Profit

  in the pricing

So, what happens in the planning and budgeting process then?

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Planning and budgeting

So, what happens in the planning and budgeting process then?

- As **noted previously**, there are
  1. Activities of <u>direct work</u> in an engineering contract and each has a **cost**.
  2. <u>Other activities</u> that are <u>support in nature</u>, both
     i. Direct
     ii. Indirect

     are **only cost items**.

But still not sure how to plan and control!

Planning and budgeting

But still not sure how to plan and control!

1. Contract progress is tracked against the **work activities**
2. Costs are tracked against all activities and other cost items

- Thus, the project control system must be designed to **control** both work and cost.

Could you please be more specific?

Planning and budgeting

Could you please be more specific?

- When planning any project, it is desirable to **divide the project** into well-defined, manageable parts for purposes of control.
- By controlling the **individual parts**, it is possible to establish control of the **total project**.
- Figure 1 is a matrix representation of the **budget** that might be established for a typical engineering project.
  1. **Certain items** on this budget include allocations of work-hours as well as costs.
  2. **Others** are budgeted only for cost.

Could you please show me an example?

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Planning and budgeting

Could you please show me an example?

ENGINEERING BUDGET MATRIX

FUNCTION \ ACTIVITY OR COST ELEMENT		DESIGN & DRAWINGS	SPECS	PROCUREMENT SUPPORT	FIELD SUPPORT	SUPERVISION & CONTROL	TRAVEL	SUPPLIES & SERVICES
MANAGEMENT						WH & $		
PROCUREMENT				WH & $	WH & $			
DISCIPLINES	CIVIL	WH & $	WH & $	WH & $	WH & $	WH & $	$	$
	ELECTRICAL	WH & $	WH & $	WH & $	WH & $	WH & $		
	ETC.	WH & $	WH & $	WH & $	WH & $	WH & $		

The COST BREAKDOWN STRUCTURE (CBS) is composed of all elements in the Budget Matrix for which dollars have been budgeted. The total dollar value of all of these elements equals the total engineering budget.

The WORK BREAKDOWN STRUCTURE (WBS) is developed from those budget items in the Budget Matrix which cover tasks that lend themselves to progress control, such as drawings and specifications. These items have been shaded in the matrix. The detailed WBS would be expanded from these budget items. For example, a drawing list would be developed to include all drawings in the Electrical Drawings budget, and each drawing would be budgeted a number of work-hours (WH). The total of these work-hours would equal the total in that budget item.

Figure 1. Engineering Cost Breakdown Structure and Work Breakdown Structure

How to estimate?

Planning and budgeting

How to estimate?

- **Experienced engineering organizations** are able to estimate **quite accurately**
  1. Number of engineering documents required
  2. Work-hours required

- They are also able to estimate
  1. Quantity and work-hour requirements for their **other products**
  2. Costs of other reimbursables and nonreimbursables
  3. Having done this, to establish a **multiplier**

These estimates become the basis for project control

So, how to control?

Planning and budgeting

So, how to control?

- Control of work is **best based** on

  control of budgeted work-hours for **individual work activities** (will see examples)

  - As part of this control, there **must be some method** for evaluating percent complete of each activity.
    - ✓ The methods are **established** during the planning operation.

*Methods available are summarized in **Appendix A**.*

Could you please be more specific?

Terminology

Could you please be more specific?

Remaining discussion will describe a variety of terms used in the controlling process

Terminology

First you need to have logic and process of performing work

- Figure 2 may prove helpful in **explaining** and **interrelating** these terms.
- The **example** uses a simple process system composed of **two vessels** and **interconnecting piping**.
- It traces the flow of engineering work and relates that to the components of the completed process system.

Could you please show me an example?

Terminology

Could you please show me an example?

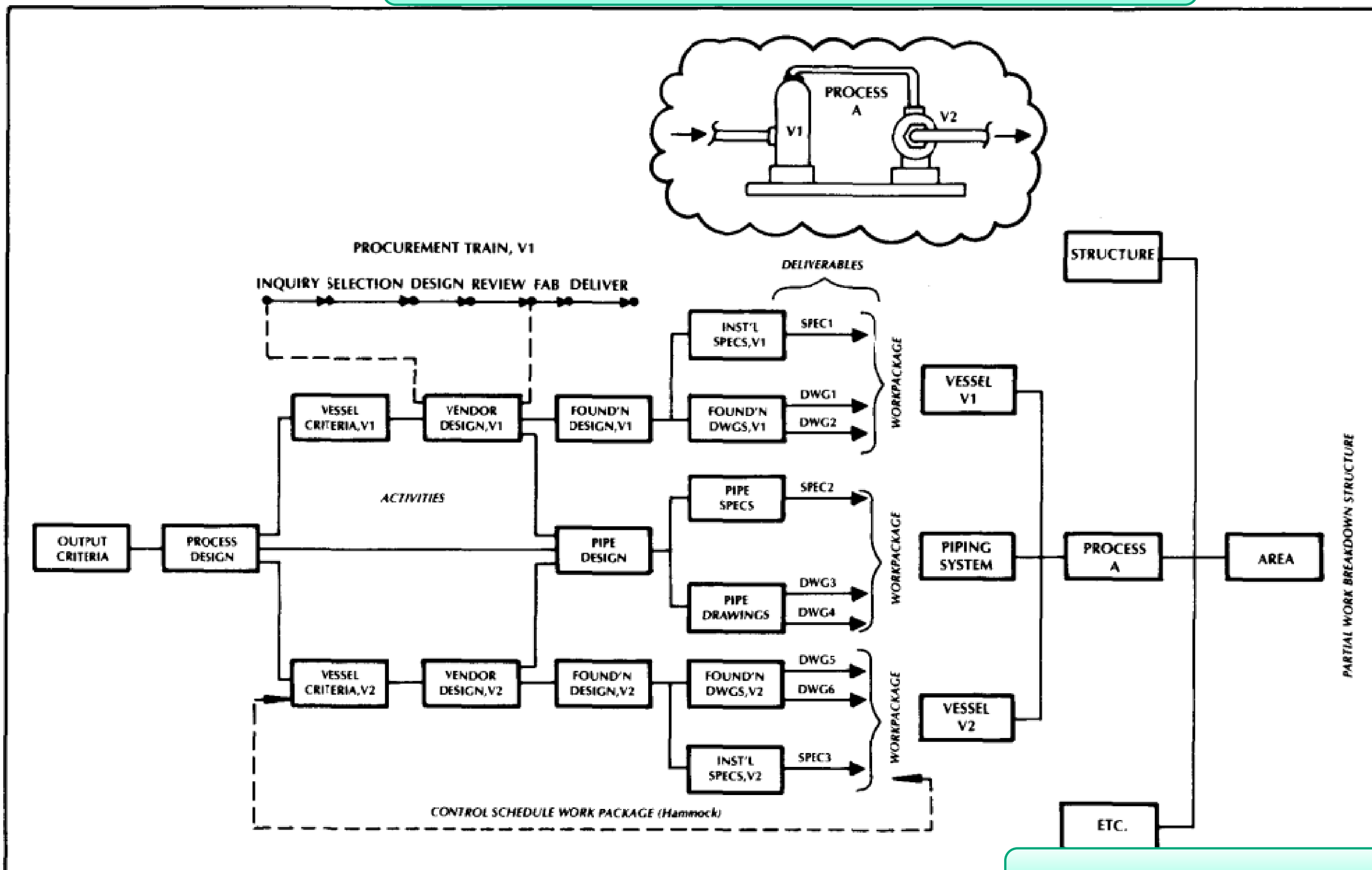

Figure 2. Example to Illustrate Logic and Use of Terms

How to develop CBS?

Breakdown structures and work packages

How to develop CBS?

- The **Cost Breakdown Structure (CBS)** for the project includes every element of cost for the project.
    - In effect, it is a **summary** of the **budget** by category.
        - ✓ The **total of all categories** equals the total project budget.

- Referring again to Figure 1, this matrix is a **visual representation** of the CBS for an **example project**.

Breakdown structures and work packages

ENGINEERING BUDGET MATRIX

FUNCTION \ ACTIVITY OR COST ELEMENT		DESIGN & DRAWINGS	SPECS	PROCUREMENT SUPPORT	FIELD SUPPORT	SUPERVISION & CONTROL	TRAVEL	SUPPLIES & SERVICES
MANAGEMENT						WH & $		
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DISCIPLINES	CIVIL	WH & $	WH & $	WH & $	WH & $	WH & $		
	ELECTRICAL	WH & $	WH & $	WH & $	WH & $	WH & $		
	ETC.	WH & $	WH & $	WH & $	WH & $	WH & $		

The COST BREAKDOWN STRUCTURE (CBS) is composed of all elements in the Budget Matrix for which dollars have been budgeted. The total dollar value of all of these elements equals the total engineering budget.

The WORK BREAKDOWN STRUCTURE (WBS) is developed from those budget items in the Budget Matrix which cover tasks that lend themselves to progress control, such as drawings and specifications. These items have been shaded in the matrix. The detailed WBS would be expanded from these budget items. For example, a drawing list would be developed to include all drawings in the Electrical Drawings budget, and each drawing would be budgeted a number of work-hours (WH). The total of these work-hours would equal the total in that budget item.

How to develop WBS?

Figure 1. Engineering Cost Breakdown Structure and Work Breakdown Structure

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Breakdown structures and work packages

How to develop WBS?

- The **Work Breakdown Structure (WBS)** for the project relates only to the **engineering work products** that

  the **project manager** chooses to **status** as a basis for progress reporting.

  - Drawings are traditionally a **status item**.
  - Designing, specification writing, study preparation, model construction, and equipment material procurement involve deliverables, and thus are other logical choices.

The more of these tasks chosen for control,

the more positive and informative the control system will be.

Let’s see more detail!

Breakdown structures and work packages

- On Figure 1, the shaded portions are the **budgets** for those elements of the CBS which will **comprise the WBS** for this example project.

- In this example, only Design & Drawings, Specs, Procurement Support, and Field Support transactions have been **chosen for work control**.

- The **activities accounted** for within these budgets are essentially the greatest level of detail in the **WBS**.
  - Thus, the **WBS** is incorporated **within the CBS**.

Could you please show me an example?

Breakdown structures and work packages

Could you please show me an example?


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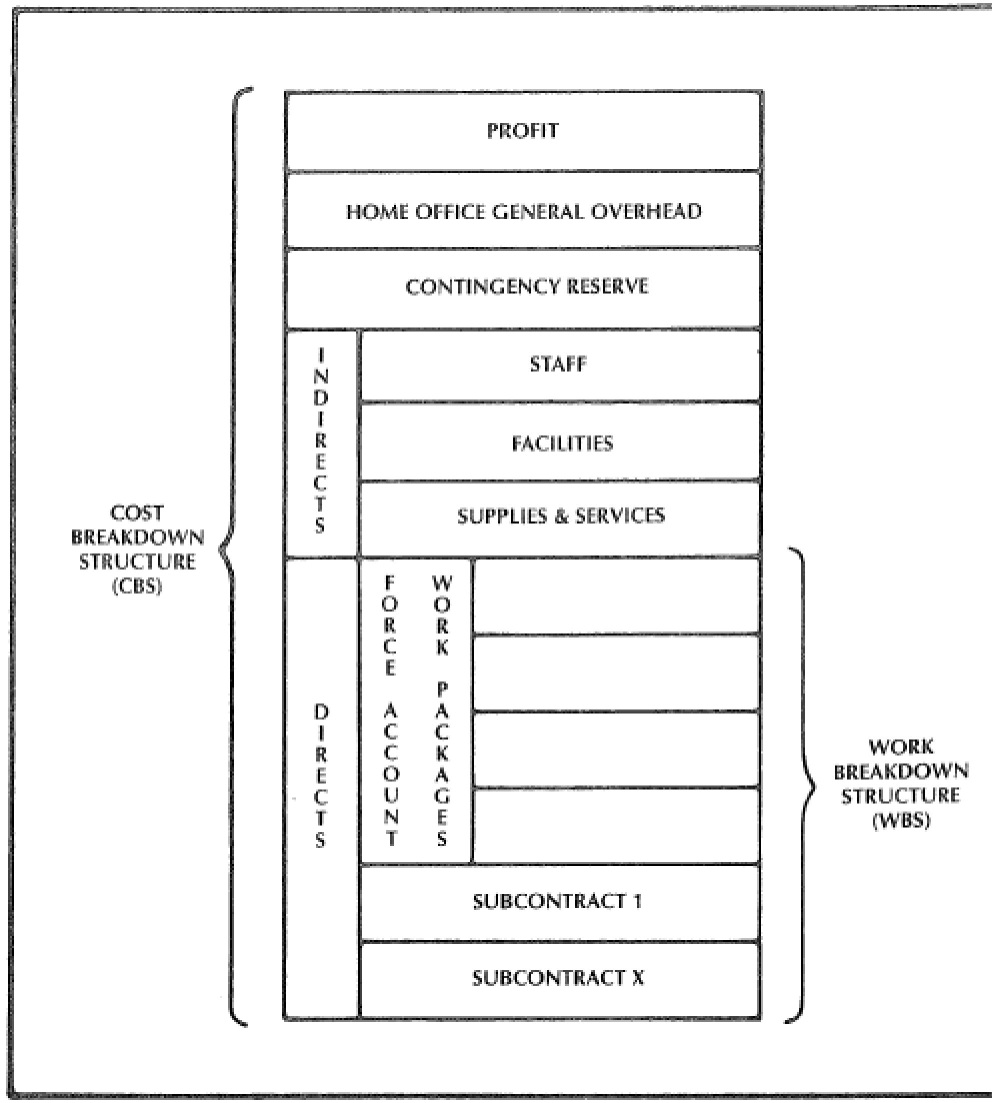
MODEL PLANNING AND CONTROLLING SYSTEM FOR EPC OF INDUSTRIAL PROJECTS

How to develop hierarchical WBS?



Breakdown structures and work packages

How to develop hierarchical WBS?

- Actually, the **complete WBS** for the project will have the total facility to be designed as the **ultimate summary level**.

- The facility is **then divided** into well-defined areas, systems, and structures which in turn can be further sub-divided into well-defined
  1. Sub-areas,
  2. Sub-systems, and
  3. Sub-structures

  to form a **hierarchical WBS** describing the total facility to be constructed.

How to develop work packages?

Breakdown structures and work packages

How to develop work packages?

- The WBS is **continued** beyond that point to identify those activities required to prepare documents that are used to guide both
  1. construction of a facility
  2. manufacture of engineered equipment for installation in such a facility

- A work package is any **one set of these activities** which are targeted on a given procurement or construction need date.

What to do with indirect activities?

Breakdown structures and work packages

What to do with indirect activities?

- A **contractor** **may include** selected indirect activities such as supervision or project controls in a progress control system, and use the Ratio or Judgement method of **reporting status** (see Appendix A).

How WBS and CBS related?

In such a case, the **CBS/WBS relationship** will be more like that shown in Figure 3.

Breakdown structures and work packages

Activities	Indirects [3]	Labor		Equip.
Supervision	$	WH	$	$
internal Support	$	WH	$	$
Procurement	$	WH	$	$
Study	$	WH	$	$
Design	$	WH	$	$
Document Preparation	$	WH	$	$
Document Review	$	WH	$	$
External Support	$	WH	$	$
Other[4]	$			

Notes: 1. The CBS is composed of all activities in the matrix for which dollars ($) are budgeted. The total value of these equal the project budget.

2. The WBS is composed of those direct labor activities in the matrix for which work-hours (WH) are budgeted. They may be used for work progress measurement.

3. "Indirects" includes supervision above first level, staff, facilities, supplies & services, travel, etc.

4. "Other" includes office overhead, contingency reserve, profit, etc.

Figure 3. Example CBS/WBS Relationship [1,2]

How WBS and CBS related?

However, **indirect functions** do **not directly contribute** to deliverables and inclusion of them will distort progress on deliverables.

Breakdown structures and work packages

PHASES	INDIRECTS (1)	DIRECTS: LABOR		DIRECTS: MATERIAL	DIRECTS: EQUIPMENT
Conceptual Engineering	$	WH	$	$	$
Detailed Engineering	$	WH	$	$	$
Procurement	$	WH	$	$	$
Construction	$	WH	$	$	$
Start-Up	$	WH	$	$	$
Other (2)	$	WH	$	$	$

Legend: The COST BREAKDOWN STRUCTURE (CBS) is composed of all elements in the matrix for which dollars ($) are budgeted. The total dollar value of all of these elements equals the project budget.

The WORK BREAKDOWN STRUCTURE (WBS) is composed of those direct labor elements in the matrix for which work-hours (WH) are budgeted and lend themselves to work progress measurement.

Footnotes: 1. Supervision above first level, staff, facilities, supplies and services, travel, etc.

2. Home office overhead, contingency reserve, profit, etc.

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MODEL PLANNING AND CONTROLLING SYSTEM FOR EPC OF INDUSTRIAL PROJECTS

How to develop the schedule?

Schedules

How to develop the schedule?

- **Different** levels and types of schedules are appropriate for **control of engineering work**.

- The **most detailed schedule control** occurs in the controlling of **individual engineering deliverables**.
  - At that level, **barchart schedules** may be appropriate,

    but for **effective schedule control** the rollup of such tasks must be related to activities in a CPM-formatted engineering schedule.

Is there any difference between E-O and EPC projects?

Schedules – Preparation

Is there any difference between E-O and EPC projects?

1. **E-O projects:** The **project's control schedule** may be in barchart form with milestones and key interfaces on an **E-O contract**,

   but networking is certainly appropriate.

2. **E-P-C projects**: the **control schedule** should be in network format and interrelate with the procurement and construction schedules –

   engineering work package completion usually **constrains**

   start or continuation of a procurement or construction activity on E-P-C projects.

Is it good to have so many details in the schedule?

Schedules – Preparation

- This **philosophy** must be balanced against having too much detail on the control schedule

  since it must be **simple enough** to permit human review and analysis.

So, what is the solution?

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Schedules – Preparation

So, what is the solution?

- The **solution** is to keep the **project's control schedule** at a network summary level supported by **individual detailed schedules**.

- When this is accomplished and the **total system is integrated**, it will be possible to **trace** the effects of any changes and deviations throughout the project.

How to model engineering work packages?

Schedules – Preparation

- Engineering work packages are the activities on the control schedule and as such are **hammocks for more detailed subnets** that trace both sequential and parallel steps in accomplishing the activities included **within the work package**.

  However, be aware that it's an older project scheduling term, and you may find your software confusingly labels similar tasks as level of effort activities.

Hammock activity duration

A hammock activity has no fixed duration. The time assigned to the activity is flexible and is driven by logic from the rest of the schedule. When the duration of other scheduled tasks changes, the hammock is updated automatically to reflect the changes. It reflects the overall duration of the individual activity.

The duration of the hammock is calculated from the start date of the earliest task in it, and the finish date of the task that finishes last. The order of the tasks might not matter, and they could switch around as the work progresses.

What is the purpose of it?

Schedules – Preparation

Purpose of a hammock activity

The purpose of a hammock activity is to carry overhead costs and resources during a portion of the project. Like a level of effort task, it's a way to apportion overheads without having to split them between the other activities or to summarize time required as a result of several tasks. The project manager's time is one item that might be appropriate to apportion in this way, if the effort cannot be adequately accounted for in another way.

Another benefit for project managers and schedulers is that the tasks within the group do not need to be related to each other. Dissimilar work can be 'hung' together and grouped in a way that makes sense for management effort.

Hammock activities can also be used to create summary reports. However, one of the advantages of using hammocks over 'standard' summary tasks is that they can summarize activities across multiple areas of the project schedule, not just tasks in a single section.

https://tensix.com/what-is-a-hammock-activity/

Schedules – Preparation

- More on this subject is contained in the CII publication, **Model Planning and Controlling System for Engineering-Procurement-Construction of Industrial Projects.**

Probably next year!


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MODEL PLANNING AND CONTROLLING SYSTEM FOR EPC OF INDUSTRIAL PROJECTS

Could you please talk about updating and control?

Schedules – Control

Could you please talk about updating and control?

- Schedule control and updating will take **several forms**.
  - Approved changes will be the basis for changing the **update schedule**.
  - Controllers also will maintain a **working schedule** which documents
    1. Performance to date
    2. Plans work from that point
  - Short-term, **detailed scheduling** will be used for planning work for the near term future (30-90 days).
  - Throughout the project, the **update schedule** will serve as the target, and as such, must be the **basis for all reporting** of items such as schedule conditions, progress, and others.

Codes of accounts

- A relatively **complicated system of coding** is needed for control of engineering work.

ENGINEERING BUDGET MATRIX

FUNCTION \ ACTIVITY OR COST ELEMENT		DESIGN & DRAWINGS	SPECS	PROCUREMENT SUPPORT	FIELD SUPPORT	SUPERVISION & CONTROL	TRAVEL	SUPPLIES & SERVICES
MANAGEMENT						WH & $		
PROCUREMENT				WH & $	WH & $			
DISCIPLINES	CIVIL	WH & $	WH & $	WH & $	WH & $	WH & $		
	ELECTRICAL	WH & $	WH & $	WH & $	WH & $	WH & $	$	$
	ETC.	WH & $	WH & $	WH & $	WH & $	WH & $		

The COST BREAKDOWN STRUCTURE (CBS) is composed of all elements in the Budget Matrix for which dollars have been budgeted. The total dollar value of all of these elements equals the total engineering budget.

The WORK BREAKDOWN STRUCTURE (WBS) is developed from those budget items in the Budget Matrix which cover tasks that lend themselves to progress control, such as drawings and specifications. These items have been shaded in the matrix. The detailed WBS would be expanded from these budget items. *For example, a drawing list would be developed to include all drawings in the Electrical Drawings budget, and each drawing would be budgeted a number of work-hours* (WH). The total of these work-hours would equal the total in that budget item.

Figure 1. Engineering Cost Breakdown Structure and Work Breakdown Structure

How to start the numbering?

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Codes of accounts

How to start the numbering?

- First, a two-part code will reflect the CBS matrix illustrated in Figure 1,
  1. Function
  2. Activity

- **Engineering personnel** will use this code when **logging their time** so that it is charged to the **proper budget category**.

You will learn
If you learn Financial Management Course

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Codes of accounts

- **Another numbering system(s)** is appropriate for drawings, specifications, and other deliverables.
  - These numbers can be sequential in nature and need not include any cross-reference to the **WBS**.
    - ✓ Drawing, specification, and other deliverable lists and control numbers are developed during the planning and budgeting phase.

How to create codes for activities?

Codes of accounts

How to create codes for activities?

- The deliverables coding is needed for **cross-referencing** to work packages.
- It is also useful for **personnel working on these items** to use in **charging time** on their time cards.
  - In this case it is used **in conjunction** with the CBS identifier as a first step in work-hour tracking.
    - ✓ *For example and referring to Figure 1, assume that the electrical discipline function has the code "EL," that the budget category is "design and drawings" (code "01"), and the drawing number is 4567 - the **coding for work** on this would be:*

EL-01-4567

What to do for activities that contribute to more than one deliverable?

Codes of accounts

What to do for activities that contribute to more than one deliverable?

- For activities that **contribute to more than one deliverable** (e.g., various criteria development),

  the deliverable portion of the code can be **replaced** by an activity code.

Could it be helpful for project control?

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Codes of accounts

Could it be helpful for project control?

- **This numbering system** is particularly useful in cost control since it **collects data** at the budgeting (CBS) level.
- This format also permits summary of data **against** function, activity, or specific deliverable or activity type for **historical purposes.**
- It can also be **incorporated** in the schedule activity identification numbers used at the **detailed (sub-hammock) level.**

Coding for activities done!
What to do for working packages?

Codes of accounts

Coding for activities done!
What to do for working packages?

- Still **another coding system** is needed for work packages.
  - Since **work packages** are really an extension of the WBS,

    the **codes for work packages** are really a detailed extension of the WBS code.

How to do that?

Codes of accounts

- A typical engineering work package includes an **classification** of engineering documents and any given document can be a **component** of **several work packages**, and

  thus **this numbering system** should be **separate** from **that used** for included components.

- Included documents will be **cross-referenced** to **work packages** and

  work packages to the **WBS within datasets** of the integrated control system.

What to do with materials and equipment?

Codes of accounts

- The **materials tracking system** will require a coding system to identify equipment items and commodities so that their tracking can be **integrated with the schedule**.

- This coding system will also permit **generation** of equipment, instrumentation, and other lists used within the control system.

You will learn it in Financial management course!

How to measure progress?

Progress measurement

How to measure progress?

- Percent complete is determined by the method chosen during the **planning operation** for the task in question (See Appendix A).
- Earned value techniques are used for **summarizing overall work status**.
- The earned value of any one item being controlled is:

Earned Work-Hours = (Budgeted Work-Hours) x (Percent Complete)

Note: Budgeted Work-Hours equal original budget plus approved changes.

How to measure overall progress?

Progress measurement

How to measure overall progress?

- **Overall percent complete** of the project or of a work package is found by this formula:

$$\text{Percent Complete} = \frac{\text{Sum of Earned Work-Hours of Tasks Included}}{\text{Sum of Budgeted Work-Hours of Tasks Included}}$$

How to measure trends and productivity?

Progress measurement

How to measure trends and productivity?

- **Trends** can be tracked through various indices.
- The Productivity Index (PI) and the Schedule Performance Index (SPI) are particularly useful for this purpose.
- The **PI** provides a **comparison** of
  1. Number of work-hours being spent on work tasks
  2. Number of work-hours budgeted

  and is an indicator of productivity.
- The formula is as follows:

$$PI = \frac{\text{Sum of Earned Work-Hours of Tasks Included}}{\text{Sum of Actual Work-Hours of Tasks Included}}$$

Note: For the above to be a true indicator of productivity, only those tasks for which budgets have been established should be included in summations.

How to measure SPI?

Progress measurement

How to measure SPI?

- The **SPI** relates the amount of work performed to the amount scheduled to a point in time.

The formula is:

$$\text{SPI} = \frac{\text{Sum of Earned Work-Hours to Date}}{\text{Sum of Scheduled Work-Hours to Date}}$$

Note: Scheduled work-hours used in this formula are summarized from the task schedules.

What targets are appropriate?

Progress measurement

What targets are appropriate?

- In both the PI and SPI formulas, an index of **1.0 or greater is favorable**.

- Trends can be noted by **plotting** both
  1. "This period"
  2. "cumulative"

  PI and SPI values on a graph.

Could we rely only on these indices?

Progress measurement

- While the **SPI** for the total project or for a work package is somewhat of an indicator of schedule performance, it tells **only part of the story**.
- The SPI only compares volume of work performed to volume of work scheduled.
- There can be an **SPI in excess of 1.0**, but the project can still be in danger of not meeting milestones and final completion dates

  if managers are expending effort on **non-critical activity** at the expense of critical activity.

  - The **SPI does not show** if work is being completed in the proper sequence.

*Thus, as part of schedule control, **controllers must** regularly **examine the schedules** of **all included tasks** in **each work package** so that any items behind schedule can be **identified** and **corrective** action taken to bring them back on schedule.*

How about cost performance?

Progress measurement

How about cost performance?

- **Cost performance** on the project is tracked by comparing
  1. Actual costs to
  2. Those in the budgets of the CBS
- Unfortunately, significant **lags** between incurrence of cost obligations and receipt of invoices or other cost notification for many accounts

  can make it **difficult to maintain a timely**, responsive cost control system.
- It is **possible to use an earned value** approach for cost control if an owner or contractor so desires.
- Appendix B describes such a system as utilized on some U.S. Government contracts.

What to do with procurement activities?

Procurement activity

What to do with procurement activities?

- Two types of procurement activity are associated with engineering.

1. The first type is the **procurement of equipment/material** to be engineered by others.
   - **Some engineering activity** may have to be **put on hold until** approved vendor documents are available **(e.g., foundations and piping connections).**
     - ✓ Often the **timing** for these **vendor documents** to support follow-on engineering is more of a determinant for the schedule of early procurement train activities than the **item's need date for construction**.

How to prepare them?

Procurement activity

How to prepare them?

- Two types of procurement activity are associated with engineering.

1. The first type is the procurement of equipment/material to be engineered by others.
   a) With this type procurement, the **design engineers**
      1. **Develop** performance specifications and other criteria for an item
      2. **Provide** them to the selected vendor
   b) The vendor
      a) **Designs** the item to meet the **specified criteria**
      b) **Forwards** the **design documents** to the engineer for review
   c) Following drawing approval, the vendor will
      a) Fabricate
      b) Deliver the item

What is the second type?

Procurement activity

What is the second type?

2. A second type of procurement is the **more general type** which results in the delivery of off-the-shelf pieces of equipment or commodities.

How to control procurement activities?

Procurement activity

- A given procurement action is a train of sequential activities.
- Each of these activities must be **included in the detailed schedule**,

  although the **overall procurement** of a component can be a **single activity** on the control schedule.

  - For **procurement tracking**,
    1. **Each procurement train** can be treated as a unit and tracked using the incremental milestone method

       Or
    2. **Each train activity** can be tracked separately using a **method most appropriate** to that activity (Appendix A).

How the controlling process happens?

How the controlling process happens?

- The **system described** is intended to provide the **project manager and other project participants** with the information needed for control of the project.
- Data generated from the system are **continually analyzed** for the purpose of identifying trouble spots or unfavorable trends.
- If the **system has been designed properly**, timely reports will be available so that corrective action can be taken when and where needed.

Do we need historical data?

Historical data

Do we need historical data?

- **Planning of future** projects relies heavily on experience on past projects.
- Datasets within the system should be designed to summarize and accumulate experience data in a format directly **usable in future planning**.

How to design a system and select computer software?

System design and computer selection

How to design a system and select computer software?

- Integrated project control is an **objective** in the selection or design of the computerized project control support system.
- The **following features** are desirable in the system.
  - The **computer software** should have both a scheduling module and database management capability.
  - The **schedule module** must handle network type scheduling.
  - The **databases** should be linkable to the **schedule module**.

System design and computer selection

- The following features are desirable in the system.
  - A **graphics capability** should be included which is capable of producing network logic diagrams, barcharts, histograms, and graphs from system databases.
  - The system should be capable of
    1. **Generating** user-designed reports using data directly from **any combination of the datasets**, and
    2. **Performing** calculations or summations from the data
  - Databases should be **structured** so that it is **not necessary** to enter a piece of data more than once.

Is there an official policy in U.S.?

DOE/DOD cost & schedule control systems criteria

- The U.S. Departments of Energy (DOE) and Defense (DOD) have adopted a policy concerning **control systems** used by contractors on certain types of projects.

- This policy is described under the Cost & Schedule Control Systems Criteria (CSCSC) for Performance Measurement.

- A **brief description of CSCSC** features as **applied to engineering** and as related to previous sections of this document is in order.

- Appendix B is an **overview** of the system.

Other Observations and Findings

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Obtaining project participant support

- In order for a project control system to be effective, it must be understood and accepted by **all who use it.**
- Unfortunately, it is a fact that very few engineering programs in the universities and colleges of the United States include any required course material on planning and controlling engineering work, **nor** are such subjects as procurement, construction methods, and constructability included.
- Thus, **in-house training of engineering personnel** in these subjects is a must if management is to expect their understanding, commitment, and support.
- Additionally, **individuals** providing data to the system should be given a voice in the design of input format and the system should be designed to provide feedback to the participants.

What is the key role of project manager here?

The key role of the project manager

What is the key role of project manager here?

- Management commitment to a program is essential if a program is to succeed.
  - Thus, in the case of **project controls**, it is essential that **project managers** understand the theory and potential of a **modern project controls system**.

- Once a **project manager is committed**,

  steps can be taken to assure understanding and commitment of **all other project participants.**

How much should be spent on project controls?

How much should be spent on project controls?

How much should be spent on project controls?

- The portion of the budget which engineers and contractors spend on project controls **varies**.

- Since every project is unique and client requirements differ,

  it is **difficult to determine** the **exact level of control** needed in terms of project budget.

  - However, based on **projects observed**, it appears that good project controls performance is best assured

    if **at least 8 percent** of the **engineering budget** is committed to this effort.

Should we also control changes?

Changes

Should we also control changes?

- Project control systems are based upon **planned budgets and schedules**.
- When changes are introduced, the plans and schedules must be **revised**.

1. **Some changes** are the result of scope change;
2. **Others** result from value engineering, constructability studies, or engineering error.

❖ Unfortunately, **changes seldom** affect only one engineer or discipline;

they can have a **ripple effect** on the **entire project**.

✓ Thus, it is **essential** that an **engineering organization** have formal scope control and change control programs.

How to become successful?

What makes projects a success?

How to become successful?

- **Those interviewed** were asked to identify the factors that distinguish successful and unsuccessful projects, with the following results:

Successful Projects:

Well-defined scope
Early, extensive planning
Good leadership, management, and supervision
Involved, positive client relationship
Proper chemistry among project participants
Quick response to changes
Engineering managers concerned with total project, not just engineering

Unsuccessful Projects:

Ill-defined scope
Poor management
Poor planning
Poor communication between engineering and construction
Unrealistic schedules and budgets
Poor personnel quality
Excessive changes
Poor project controls

Let's see what CII predicted in 1986!

The future

Let's see what CII predicted in 1986!

- **Advancing technologies** and new ideas can be expected to **influence project controls** in the future.
- The following have been identified:

1. **Computer-Aided Design (CAD).** Computer-aided design has become commonplace in engineering organizations, but **systems which directly tie into estimating and project controls** are in their **early stages**. In the future there should be systems which automatically generate equipment and material lists that **feed into the estimating system** and **resource-load the schedule** while also prompting procurement activity.

The future

- The following have been identified:

2. **Expert Systems.** Expert systems would be valuable **during conceptual engineering** to generate major equipment lists, bulk quantities, and other information for various processes and to **produce resulting cost estimates**. Such systems would also greatly **simplify value engineering studies** during the conceptual engineering phase of a project and facilitate various decision processes throughout the detail engineering phase. Other applications include forecasting, risk analysis, and personnel training.

The future

- The following have been identified:

3. **Engineering Control Based on Quantities Designed. Traditional tracking** of engineering work is based on engineering units of production. Some firms are experimenting with a tracking system based on **quantities designed** (e.g., cubic yards of concrete, linear feet of pipe). Such a system would **parallel engineering control** with **construction control**. This approach could be **automated within CAD**: However, development of **good quantity estimates** during the budgeting process is a major **hurdle for this approach**.

The future

- The following have been identified:

  4. **Inclusion of Quality in Project Control.** Time, cost, and quality control are the **goals of every project manager**, yet quality control is **not formally included** in the project control system. Use of a **quality performance index** along with other indices used in control systems should be considered **for the future.**

Appendix A:
Progress Measurement Systems

Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

  1. **Units Completed.**

  - This method is **suitable when**

    a) Total scope of an activity consists of a number of **equal or nearly equal parts**, and

    b) Status is logically determined by counting parts completed and comparing that to the total number of parts included in the activity.

Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

  1. **Units Completed.**

  - Ideally, **each unit** is of relatively short duration.
  - While this method has **considerable application** in the construction phase, it has **limited use** during engineering.
    - *A possible application is in the **writing** of a number of specifications of a given type where **all specifications** are considered to have essentially equal weight.*

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Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

2. **Incremental Milestone.**

- This method is appropriate for activities of **significant duration** which are composed of
  a) Easily recognized
  b) Sequential sub-activities
- **Percentage completion** values are established based on the effort estimated to be required at each milestone point **relative** to the total for the activity.
  - ✓ *This method is **ideal for control** of*
    a) Drawings and
    b) Can be used in procurement

Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

2. Incremental Milestone.

- A typical example for drawing control is:

Start drafting	0%
Drawn, not checked	20%
Complete for office check	35%
To owner for approval	70%
First issue	95%
Final issue*	100%

****Only when no additional engineering is anticipa***

A typical example for procurement is:

Bidders list developed	5%
Inquiry documents complete	10%
Bids analyzed	20%
Contract awarded	25%
Vendor drawings submitted	45%
Vendor drawings approved	50%
Equipment shipped	90%
Equipment received	100%

Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

3. **Start/Finish Percentages.**

   - This method is **applicable** to those activities which
     a) Lack readily **definable intermediate milestones**, and/or
     b) Effort/time required is **difficult to estimate**
     - For these tasks, controllers credit
       i. **20-50 percent** when the activity is started and
       ii. **100 percent** when finished.

Why percentage assigned when starting?

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Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

  3. **Start/Finish Percentages.**

     - The **reason** that a percentage is assigned for starting is that this compensates for the **long period** between start and finish ________**when no credit** is being given.

       - ✓ *This method is **appropriate for work** such as*

         1. *planning, designing, manual writing, model building, and studies.*
         2. *It can also be used for specification writing*

Basic methods

- The determination of percentage completion on a single activity can usually be handled under **one of the following four systems**:

  4. **Ratio or Judgement.**

     - This method is applicable to **tasks** such as project management, constructability studies, project controls, and comparable activity which
       a) Involves a **long period of time**,
       b) has **no particular end product**, and
       c) is estimated and budgeted on a **bulk allocation basis** rather than on some **measure** of production
       d) It can also be used on those tasks for which the Start/Finish method is **appropriate**.

Basic methods

Percent complete at any point in time is found by dividing

1. *Hours (or dollars) spent to date by*
2. *Current estimate of hours (or dollars) at completion*

Appendix B:
Cost & Schedule Control Systems Criteria

The CSCSC systems

- Following are **key features** of the DOE/DOD Cost & Schedule Control System Criteria (CSCSC) for Performance Measurement.

The CSCSC systems

- **Breakdown Structures.**
  - A **Work Breakdown Structure (WBS)** for the project is developed similar to that previously described in this document.
  - This breakdown is product-oriented and defines the **columns of a matrix**.
  - The **rows** of the matrix are defined by an Organization Breakdown Structure (OBS),

    which details in **hierarchical fashion all organizations responsible** for the work.
  - The rows and columns meet to **describe cost accounts** which include **all specific tasks**

    to be **performed by an organization** with respect to an item on the WBS.

The CSCSC systems

- A **typical cost account**
  1. Might be the electrical design by firm A of a specific system.
  2. It can also be an indirect item such as **quality control or supervision**.
- Cost accounts can be **further broken down** into specific tasks such as **drawings** and **specifications**.
- The **term work package** is used to describe both tasks and combinations of tasks in the **CSCSC system.**
- The **CBS of Figure 1** is essentially a simplified version of the CSCSC's WBS/OBS matrix.

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The CSCSC systems

- Terms. **A number of terms** are established for use in reporting the status of a project. These are:
  - **Budgeted Cost for Work Scheduled (BCWS).** BCWS is the cost account or total contract budget less any **"management reserve"** (funds held in reserve to be used in case of scope growth).

    It is time-phased based on the cost-loaded schedule.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **<u>Budgeted Cost for Work Performed (BCWP).</u>** BCWP is the earned value, <u>expressed in dollars</u>, for all work accomplished during a period. It is equal to the sum of the budgeted costs of that work.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Actual Cost of Work Performed (ACWP).** ACWP is the total of all costs actually incurred in accomplishing work within a given period and recorded at the **cost account level.**

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Budget at Completion (BAC).** At the **cost account level**, BAC is the total **authorized budget** for that account. For the project, it is the **total including management reserve.**

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The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Estimate at Completion (EAC).** EAC is the **latest cost estimate** for a cost account or the total project.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Cost Variance (CV).** CV is the difference between BCWP and ACWP, and shows whether work performed has been costing more or less than budgeted.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Schedule Variance (SV).** SV is the difference between BCWP and BCWS, and shows whether more or less work was performed than scheduled.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **At Completion Variance (ACV).** ACV is the difference between EAC and BAC, and shows whether an **overrun or underrun is expected**.

The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Cost Performance Index (CPI).** CPI is an index found by dividing BCWP by ACWP. It can be calculated on a "this period" or cumulative basis, and when plotted on a graph is an effective way of showing cost trends. A CPI of 1.0 or greater is favorable. It is an alternate presentation of the CV.

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The CSCSC systems

- Terms. A number of terms are established for use in reporting the status of a project. These are:
  - **Schedule Performance Index (SPI).** SPI is an index found by dividing BCWP by BCWS. It compares the volume of work being performed to the volume scheduled. As with the CPI, it is suited for trend charts. An index of 1.0 or greater is favorable. It is an alternate presentation of the SV.

Cost accounts

- These take one of three forms:

  1. **Work Packages.** Work involving easily identified **end products**.
  2. **Level of Effort (LOE).** Support type activity which does not have a final product and which is not specifically related to **individual work packages**.

     Management, project controls, and other staff activities are typical LOE cost accounts.
  3. **Apportioned Effort.** Support activities which are directly tied to individual work packages.

     Quality inspection and testing is an example of a cost account in this category.

Applicability of CSCSC to civilian design projects

- The **structure of CSCSC** is complicated and difficult to use.
- It was designed for high-dollar value, cost-reimbursable, and complex defense and energy projects, **not the more typical commercial and industrial projects**.
- It monitors both cost and work through a cost control system.
- Unfortunately, costs do not flow into a project in a **timely manner**, **thus** a work control system based on cost is not timely.
- **Most contractors** prefer a work statusing system based on work-hours and work quantities (normally reported daily) for day-to-day management of work.
- **If operating under CSCSC**, contractors will usually employ a work-hour/work quantity system for **internal control** in addition to complying with CSCSC for reporting to DOE or DOD.
- The CSCSC recognizes and allows such supplementary control systems by contractors.

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