Welcome

Learning Objectives

Upon completion of this lesson, you will be able to:

- Identify the types of maintenance labor costs included in estimates of system maintenance costs
- Explain the factors that influence maintenance labor costs
- Describe the various cost estimating methods as they relate to maintenance labor costs

Closed Captioning

Upon completion of this lesson, you will be able to:

- Identify the types of maintenance labor costs included in estimates of system maintenance costs,
- Explain the factors that influence maintenance labor costs, and
- Describe the various cost estimating methods as they relate to maintenance labor costs.

Why Is This Important?

Supply and maintenance are inextricably linked in terms of product support planning, and not surprisingly, in managing O&S costs as well. While design is the most significant factor driving maintenance, supply is driven by maintenance. While the impacts of design on O&S cost are readily apparent, maintenance and supply, which are driven by RAM decisions, are significant cost drivers as well.

For the PSM, the length of time he or she will be planning, monitoring, and adjusting the program's maintenance and supply infrastructures will be far longer than time spent "designing for support."

Let's examine maintenance first.

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Long Description

Helicopter landing on a aircraft carrier deck, worker fixing equipment, workers measuring and recording information.

"Traditional" Levels Of Maintenance

The three most common levels of maintenance are Organizational (O-Level), Intermediate Level (I-Level), and Depot (D-Level). Note that Organizational level maintenance is also sometimes called "field" level maintenance. The lines between these levels of maintenance can sometimes become a bit blurred, and some systems will have only two levels while others may have multiple "sub-layers" within the levels of maintenance.

O - Level

I - Level

Depot

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Long Description

O-Level - Pie chart, I-Level - figure going up stairs, Depot - figure with toolbox.

"Traditional" Levels Of Maintenance, Cont.

Characteristics of the "Traditional" Levels Of Maintenances include:

- **Organizational (O-Level) aka field level maintenance**
  - Maintenance and repair performed within the activity's capability by the organization that uses the system
- **Intermediate (I-Level)**
  - Maintenance and repair which the organizational level is incapable of performing, but which do not have to go to depot level
- **Depot (D-Level)**
  - Major overhaul or complete rebuild of parts, assemblies, subassemblies, and end items
    - Including the manufacture of parts, modification, testing, and reclamation as required
    - Requires more extensive shop facilities and personnel of higher technical skill than are normally available at organizational and intermediate maintenance activities

Maintenance Terminology

This is a depiction of the multiple echelons that can exist within the various levels of maintenance. Why is this important? Because the costs associated with, for example, a forward deployed support unit and a theater support unit might be significantly different.

Another recurring theme is that the PSM must thoroughly understand the operational context of the system and also thoroughly understand the context in which the various maintenance echelons will function.

Functions Performed	On/Off Equipment	Level	Echelon	
Adjustments, Repairs by Replacement, Scheduled & Preventative Services, Cleaning, Lubrication, Tightening	On-Equipment	Organization (O-Level)	1st Echelon	Individual
	On-Equipment		2nd Echelon	Owning Unit
Diagnosis, Fault Isolation, Repair by Replacement, Calibration, Battle Damage Assessment	Off-Equipment	Intermediate (I-Level)	3rd Echelon	Forward Deployed Support Unit
Repair of assemblies, components and modules	Off-Equipment		4th Echelon	Theater Support Unit
Rebuild Major Components, System Inspection & Overhaul	Off-Equipment		5th Echelon	Depot

Scheduled and Unscheduled Maintenance Events

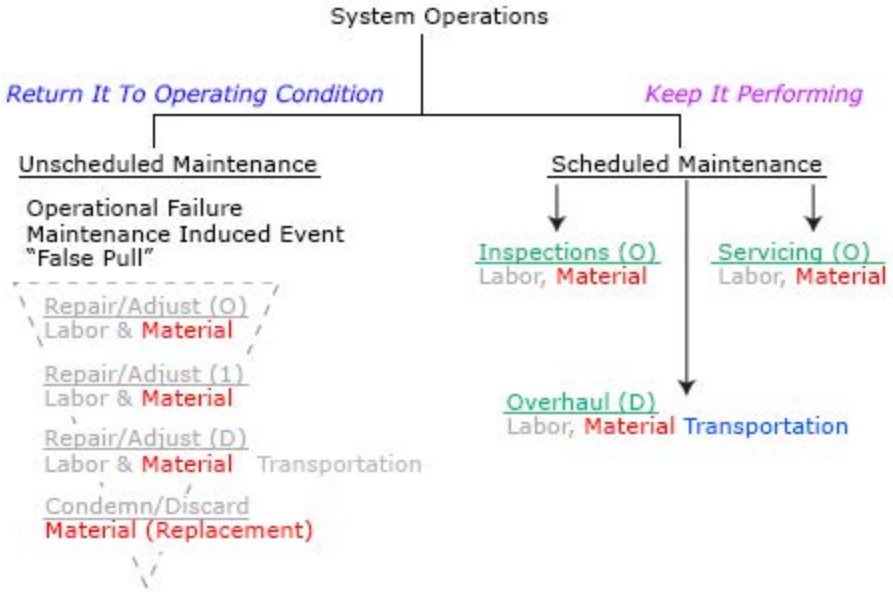
There are two major categories of maintenance costs, those events associated with **unscheduled maintenance** and those events associated with **scheduled maintenance**.

Unscheduled maintenance occurs as a result of failures or perceived failures or can be the result of a maintenance-induced event. It may also be considered a maintenance action that occurs as a result of some other maintenance action having taken place.

Scheduled maintenance involves servicing tasks, inspections and overhauls and can be performed on an event basis (i.e., the return of an aircraft from a mission), a calendar basis, or on an operating hour basis.

Scheduled and Unscheduled Maintenance Events, Cont.

Organizational, intermediate, depot and contractor activities can be involved with unscheduled maintenance. For scheduled maintenance, servicing is usually performed only at the O-level, inspections at the O and I levels and overhauls at the Depot level. Direct costs expended for maintenance actions include labor, materials and transportation. These direct costs are then augmented to account for overhead and administrative functions necessary for providing the facilities, tooling, logistics and management support. **Select the image to enlarge.**



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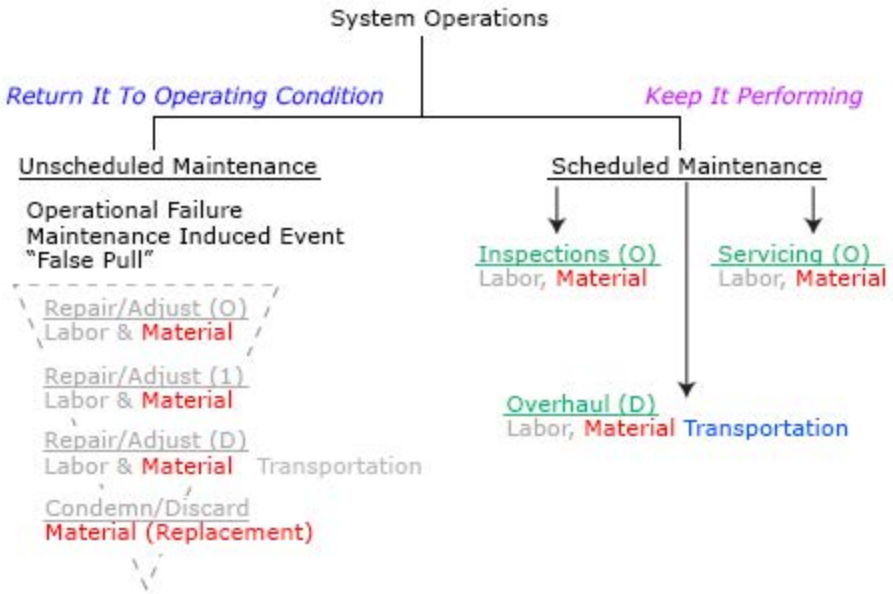
Long Description

Chart reads from top to bottom. The flowchart describes the direction and servicing to be performed in two main areas, Returning to Operating Condition and Keeping It Performing. Under the Keeping It Performing branch, inspections and servicing are listed as O-Level while Overhaul is Depot Level. Under the Unscheduled Maintenance branch, services branch down from Repair to Condemn and Discard.

Scheduled and Unscheduled Maintenance Events, Cont.

If the system is unreliable, there will likely be more unscheduled maintenance and thus, more cost. Maintainability, another design-driven characteristic, will impact both unscheduled and scheduled maintenance, particularly in labor costs. The longer it takes to return the system to operating condition or to perform scheduled maintenance, the more labor costs will be incurred. **Select the image to enlarge.**



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Knowledge Review

Part X is removed from an aircraft, having been identified as a failure. The flight line mechanic places the failed part in a container and returns it to a designated contractor's plant for repair. This repair is probably a _____.

- [x] Depot Level Repair
- [ ] Intermediate Level Repair
- [ ] Field Level Repair
- [ ] 2nd Echelon Repair

Check Answer

This scenario represents a **Depot Level Repair (D-Level).**

Maintenance Cost Estimating Methods

The PSM will use five possible methods for maintenance cost estimation including:

1. **Direct**: an estimate the number of maintenance events expected over the analysis period and the cost per event. (A prediction equation based on theory.)
    A. Subsystem design "complete"
    B. Testing begun
2. **Analogy:** to obtain data on similar systems and adjust as necessary to account for known differences. (An adjustment of data from similar systems.)
    A. Early in a program
    B. Design incomplete
3. **Cost Estimating Relationship (CER):** uses a prediction equation based on historical data that depends on design and operational parameters.
    A. System level design "complete"
    B. If available and verifiable
4. **Expert Opinion:** is used when none of the above methods are applicable or results from using one of the above methods have to be modified.
    A. Fielded Systems and reliable data collection
    B. Predictable pattern
5. **Combination:** to employ two or more of the above methods such as using the direct method based on a reliability estimate for the number of events and data from an analogous system for the cost per event.

Direct Estimation Method: Factors

Now we will take a closer look at two of the Cost Estimating approaches, Direct and Analogy. We will begin with the Direct approach to cost estimating and its factors. The following equation represents the direct method of multiplying estimates of the number of events by the cost per event.

Cost = Number of Maintenance Actions x Cost per Action

Direct Estimation Method: Examples

The following examples each have the basic form of number of events multiplied by the cost of the event. The number of events is determined by the operating exposure, the reliability, and the maintenance policy. The cost per event is determined by such factors as maintainability, the support infrastructure, and system complexity and cost.

Supportability analyses conducted during the development phases such as the Maintenance Task Analysis and the Level of Repair Analysis (LORA) and contractor studies can provide useful data and information for this type of estimate.

A. **DLR cost/year** = Number of DLR replenishments per year x Cost per DLR replenishment

B. **Engine overhaul cost/year** = Number of engine overhauls per year x Cost per overhaul

C. **Periodic inspection cost per aircraft per year** = Number of periodic inspections per aircraft per year x Cost per periodic inspection

Direct Method: Estimating the Number of Maintenance Actions

This slide provides an example of an equation for directly estimating the number of maintenance actions, in this case, the general term "demands" is used. This formula is provided primarily for reference to show the types of data needed to make one of these calculations. Even this calculation, which would rely heavily on the output of supportability analyses, needs to be examined by the PSM.

How were the various components of this formula derived? Do they make sense? The reality is that on many weapon systems, projected reliability is overstated and projected maintenance time is understated. An overly optimistic approach could significantly understate the estimated O&S cost.

This is a typical Cost Analysis Strategy Assessment (CASA) Equation:

$$DPM_{iy} = \frac{(AVGOPS_y)(SOH)(QPS_i)}{MTBMA}$$

Legend

DPM_{iy} = demands per month of ith item in year y
$AVGOPS_y$ = average number of operating systems in year y
SOH = system operating hours per month
QPS_i = quantity of ith item in each system
$MTBMA_{iy}$ = mean time between maintenance actions for the ith item in year y

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Long Description

Demands per month of the item in year y is equal to average number of operating systems in year y multiplied by system operating hours per month multiplied by quantity of ith item in each system, the product of which is divided by mean time between maintenance actions for the ith item in year y.

Analogy Method

Now we will take a look at the Analogy method. This is a general equation for estimating by analogy. F1, F2, … are factors that are relevant to estimating an element of maintenance cost. Usually such factors will be related to the frequency of occurrence of the maintenance event under consideration and the corresponding cost of the maintenance action.

A typical relevant factor is the procurement cost. The formula itself is less important to the PSM than the recognition that factors must be applied to "old" system data. The PSM should be aware of the rationale behind the application of those factors to make sure that they are logical and intelligently applied. He or she must use data from existing, relevant systems and be able to adjust the historical cost to reflect differences.

This is a general equation for estimating by analogy.

$$New = Old \left(\frac{F_1, new}{F_1, old} \right)^{x1} \left(\frac{F_2, new}{F_2, old} \right)^{x2} \ldots$$

Legend

F_1, F_2, etc. are relevant adjustment factors
x_1 , x_2 are exponents typically = 1 but sometimes $0 < x < 1$

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Long Description

New system data is equal to Old System data multiplied by relevant adjustment factors.

Using Data From Historical Analogies

In many cases, the use of historical analogies is as much of an art as it is a science. There are many areas where inaccuracies can be introduced. But, keep in mind that sometimes that is your only option.

Using Data From Historical Analogies method has many risks in identifying similarities and differences. The risks include:

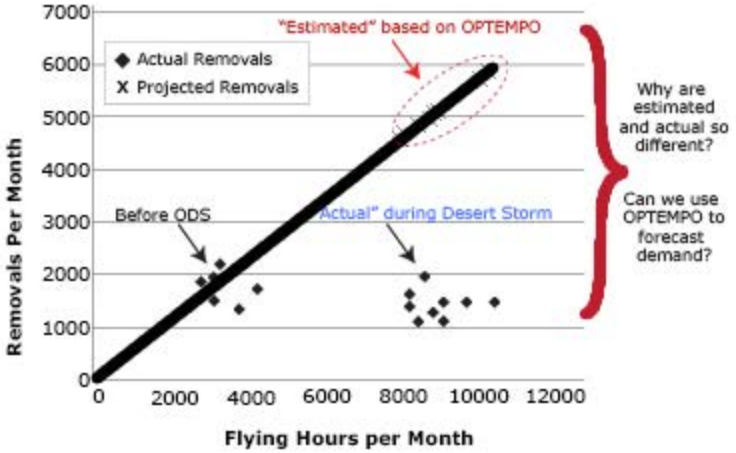
- New or changed practices and policies
- Affects of operating environments
- Scaling (indivisibility problem)

Sometimes using historical analogies is the best available option, and if so, factoring in adjustments that have been made becomes critical. Typical adjustments include:

- R&M improvement forecasts
- Operating assumptions (e.g. OPTEMPO)

Using Historical Data Properly: The Desert Storm Example

In using historical data to draw analogies, we have to be very careful how we use this data. Here is an example of some calculations that were made using historical data to project removals based on flying hours. The projection was that there would be, based on OPTEMPO, a significantly larger number of removals occurring based on the increase in flying hours driven by a wartime environment. What actually happened during Operation Desert Storm was something startling and considerably different than the projected removals. Actual removals were much fewer. Why did this happen? **Select the image to enlarge.**



Source: "A Physics-Based Alternative to Cost-Per-Flying-Hour Models of Aircraft Consumption Costs," Wallace, et. al., LMI, August 2000
(Fig 1-1. Projected and Actual C-58 Removals, Before, During Operation Desert Storm

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Long Description

Graph from Desert Storm activity showing Flying hours per month on horizontal axis vs Removals per month on vertical axis. Graph shows a significant number of removals based on projections based on OPTEMPO. The actual removals were about what was projected but over a much more significant amount of flying hours.

Using Historical Data Properly: The Desert Storm Example, Cont.

A number of factors might account for the difference between the projected and the actual data for removal. For example:

1. Removal data was not fully reported (bad data).
2. Maintenance was deferred during Desert Storm (some defects were not fixed immediately).
3. "Not Flying" creates more removals than flying.
4. Removals are not really "driven" by flying hours.
    A. Engines typically are stressed by "cycles" and long duration missions have fewer cycles per flying hour.
    B. Some components are more affected by take-offs and landings than flying hours and long duration missions have fewer take-offs and landings per flying hour.

Operating Environments and O&S Data

As we saw in the Desert Storm example, the operational environment matters. If we are going to use historical data, we need to make sure that the operating environments being compared are truly similar. If they are not then we have to account for the difference. The PSM must take into account the following implications for determining O&S costing estimates:

Know The System:

- Talk with the experts.
- If you drew data from a cost or parts usage system for a time period that included Desert Storm and believed it was typical, you could be badly mistaken using these data as an analogy basis for another system.

Know how/if the operating environment of the system you are analyzing differs from its historical predecessors.

Knowledge Review

Recent changes to the possible operating environment of your weapon system have introduced some additional risk in your cost estimate based on the type of estimation method your program chose. Which of the following is most likely the one that your program picked?

- [ ] CER
- [x] Analogy
- [ ] Actual
- [ ] Direct

Check Answer

Common risk where the operating environment changes significantly is **Analogy**.

Maintenance Personnel Quantities: Labor Costs

The cost of labor at a depot is often included in the total cost of the Depot Level Repairable. The PSM generally has no role in calculating this cost. However, labor costs at the organizational/unit level and at the intermediate level have to be calculated separately. Maintainability as a design characteristic can significantly impact these labor costs, and hence the need to examine the adjustments to any historical analogy.

The primary focus will be on unit and intermediate level maintenance organizations and include:

- Depot maintenance is often estimated as total cost - labor, materials, and surcharges.
- If labor estimates are done separately, same methods are applied as unit and intermediate labor cost estimating.

Sources and methods applied include:

- Official, validated, manpower documents [Manpower Estimate Reports (MERs), etc.]
- Historical analogy with appropriate adjustments

Adjusting For Reliability Differences

The assumption reflected here is that changes in Reliability will result in changes to the amount of labor required. Again, the emphasis is on making sure we are comparing the proverbial "apples to apples". In the formula, the "U" in the first equation stands for "Unit." The "FR" stands for "Failure Rate." In making these calculations we need to make sure that the Failure Rate, or the inverse of the Reliability, is at a consistent level.

For example, the "FR-new" should not be for a landing gear if we are trying to calculate the labor necessary to do maintenance on an entire aircraft.

$$Labor_{new} = Labor_{old} * (MTBUMA_{old} / MTBUMA_{new})$$

$$Labor_{new} = Labor_{old} * (FR_{new} / FR_{old})$$

The following are the assumptions for this equation:

- The labor is proportional to failure rate (1/MTB_)
- Mean Time Between Maintenance Action (MTBUMA) is more meaningful than Mean Time Between Failures (MTBF)
- The PSM must account for labor for scheduled and unscheduled maintenance tasks separately
- Reliability must be at the same system level where maintenance labor is being estimated

D

Long Description

New labor is equal to old labor multiplied by the quotient of old Mean Time Between Maintenance Action over new Mean Time Between Maintenance Action.

New labor is equal to old labor multiplied by the quotient of new Failure Rate over old Failure Rate.

Adjusting For Maintainability Differences

As we attempt to define the adjustments we must make to our estimate based on differences in maintainability, there are a few things the PSM and cost estimator have to keep in mind.

First, labor is the cost driver and is much more important to the cost estimate than Mean Time To Repair (MTTR), the most common Maintainability metric.

Second, while Reliability primarily impacts Unscheduled maintenance, Maintainability affects both scheduled and unscheduled.

$$Labor_{new} = Labor_{old} * (MMH/MA_{new} / MMH/MA_{old})$$

MMH=Mean Maintenance Hours
MA=Maintenance Actions

The following are the assumptions for this equation:

- The labor is proportional to maintainability (MMH/MA).
- Maintenance labor per maintenance action is more meaningful than mean time to repair (MTTR).
- Maintainability applies to both scheduled and unscheduled maintenance.

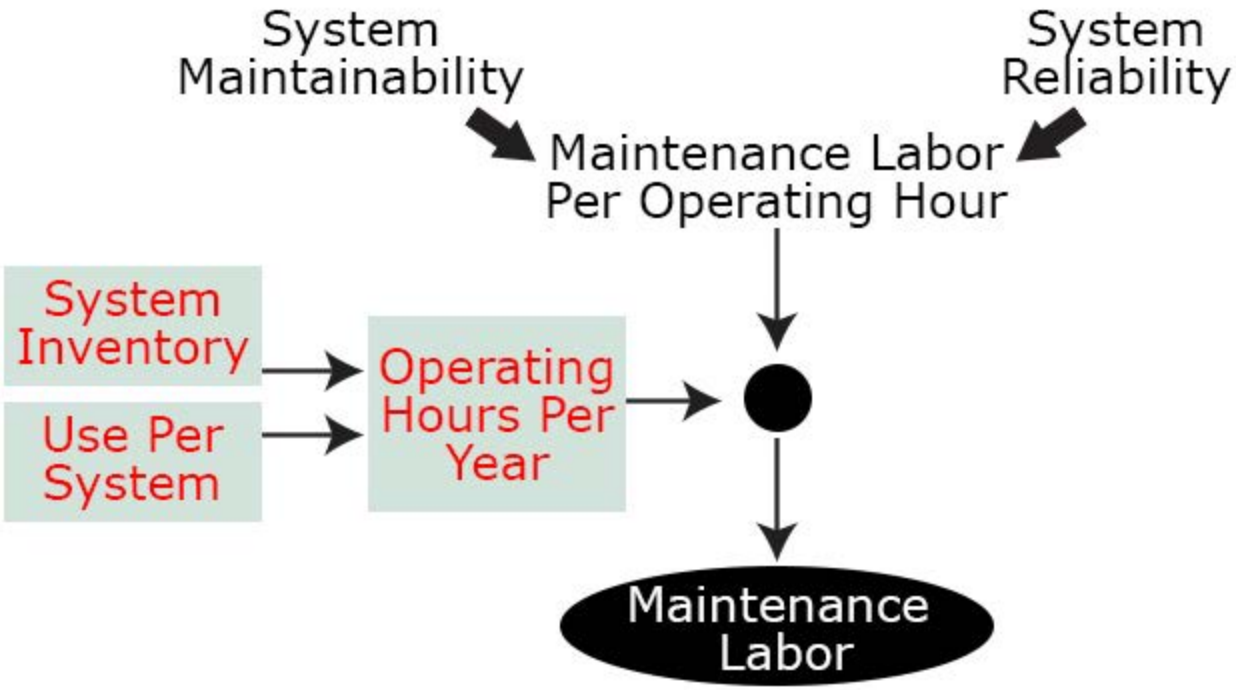
D

Long Description

New Labor equals old labor multiplied by MMH to new MA ratio divided MMH to old MA ratio.

Simplified Approach To R&M Interactions

When you are calculating the cost of maintenance labor, recall that Maintainability and Reliability will determine the Maintenance Labor per Operating hour. The operating environment will determine the number of operating hours. These factors influencing the cost are shown in this diagram.



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Long Description

Graphic showing how maintainability and reliability affect Labor per operating hour. Graphic reflects Maintainability and Reliability going into Maintenance Labor per operating hour. That combined with the operating hours per year gives an overall maintenance labor cost.

Knowledge Review

The warfighter has complained that System Y is a very maintenance-intensive system, and is taking too many personnel away from the operational mission to do maintenance. In examining alternatives and their impacts on O&S cost, the PSM concludes that reducing the number of maintenance hours per maintenance action will most likely affect _____.

- [ ] Scheduled Maintenance
- [ ] Unscheduled Maintenance
- [ ] Labor Costs
- [x] All of the above

Check Answer

All of the above is correct. In examining alternatives and their impacts on O&S cost, the PSM concludes that reducing the number of maintenance hours per maintenance action will most likely affect scheduled and unscheduled maintenance and labor costs.

Lesson Summary

In determining the O&S costs for Maintenance, the major cost drive is Labor Costs. In this lesson, we looked at types of labor costs and the different methods of estimating them.

The three traditional levels of maintenance include Organizational Level (O-Level), Intermediate Level (I-Level), and Depot Level (D-Level). The key driver in labor costs is the number of hours expended in both unscheduled and scheduled maintenance, primarily at the organizational and intermediate levels of maintenance.

There are five methods that the PSM may rely upon for cost estimating including:

1. Direct
2. Analogy
3. Cost Estimating Relationship (CER)
4. Expert Opinion
5. Combination

The cost of labor at a depot is often included in the total cost of the Depot Level Repairable. The PSM generally has no role in calculating this cost. However, labor costs at the organizational, or unit level and at the intermediate level, have to be calculated separately.

Lesson Summary, Cont.

Congratulations! Now that you have completed the Maintenance and Maintenance Labor lesson, you should be able to:

1. Identify the types of labor costs included in estimates of system maintenance costs.
2. Explain the Factors that influence maintenance labor costs.
3. Describe the various cost estimating methods as they relate to maintenance labor costs.

Lesson Completion

You have completed the content for this lesson.

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