

Maintenance Planning,  
Scheduling & Coordination

Auteurs: Don Nyman.

Joel Levitt.

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**Preface**

Maintenance Excellence is requisite to the achievement of World-Class Operations (an organization that is competitive with the best in the world).

Well-planned, properly scheduled, and effectively communicated jobs accomplish more work, more efficiently, and at a lower cost.

**Introduction**

Maintenance organizations everywhere have the responsibility to assure optimum use of the capacity of an enterprise.

Preventive/Predictive Maintenance (PPM) is not conceived to put equipment in proper condition, but to maintain it in that condition from the time of acquisition or restoration.

Proactive maintenance requires a cultural transition from a reactive to a proactive environment.

Integrated maintenance and production management partnership:

<b>Governing principles and Concepts</b>		= shared beliefs
*	Status Assessment	= measurement of current state of shared beliefs
*	Goals & Targets	= established objectives
*	Master Plan	= what, who, when ... to close the gap between current status and the goals
*	Budgetary Control	= support of the Master Plan
*	Management Reporting and Control	= feedback necessary to earn sustained management commitment

<b>Preventive/Predictive Maintenance</b>		= vehicle by which reliability is assured
*	Maintenance Engineering	= function to optimise the PM/PdM process
*	Equipment History	+ Reliability Centered Maintenance are used by Maintenance Engineering

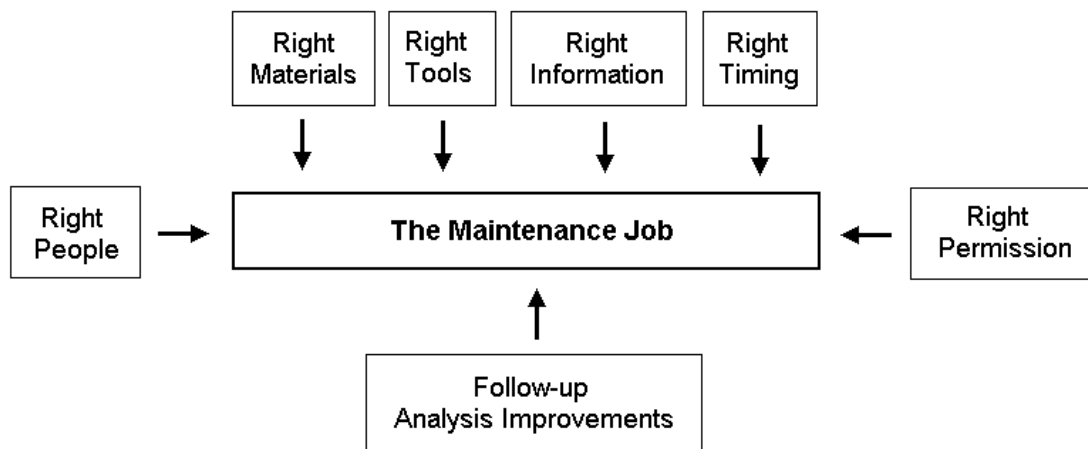
<b>Organization structure</b>		= structured for proactive rather than reactive response
*	Skills Training	= essential elements and a source of pride
*	Facilities, Tools and Equipment	
*	Supervision	+ practices to achieve ...
*	Quality Assurance	+ adherence to policies and procedures

<b>Planning, Coordination &amp; Scheduling</b>		= needed to fulfil expectations through ...
*	Computerized Work Order System	
*	Cost Distribution	
*	Work Measurement	

### Definitions

Planning (how to do the job) is the development of a detailed program to achieve an end (i.e. a maintenance repair or rebuild).

The planner's role:



Coordination encompasses the logistical efforts of assembling all necessary resources so the job is ready to be scheduled.

Scheduling (when to do the job) is the written process whereby labour resources and support equipment are allocated/appointed to specific jobs at a fixed time when Operations can make the associated equipment or job site accessible.

### Why plan, coordinate and schedule maintenance jobs?

Most maintenance departments do not plan to fail, they simply fail to plan and therefore do indeed fail. The major reason behind failure to plan is that putting out today's fires is given priority over planning for tomorrow – thereby insuring that future equipment failures will require reactive response ...

Reactive maintenance is simply a vicious circle, a continuous downward spiral.

We plan because planned maintenance reduces waiting and delay times that mechanics inevitably encounter when performing work that has not been properly prepared for.

Mismanagement is highly visible to the workers on the front lines.

Do we really work best under pressure, or do we simply work faster and less effectively due to lack of preparation and hasty judgements?

The measure of true management is the ability to distinguish important from urgent, refusal to be tyrannized by the urgent, refusal to manage by crisis.

Advanced planning, coordination, scheduling and the pursuit thereof are proactive skills.

If you do not have the time to do it right, will you have the time to do it over?

#### Learn to say NO

Decide what not to do. "I don't know the key to success but the key to failure is trying to please everybody." [Bill Cosby]

See annex 1: The Rush Job - *Anonymous*.

#### Objectives of work preparation

Without proper planning and scheduling, maintenance is haphazard, costly and ineffective, and will consistently fail to meet promised dates. These failures will cause constant problems for Operations, who will become increasingly reluctant to release equipment in the future.

#### Prerequisites

Proven prerequisites for maintenance objectives:

- Lead-time is essential
- A strong institutionalised Work Order System
- An organizational structures that fosters Pro-action
- Reasonable span of control for supervisors
- Understanding the department's mission in relation to company objectives
- Assistance for Operations in establishing a practical level of maintenance
- Regards for operations as an internal customer

Maintenance customers deserve to have their work performed on a timely basis. Therefore, backlogs must be kept within reasonable limits.

Each hour of effective planning typically returns three to five hours in mechanic time or equivalent savings (measured in cost of material and production downtime).

## **Chapter 1 - Selling Planning, Coordination and Scheduling to Management and Operations**

### Selling management

Contributions of maintenance:

- Capacity assurance,
- Reliability,
- Customer satisfaction,
- ... at a lower unit cost.

### Work Sampling

The Active Sampling technique uses random observations of the maintenance work force with categorization by nature of each observation. 700 observations for a single population (ex.: 1 shift of electricians) are needed.

### Typical Maintenance Worker's Day – with and without planning & scheduling

<b>Category</b>	<b>Reactive</b>	<b>Proactive</b>
Receiving instructions	5%	3%
Obtaining tools and materials	12%	5%
Travel to and from job	15%	10%
Coordination delays	8%	3%
Idle at job site	5%	2%
Late starts and early quits	5%	1%
Authorized breaks and reliefs	10%	10%
Excess personal time	5%	1%
<b>Subtotal</b>	<b>65%</b>	<b>35%</b>
<b>Direct Actual Work accomplished</b>	<b>35%</b>	<b>65%</b>

### Symptoms of ineffective job planning

For lack of proper preparation, much time is lost:

- Gaining detailed knowledge of the required work
- Obtaining permits
- Identifying and obtaining materials, tools, etc.
- Delivering the above inputs to the job site
- Waiting for required spare parts that are not in stock

Convey the many benefits that accrue to each stakeholder

Planning, scheduling & coordination provide significant benefits to management by:

- Providing a central source of information
- Improving employee safety
- Improving regulatory compliance
- Achieving the optimal economic level of maintenance
- Challenging the need for work requests
- Accurately forecasting labour and material needs
- Establishing expected workload and analysing the variations
- Improving efficiency through avoiding delays
- Providing factual data
- Identifying problem areas
- Reducing total unit cost
- Increasing useful life of assets
- Improving preparation, management and control of major shut-downs

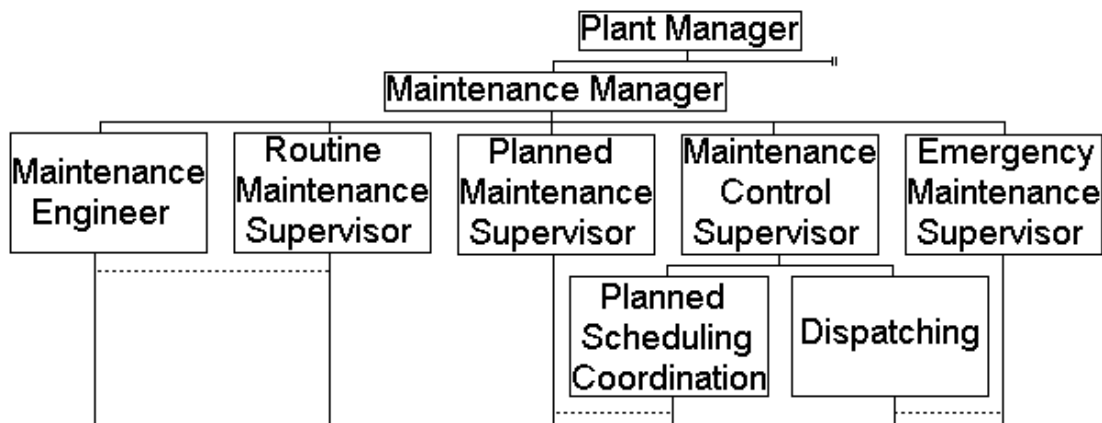


## Chapter 2 - Understanding the Nature of Maintenance Activities & Organizing Accordingly

Organizationally, there must be recognition of and provision for the three broad types of work performed by the maintenance department: prompt emergency response, reliable routine service and timely backlog relief.

As managers, we must not allow urgency alone to consume all available resources. Resources must be preserved or provided for the important work that improves future reliability and thereby reduces future urgencies.

Organization by work type:



The routine maintenance group and the emergency maintenance group are two minimally sized crews.

Routine include all PM/PdM and other inspections, as well as lubrication, calibration, tests, cleaning, adjustment, tightening, etc.

Backlog consist of all plannable work still open. In a proactive environment, the bulk of the maintenance workload should be plannable (65% tot 75%). Backlog work originates from PM/PdM inspections, in the form of Corrective Work Orders, from projects and non-urgent requests from sources throughout the organization.

### **Chapter 3 - Where Planning Fits Into Good Maintenance Practices**

When a maintenance planning and scheduling function is being established, the first question that usually arises is where and how it fits into the organization. The first answer is that it is structured within the maintenance organization, not outside of it. Secondly, it should be organizationally independent of the specific maintenance supervisor(s) it is tasking, as well as supporting.

Planners therefore should be on the same organizational level as the supervisors they support on a week-to-week basis. Neither should be superior or subordinate to the other.

The maintenance supervisor and the maintenance planner form the most important partnership within the maintenance department.

#### Should work preparation be a separate and distinct function?

As Peter Drucker once said: “The productivity of work is not the responsibility of the worker but of the manager. A worker will not plan for his own efficiency.”

Unfortunately, under modern principles of human behaviour, the common belief is that separation of preparation from execution is unnecessary. ... Consistent with concepts of worker involvement and self-direction, job preparation is being forced to the lowest organizational level possible.

#### The assigned craftsman

If planning is left to technicians it is rarely performed well.

Because of his position in the organizational hierarchy, the craftsman is not well-positioned for many of the liaisons associated with the planning and scheduling role.

#### The responsible supervisor or team leader

Given the demands of daily maintenance execution, supervisors are forced to concentrate on the immediacy of today's problems and have little time left to focus on effective preparation for future activities. If they are tasked to address both preparation and execution, planning for future jobs is almost always neglected due to the pressure of today's work.

#### The proven answer

Experience shows that the functions of preparation, supervision and maintenance engineering are best separated. All three require different skills, and a combination of all these skills in one person is the exception rather than the rule.

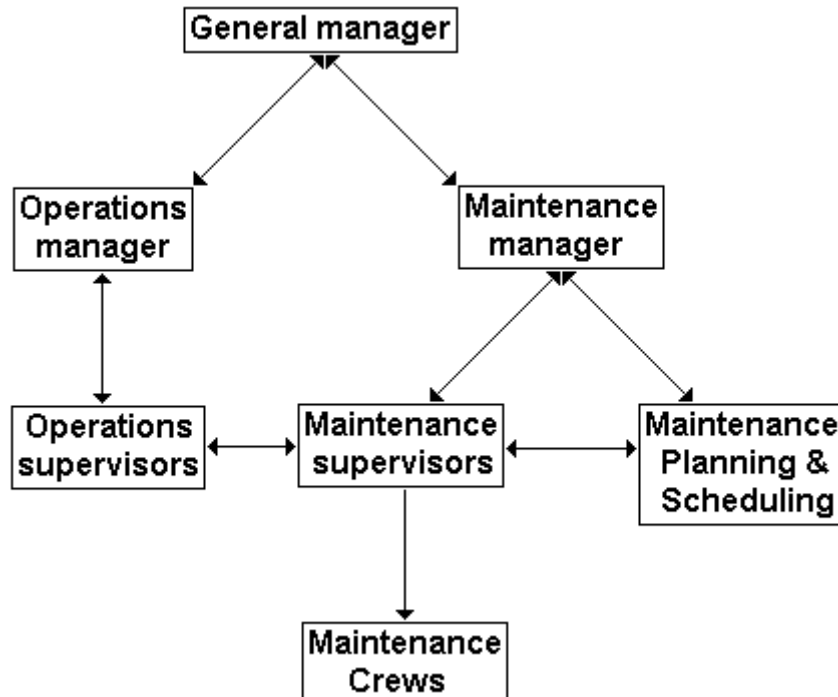
This separation of the planning function does not mean that the maintenance technician is not involved in the planning portion of preparation. Mechanics, supervisors and planners all contribute to the planning process. Craftsmen contribute in five important ways:

1. Some jobs either by design (minor) or by default (urgency) are not covered by a planned job package.
2. There are situations where the backlog waiting for planning gets out of control.
3. There are situations where the knowledge of a given mechanic simply exceeds that of the planners or supervisors.
4. Craftsmen can be utilized as planning assistants on a temporary, rotating basis.
5. Participative team concepts may want one member of the team to be designated as the planner or coordinator for a period of time.

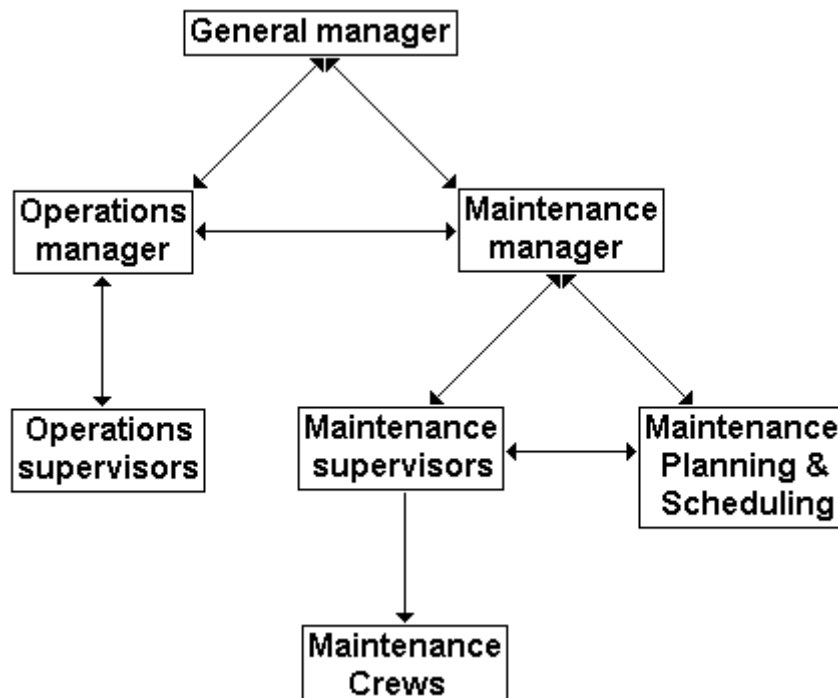
Channels of coordination and communication

The Planning and Scheduling group is the hub of inter and intra functional/organizational coordination and communication. Planners are the principal point of contact and liaison between maintenance, operations and other support departments.

This relationship, called direct liaison, is depicted in the following figure:



The antithesis, where planners are seen to support only the maintenance manager as a staff assistant, is presented in the following figure:



Working liaisons

In large organizations, in order to improve coordination between maintenance, operations and other internal customers, consideration should be given to the identification of primary points of contact (Maintenance Liaisons).

Therefore, it is recommended that large organizations establish a specific person in each operating department as a focal point for communications and liaison with maintenance.

Should planning be separate from scheduling?

The selection is a local decision. Many organizations are too small to consider separation of the duties.

It is often difficult to identify a potential planner capable of planning electrical as well as mechanical work. This difficulty relates to the planning portion of the job, not to the scheduling portion.

If the functions are separated, planning is decentralized to where the work occurs, while scheduling is centralized with responsibility to distribute resources based upon location of the workload.

Clarification of roles

The Maintenance Supervisor is responsible for the well being, training and leadership of team members.

The Maintenance Engineer is responsible for application of technical skills and ingenuity to the avoidance and correction of equipment problems causing excessive production downtime, quality variations and maintenance work.

The Planner/Scheduler is responsible for logistic support to remove all avoidance barriers standing in the way of effective completion of maintenance work.

Control spans for the three functions must comply with good maintenance practice:

<b>Function</b>	<b>Control Span</b>
Supervisor	1 : 10
Planner/Scheduler	1 : 20
Maintenance Engineer	1 : 40

Factors influencing planner/scheduler control span

Control span ratios should be used only as guidelines.

See annex 2: Worksheet for determining the ratio of craftsmen to planners.

Relationship with other functions

Maintenance Planners need:

- Clear definition of their relationships with maintenance superintendents, supervisors, mechanics and operations
- Proper computer support to allow development of a comprehensive planning database
- Commitment from maintenance and operating management to hold structured weekly coordination and scheduling sessions to establish priorities for daily, weekly, down day and major outage work
- Cooperation from maintenance supervisors, mechanics and operating supervisors in the effective use and application of efforts put into meaningful planned job packages
- Feedback from mechanics and supervisors (maintenance and operations) regarding specific shortfalls in planned job packages so that improvement of future packages is facilitated
- Feedback from maintenance supervisors regarding compliance with and exceptions to the weekly schedule with noted “reasons”.

## ***Chapter 4 - Managing the Planning and Scheduling Function***

### Management of Planners

Maintenance managers themselves normally manage small planning groups with one to three planners. In larger planning departments with several support positions a Manager of Maintenance Support Services is recommended.

Planning works best when planners do not report to crew supervision. They should be on the same organizational level as the supervisors they support and not subordinate to them. If planners work directly for supervisors, the tendency is for them to be used as expeditors, clerks or purchasing agents in support of daily activity rather than as planners for future (next week) jobs.

### Managing planning

Managing the planning usually boils down to regular assessment of continuous improvement.

For details about measuring the effectiveness of maintenance and maintenance planning see chapter 16.

## **Chapter 5 - Backlog Management and Work Programs**

Control of the backlog is key to successful management of the maintenance function. Backlog is defined as the net workload, measured in labour hours, requested but not yet completed.

Planning for Maintenance Excellence begins with “Macro-Planning”, which is the perpetual balancing of maintenance sources with maintenance workload. Past misuse and deferral of essential maintenance work accelerates deterioration and thereby further increases the requirement for maintenance resources.

Once an organization fails to keep up with deterioration, it cannot maintain a proactive program if one is in place and certainly cannot climb out of an existing reactive state without an influx of adequate resources.

As a practical matter, when an organization is in this state, any deficiencies found by proactive inspections are not likely to be corrected before failure. This condition renders the proactive crew impotent and destroys the morale and effectiveness of the entire maintenance organization.

The current backlog borne by each crew or trade (measured in weeks) must be calculated and displayed on a monthly basis.

### Backlog management

Well-managed maintenance departments hold their backlog within established upper and lower control limits. Backlog ready to be scheduled is part of, but isolated within, the total backlog. Two to four weeks of “Ready” backlog and four to eight weeks of “Total” backlog are considered the norm.

A well-designed and administered “Priority” coding structure with an ageing feature can prevent indefinite delays to individual jobs in the backlog. Medium- and even low-priority jobs are still to be completed within a reasonable time frame.

### Job status

It is essential that planners know the current status of each job in the backlog. Such status is documented via “Status” code within the Computerized Maintenance Management System (CMMS).

The Backlog must be complete, current, pure and reliable. How would the integrity of your current backlog stand up to the following test?

See annex 3: Check-list for Backlog Integrity

### Development of Work Programs

Because maintenance is managed by controlling backlog within established limits, the current backlog upon maintenance crews must be calculated and analysed. A Work Program should be developed for each maintenance team at least monthly.

See annex 4: A weekly example of a Work Program

This data should then be plotted on a trend chart (annex 5) to trigger managerial reaction, as appropriate. Resources should be flexed (adjusted) up or down as analysis indicates necessity. There are three resources that can be flexed:

- Overtime is the easiest resource to adjust (if not already excessive);
- Contract Support is the second most flexible strategy;
- Permanent Staff is the least flexible alternative.

Do not develop Work Programs only for the maintenance work force in total. This defines the average condition. Balance must be preserved at the crew level, not simply for the entire maintenance organization.



## **Chapter 6 - Sizing the Maintenance Staff**

How many maintenance positions are required to properly maintain a facility? Although surveys offer some insight, the only meaningful response requires a “definition and measurement of inherent workload”.

### Existing staffing processes

Existing staffing processes for the maintenance function are generally inadequate and indefensible. Typically, maintenance does little to justify current staffing, much less build a case for required staffing.

Without records of backlog trends by craft there are no hard justification for additional resources. The maintenance leadership team is reduced to anecdotal evidence and indirect measures of increases in workload (rising customer complaints, increased downtime, growing use of contractors, etc.). Unfortunately such indicators at best are “lagging indicators”.

The figure (annex 6) provides an illustration of how a business argument for the “required” maintenance staffing might be developed and presented to management.

### Preventive/predictive maintenance inspections

In the example, the required staff resources for PPM were quantified at 15 as follows:

Total Labour Hours for all PPM inspections per year =	27,000
Number of Labour Hours per year =	1,800
Required staff = 27,000 : 1,800 =	15

The number should not be questioned without engineering reasons to modify the program.

Do not develop this number from history. History would provide the proper number only if on-time PPM-compliance was 100%.

### Steady state backlog relief

The steady state backlog relief is the rate at which new requests for plannable work keep coming in. Please note that in the example the 15 PPM positions will be generating a good deal of this backlog through their inspection activity. Steady state does not include deferred maintenance.

### Urgent response

Urgent response is the reactive workload that lack of reliability forces upon the maintenance function. If you have the required resources [for proactive maintenance ...], the need for reactive response should diminish significantly.

### Deferred maintenance

The term deferred maintenance encompasses all the requested and not disapproved work that has not been completed in a reasonable time frame [over three months old]. The example assumes 40 positions to overcome the deferred state within 6 months, so the provision is gone by mid-year. Once an organization achieves this worthy objective and experiences the benefits of proactive maintenance, it should never be allowed to slide back into the deferred state ... for that is false economy.

### Capital program requirements

Translate the capital program for the coming year into terms of maintenance workers required.

### Summary of requirements

In the example, the narrow second column from the left suggests a proper internal/external scenario. Deferred maintenance and the capital program are not ongoing steady state situations. Organizations should be staffed for normal workloads, not for temporary peak-loads.

Similar analysis and logic is the soundest methodology by which to properly size the maintenance work force.

### Other considerations for staffing

There are four invisible demands – we call them invisible because they do not always show up on work orders – that should be considered in the final decision.

- Catastrophe demand: the point is that small catastrophes actually happen regularly. The question is: should provisions for storms or fires be factored into maintenance staffing?
- Construction related demand: during large constructions, tradespeople are pulled off jobs to escort contractors around, etc. When planning a large construction project, degradation in maintenance efficiency is to be expected and should be reflected in maintenance staffing.
- Social demand: ... created by visitors such as regular tours and irregular visits from company brass and outside VIPs.
- Personal Service demand: ... such as package delivery, ... working on company sponsored community projects. Much of this kind of work is off the work order system.

Another approach to the Staffing Question

An academic formula does exist for the termination of maintenance staffing.

$$\text{MBS} = \frac{[(\text{RCB} \times \text{BMR}) + (\text{RCE} \times \text{EMR})] \times \text{NMF} \times \text{LP}}{\text{AASTLR}}$$

- MBR = Maintenance Budgeted Staffing
- RCB = Replacement Cost of Buildings (& building utilities)
- BMR = Building Maintenance Ratio (the percentage of asset value that must be reinvested to ward off deterioration – for standard buildings 0.5% to 2% per year. 2% means that buildings should be replaced after 50 years.)
- RCE = Replacement Cost of Equipment (includes process , production, packaging, warehouse, mobile equipment, etc.).
- EMR = Equipment Maintenance Ratio (generally 3% to 15% per year; for electronic equipment often 12%)
- NMF = Non Maintenance Factor (the relationship between total time and material spent on all activity performed by the maintenance function and the time and materials spent on true maintenance)
- LP = Labour Percentage (percentage of the total maintenance budget on direct labour without overtime premiums, etc.)
- AASTLR = Average Annual Straight Time Labour Rate (average labour hour of all maintenance employees annualised)

## **Chapter 7 - The Planning Process (Micro-Planning)**

The process of job planning encompasses verification of all aspects of the job to be done as well as identification of the various input resources required to complete each job in an orderly manner and at an optimal overall cost.

### Steps of the planning process

To develop a beneficial job plan requires that a logical, step-by-step process be followed.

Criteria of a planned job:

- A need has been shown by a work order outlining the content and scope of the job.
- An inquiry has asked whether the job should be done and what its priority should be.
- Thorough analysis has been used to break the job down to its component tasks, so that:
  - Required skills can be identified,
  - Time estimates can be made,
  - Material needs can be identified and ordered before the job is scheduled,
  - Special tools to perform the job are committed,
  - Required specifications, drawings and other reference documents and all safety and legal permissions are provided for,
- All parties that should be notified are listed and all processes that must be rerouted, shut down or backed-up are identified.
- Preparatory and restart activities are listed and coordinated.

Finally, planning is not completed until everyone knows what is going to happen. Communicate to all parties the WHO, WHAT, HOW, HOW MUCH.

The WHEN step moves you out of the planning and into the coordination and scheduling.

Schedule the work, thus defining "when" the job will be performed.

### What work orders should be planned and how much planning is enough?

The appropriate degree or detail is often questioned. The question "Which job should be planned?" applies primarily in early installation phases of planning and scheduling when there is insufficient capacity to effectively plan all jobs.

- Generally, larger jobs are planned first on the theory that larger jobs are usually accompanied by delays and conflicts and therefore there is greater opportunity for benefit from direct planning.
- Cut-offs of four to eight hours are often established for the magnitude of jobs to be planned.

Although detailed planning can be more effort than justified on simple jobs, the usual tendency is to under-plan large jobs rather than to over-plan small jobs.

- A shorter job will have greater lost and unproductivity time as a percentage of total time than a longer job.
- The preferred approach is to focus on early efforts on the more repetitive jobs.
- Consider application of the Pareto Principle during early phases of the program installation, 80% of the benefit is commonly derived from 20% of the effort.

When sufficient planning capacity exists, "all jobs that benefit" should be planned.

Eventually, planning should cover 80% or more of maintenance man-hours.

The Maintenance Technical Library provides informational support for the planning effort

The Maintenance Technical Library (MTL) is a place where maintenance planners (among others) have access to a wide variety of maintenance information including equipment history, equipment manuals, parts lists and assembly drawings.

Considerations:

- Protect the paper and computer records from disaster such as fire, flood and theft.
- Use some kind of sign-out system if material must be removed from the area.
- Make it someone's responsibility to keep the records up to date (in coordination with ISO 900X certification requirements).
- Manage all revisions so that all copies are updated (in coordination with ISO 900X certification requirements).
- Modern CMMS have document management capabilities.

The benefits for the planners of a well-organized library are:

- The planner's job is simplified and accelerated.
- Job plans are of consistent quality.
- The library becomes a universal resource for maintenance engineering, specification and problem solving.
- There is a good foundation for further computer assistance.

Good records in these areas are important and should include:

- Equipment records,
- Equipment histories,
- Prints, drawings and sketches,
- Libraries (Planning Aids),
  - The basic concept of these libraries is to establish and document the work sequences needed for each type of equipment, class by class.
- Labour libraries,
- Labour Estimating System,
- Material libraries,
- Purchasing/stores Catalogs,
- Files of Planned Job Packages,
- Standard operating procedures,
- Other reference sources (service manuals, planner experience, maintenance engineers, ...).

#### The Planned Job Package

The Planned Job Package for any given job contains documentation of all planning efforts performed for that job. Any factors that may delay or hinder effective job completion should be anticipated and provided for in the planned job package.

As appropriate, the assembled package is reviewed with the Maintenance Supervisor and the Requester.

## **Chapter 8 - The Planning Process – Screening, Scoping, Research and Detailed Planning**

Job planning is a six-step process (plus a seventh step of feedback) that includes:

- Screening of Work Requests
- Assessing and Scoping of the job to be performed
- Job Research to avoid redundant planner effort
- Job Breakdown with Detailing and Sequencing of Job Steps
- Material Take-offs and Procurement
- Assembling the Planned Job Package
- Receipt of feedback and reflecting it in update job plans

### Screening of work requests

Planners review all work requests except those that must be performed on the same day as requested. The Maintenance Supervisor handles such requests for immediate action without benefit from planner support.

The planner reviews and screens each for redundancy, necessity, completeness and accuracy. The planner confirms that:

- The request is not a duplicate.
- The description is clear and complete with the appropriate Equipment Code.
- All requester required fields are completed with valid codes.
- Priority and requested completion dates are realistic and provide practical lead-time, enabling the job to be prepared for effective execution.
- Authorization has been given.
- The requested work is needed.

### Assessing and scoping the job

Before processing further, the required level of planning must be determined. Does the job warrant detailed planning or only cursory planning? Is the effort and cost worth the value to be gained?

One-third of the planner's day should be spent visiting job sites to analyse jobs to be planned.

The best way to catch wrongful assumptions is to get out of the office and visit future job sites before trying to plan the jobs and to visit active job sites to learn how job packages might be improved.

The process of job assessment and scoping should roughly follow the flow outlined in Annex 7: Job Assessment and Scoping Check-list.

### Dealing with scope creep

Properly defined, scope means “the range of one's perceptions, thoughts or actions” and its use is crucial to delivery performance and schedule compliance. Scope creep needs to be built into the job plan because some jobs are likely to creep.

### Job research

The third step is to search through labour libraries, reference files and the Maintenance Technical Library to determine if the job or portions thereof have been previously planned and to fill in information, knowledge and information gaps.

During research, planners should:

- Use Labour Libraries and Equipment History to determine if the job has been previously performed.
- Consider alternative approaches.
  - Should additional work be performed this time to ensure a more permanent solution?
  - Should the item be replaced rather than repaired?
  - Should the item be purchased rather than made?
- Remain conscious of alternate plans for the involved equipment.
- Safety must always be a primary concern within the planning and execution process.
- Planners are not necessarily engineers, supervisors or craftspersons, but they must use judgement and know when to call in the specialists from engineering, operating, safety, process control, environmental and quality functions as well as appropriate contractors.

### Detailed job planning (determining the breakdown of job steps)

When research is complete, the planner prepares details and phases of the job requirements.

He must know the job well enough to describe what is to be accomplished and to estimate how many man-hours will be required.

The planner must:

- Select and describe the best method for job performance.
- Determine and sequence the job by specific and logical tasks or steps.
- Identify task dependencies and consider application of PERT or CPM network analysis to facilitate the planning of complex jobs.
- Determine the labour resource requirements including required skill sets for each task.
- List determinable materials, parts and special tools required and prepare the Bill of Materials for the job.
- Determine what in-house fabrication, external contract resources and equipment rentals are needed.
- Identify special tools and equipment required, including safety items.
- Consider how to get parts and people to the job location.
- Coordinate related work of other groups by preparing Cross Work Orders if significant or add unique Tasks on the same WO if only minor support is needed.
- Consider disposal issues (asbestos, oils, etc.).
- Estimate total cost in terms of labour, material and external charges.



- Coordinate and expedite necessary authorizations.

### Job preparation

During Job Preparation, the planner assembles and documents all the above planning efforts within a "Planned Job Package".

The "Planned Job Package" should include:

- Detailed Work Order spelling out step-by-step procedures.
- Job Planning Sheet with Sequenced Tasks detailed by craft and skill level (in-house and contractor).
- Duration and labour-hour Estimates for each Task.
- Duration and labour-hour Estimates for each Task.
- Prepare a Bill of Materials including availability, commitment and staging location.
- Obtain clearances and all required permits completed to the point of safe feasibility.
- Other reference documents that the assigned crew is likely to have need for, such as prints, sketches, specifications, etc.
- A Site Set-Down Plan (for major tear downs).

As appropriate, the assembled package is reviewed with maintenance supervisor(s) and the requester. The planner then holds the planned job package until all necessary materials are procured and the job enters the coordination and scheduling phase.

### Feedback on the plan

One essential element of good planning process is feedback, to facilitate improvement of planned job packages over time. Periodically a Job Planning Survey should be added to job packages.

For what the survey may include, see annex 8.

Coordination of equipment access, permitting, safety and statutory permission

Safe and legal access to equipment must be addressed within the planning process.

Without safe access to the asset, no work can or should be started.

Reviewed below are some of the formal and informal processes by which Maintenance receives permission to work on an asset and gains control of the asset.

- Process driven issues
  - In complex environments a substantial analysis is frequently required to determine when and how to take an asset out of service (chemical industry).
- Safety driven issues
  - Most large facilities have processes for initiating safety reviews and applying for dangerous work permits.
  - Various forms of dangerous work may require open flame permits.
- Regulatory driven issues
  - Statutory permission is gained from or is in compliance with laws of a legal authority.
  - Planning check lists should include the permitting requirement to further assure compliance.

## **Chapter 9 - Detailed Planning Process – Materials, Tools and Equipment.**

To fulfil its mission effectively, maintenance is dependent upon reliable and prompt logistical support. Regardless of the cost it is important to have the item readily available to support the efforts of the mechanics in a timely manner. Lack of such material support will create delays resulting in economic loss. Time will be lost and work quality will suffer and result in diminished equipment reliability and output capacity.

### Planner/scheduler responsibilities to the material management process

Purchasing and Stores cannot do the job alone. One Purchasing executive put this printed banner over the entrance to her area: “Your lack of planning does not necessitate an emergency for me.” A reactive maintenance department is the single largest workload for purchasing departments.

Purchasing, Stores, Maintenance, Engineering and Operations should share responsibility for material support and control. Responsibilities specific to the Maintenance Planner include:

- Ordering special parts with adequate lead-time so that purchasing can do its job.
- Suggesting the inclusion of new parts in authorized stock with recommended minimum and maximum quantities.
- Reviewing at regular intervals and recommending adjustments to inventory parameters (Min, Max, ReOrder Point).
- Providing adequate lead-time for Purchasing to order non-stocked materials and to restock authorized stock items when there is an unusual demand.
- Notifying the Storeroom of delays to schedules that will delay the use of staged materials.
- Providing the Storeroom with adequate time to pick parts and stage them for pick-up or delivery to drop points and job sites.
- Assuring that unused materials are returned to the Storeroom in good and clean condition for restocking.
- Correcting job packages when excessive material is returned.
- Notifying the Storeroom of stock items that will become obsolete or in excess. A program to identify parts that become obsolete should be an ongoing routine.

Material related steps in the planning of specific jobs are summarized in annex 9.

Economics should form the basis for inventory management and each stocking decision should yield the lowest overall cost to the operation. Three major factors come into play: delivered purchase price including cost of acquisition, inventory carrying cost and the dollar consequence of not having the item on hand when needed.

Material shortages are often traceable to inadequacies within the inventory management system, an unfriendly storeroom catalogue or purchasing/stores policy driven by apparent costs (low bidder). This last item is common with functions that have inadequate concern for the impact on reliability and capacity when failing to promptly provide the needed materials to do each maintenance job promptly and properly the first time. The management and logistical teams must be persuaded that the basic prerequisite for a Just-In-Time strategy is a proactive environment within the maintenance arena. If the operation is still in the reactive mode, there had better be adequate inventory on hand.

One of the most important partnerships in the operational arena is that formed by Maintenance, Stores, Purchasing and Receiving. Without close cooperation between these functions, maintenance cannot achieve functional effectiveness in support of operational reliability. The four associated objectives are:

- Get the right materials to the right place, at the right time, at the right price.
- Avoid excessive inventory.
- Correctly charge all usage of parts and materials to appropriate work orders, thereby updating equipment history and charging appropriate accounts automatically.
- Ease of reference by all parties via an effective, current and complete (electronic) Stores Catalogue.

#### The planner's role in rebuilding

Many expensive components can be economically rebuilt. Most maintenance departments have the benches and use rebuilding as a filler job for members of the response crew.

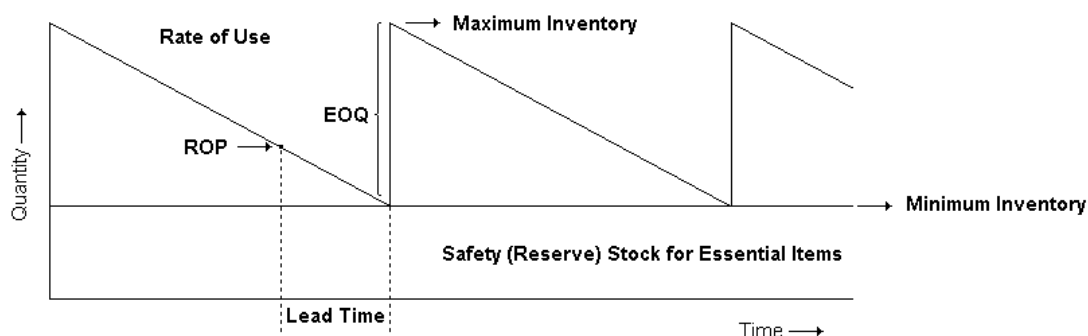
Units floating around are one of the biggest areas of confusion when an organization is trying to maintain accurate accounts for a maintenance inventory. A major issue is how much value to place on core units before rebuilding and after rebuilding.

We are concerned that re-builders are identified on the bill of material and include paperwork activating the delivery of the part to the re-builder (inside or outside shop).

#### Controlling the maintenance storeroom with statistical inventory control

The management technique by which inventories have historically been optimised is Statistical Inventory Control.

#### SIC Order Cycle:



Lead Time = Paper work Lead Time + Vendor Lead Time + Stocking Time

ROP = Reorder Point

EOQ = Economic Order Quantity

If maximum inventory level is exceeded or a stock out occurs, a system alert should trigger re-examination of reorder point and safety stock.

### JIT versus SIC

Debates often occur between advocates of JIT and SIC. Both are needed to optimise maintenance support of reliability objectives. Project work and planned maintenance jobs can rely on JIT because there is a lead-time available. However, there is no lead-time for emergency breakdowns. Consequently, well managed, on-hand inventory is essential if the maintenance function is to respond promptly to emergency demands in an effective and efficient manner. Consequently, another optimisation is needed; that of JIT on proactive work with SIC on reactive work.

Given the above logic, store room inventory is exclusively, or at least primarily, for emergency needs. That suggests that project managers/engineers and maintenance planners should not be relying on inventory to fulfil their proactive needs.

Once maintenance excellence and a proactive environment have been achieved, emergency response should consume no more than 10% of maintenance resources. Accordingly, no more than 25% of maintenance material needs should be dependent upon storeroom inventory ... ultimately.

### Other material management concepts to be deployed ...

In addition to SIC two other inventory control techniques are commonly deployed in well managed store rooms. These techniques are:

- Classification of stock items
- ABC analysis of stock items

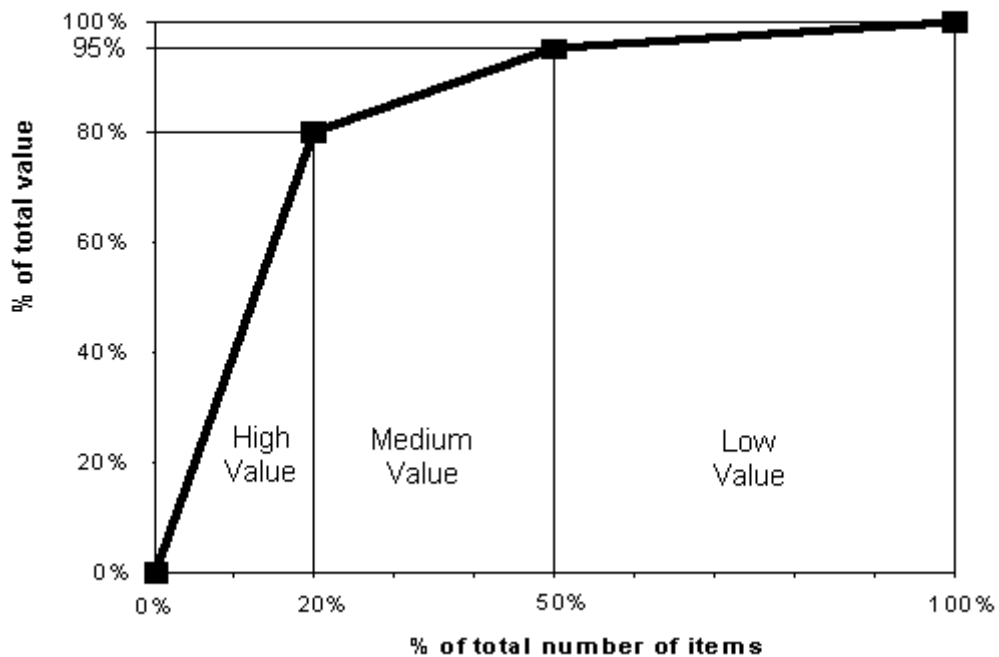
Classification segregates stock items by criticality. Stock Outs on highly critical items have serious consequences. The risk is too great to take. Risk should be taken or minimized based on consequence of stock outs. To exercise this discretion effectively, inventory must be classified in the following manner:

- Insurance spares – high cost spares or components used on critical equipment.
- Insurance parts – parts used on critical equipment or in critical components.
- Standard replacement parts – parts that can be used on more than one component or piece of equipment.
- Hardware items – bolts, nuts, washers, etc.
- Operating chemicals and supplies – used in the production process.
- General supplies – office and sanitary supplies.

### ABC analysis

It is the application of Pareto's Law to the control of inventory.

**ABC analysis**



Management and Control efforts should focus on the important items:

- A items – highest value, tightest control, close follow-up, accurate records;
- B items – normal control, good records;
- C items – limited control, free stock.

Classification of items and ABC analysis are distinct techniques that overlap as reflected in the following table:

Criticality	Stock Classification	% of items	% of value	Essential Service Level
A	Insurance spares, insurance parts	20%	80%	100%
	Others critical spares			98%
B	Standard replacement parts	30%	15%	95%
C	Hardware items	50%	5%	90%
	Small tools			90%
	General supplies			85%

When considering reductions in inventory know that if the overall inventory value is to be reduced by – for example – 10% and the critical 80% of value is (A) too risky to include, the remaining 20% of value (B and C) would have to be reduced by 50% to achieve the overall objective of 10% reduction in value!

#### Material management requirements in support of proactive maintenance

Performance standards must define the levels of material management support required if the reliability function of Maintenance is to be fulfilled. These standards should be consistent with the following characteristics.

Purchasing must:

- Process purchase order requests promptly with minimum in-hous lead-time.
- Obtain and communicate lead-time commitments from vendors and evaluate their performance in meeting these commitments.
- Track material from placement of Purchase Order Request until delivery to originator.
- Follow-up on availability and delivery of parts for planned work orders.
- Notify maintenance of delayed items prior to their scheduled delivery date.
- Expedite as necessary.

Storeroom must:

- Keep inventory orderly with parts easily identified and locatable.
- Keep adequate quantities of each stock item on hand to meet the day-to-day needs of Maintenance.
- Promptly reorder materials that are at their reorder point so stocks can be replenished before they run out.
- Maintain unique items identification of spare parts, materials, supplies and tools.
- Provide an up-to-date catalogue listing parts and supplies in stock by location.
- Cross-reference the catalogue by Store Reference Number, Vendor Serial Number and Where Used.
- Apply storeroom control in relation to item value. High value items should be controlled most closely.
- Provide quick issue service at the storeroom window.
- Process non-stock receipts and backorder receipts as quickly as possible and notify users of their arrival.
- Provide timely delivery of materials to secured locations, either at the job site or at specific drop points at maintenance shops and other areas of the facility. Delivery should be synchronized with scheduled start of planned jobs and expedited to urgent jobs.

### Storeroom benchmarks

- Service levels should be 85% to 100%, depending on the classification of the item.
- Inventory accuracy, as procedurally determined by cycle counting, should exceed 97%.

### Planning for specialized equipment and tools

The typical maintenance plan does not mention all equipment and tools. The planner's job is to identify any specialized, uncommon, large shop tools and equipment needed for the job. Planners should also list any safety items likely to be needed including personal protective equipment.

Questions that planners must answer about tools and equipment are similar to the ones they must answer about spare parts. See annex 10.



## **Chapter 10 - Work Measurement**

If you can't measure it, you can't improve it.

The US Navy developed and published "Engineered Performance Standards" for the US Navy Public Works Department, which was responsible for all US Navy bases and installations. The resulting library of maintenance standards is available for purchase from NAVFAC.

A related approach was applied to commercial industry during the 50's, 60's and 70's under the common name of "Universal measurement Standards" (UMS).

### Application of maintenance work measurement

Realistic job measurements are essential to the planning, coordinating, scheduling, control and motivating process. Before exploring the work measurement option, we should clarify the several applications of maintenance standards:

- Match manpower resources to workload (macro planning).
- Establish meaningful maintenance schedules ...Job Schedules are defined in "Duration Hours". Duration Hours x crew size = labour hours. These two variables must not be confused.
- Forward load preventive, predictive and other programmed maintenance routines in a balanced manner to avoid peaks and valleys in the demands. A common mistake is to have all quarterly, semi-annuals and annual tasks come due in clusters, rather than spreading them equally across weeks of the year.
- In the interest of customer service, promises made must be realistic.
- Realistic expectancies by which supervisory and crew performance can be evaluated and employees can be motivated. Most employees work better in an environment where they know what is expected of them and whether they are doing a good job.

The question is which measurement approach best serves each of the several applications: true standards that indicate how long jobs should take, or estimates that quantify how long jobs will probably take. The difference is most significant when maintenance is still reactive and efficiency is seldom higher than 50%. If a standard is used in such a situation, backlog is understated, schedule compliance is extremely low and completion promises to customers are seriously missed. The challenge is to develop a job estimate that will establish a challenging expectancy on one hand but produce an achievable schedule on the other.

Maintenance work is repetitive and therefore it can be measured. Many jobs occur weekly, some monthly or quarterly and even annual jobs are repetitive. Maintenance personnel stating: "Maintenance jobs never go the same way twice." accurately infer that the content is not exactly the same each time the job is performed. This opinion simply influences the:

- ... precision with which estimates can be set,
- ... methods of applying estimates to each application,
- ... time period required to accumulate sufficient jobs to level out fluctuations in individual jobs.

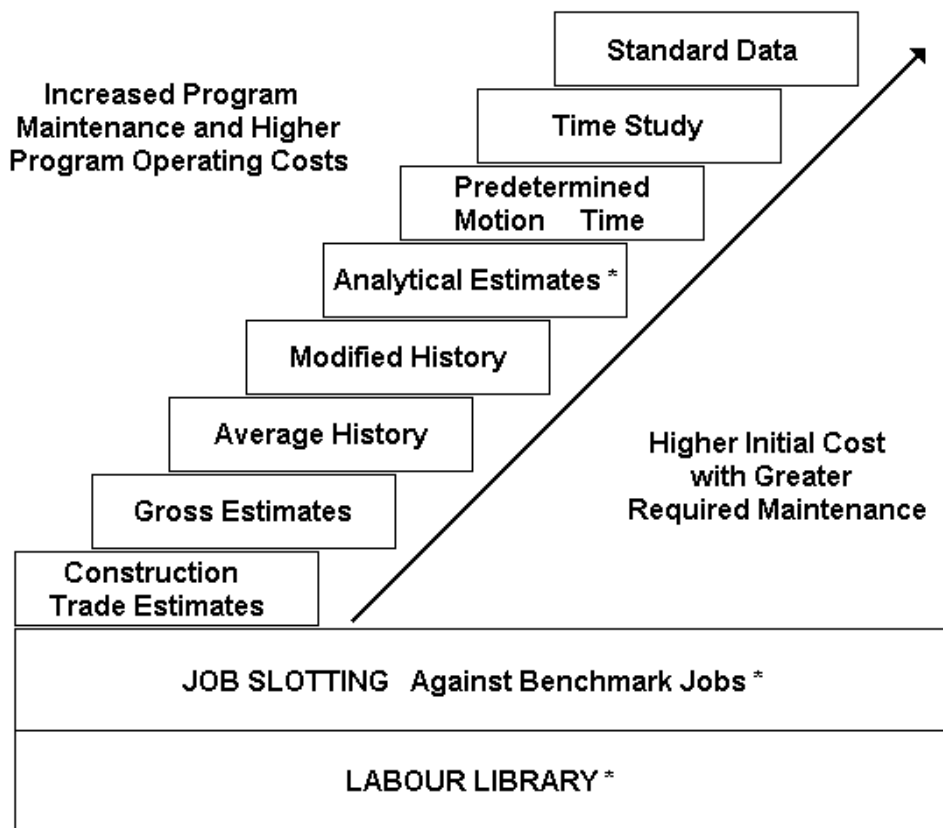
Industrial engineers strive to achieve accuracy plus or minus five percent ( $\pm 5\%$ ) for production incentive standards, but in maintenance we strive for plus or minus fifteen percent ( $\pm 15\%$ ). This level of accuracy is adequate for the applications to which we apply estimates in the maintenance arena. Accuracy for individual jobs may not be reliable, but combined accuracy over the dozens of jobs most maintenance crews complete within a week is adequate.

Maintenance work often does contain unpredictable elements, but those elements seldom influence the entire job.

An area where estimates can go wrong is where the scope of work changes dramatically. Small scope changes can be absorbed in the  $\pm 15\%$  expectation but large changes in scope require new estimates.

Optional levels of work measurement methodology

As exhibited in the figure below, several forms of work measurement exist (together or separately) for use in maintenance applications. The second phase of our discussion focuses on what method of standard/estimate development is most suitable and economically viable for maintenance needs.



*\* = Recommended*

The level of work measurement sophistication (characterized as progress up the staircase) commonly increases with:

- the maturity of the maintenance management installation,
- the level of precision required to raise maintenance performance to the next plateau,
- the focus of the installation (Efficiency Measurement or Schedule Compliance).

An Efficiency focus ( $\text{Standard Labor-hours} \div \text{Actual Labor-hours} = \% \text{ Efficiency}$ ) requires a more accurate form of measurement. A Planning and Scheduling focus requires a less precise form.

#### Advantages and Disadvantages of each Methodology

- Construction Trade Estimates (Published Standards):

Construction Trade Estimates are shown as the lowest step because they are developed for contractors to use when bidding on construction jobs. They are not recommended for application to in-house maintenance.

- Gross Estimates:

These estimates are the least costly and least time consuming. The disadvantage is that they usually reflect personal judgment of a particular supervisor, planner, or technician, and different people guess differently. These estimates are especially poor when the estimator has not personally experienced the job. However, if backlog is currently quantified in terms of “jobs” or work orders, get it quantified in labor-hours. ..now! “Jobs” is not a meaningful unit of measure because some require less than an hour, while others may require a hundred hours or more. The only common denominator is “labor-hours.”

- Historical Averages:

The labor-hours charged to previous work or individual jobs are recorded and accumulated. They are then averaged after elimination of skewed highs and lows. If the average length of time that a job has been taking is known, what could possibly be a better estimate? The answer is nothing ... provided the maintenance crews are working at 100% efficiency and the state of maintenance excellence has already been achieved. Unfortunately, the efficiency of reactive maintenance tends to be in the 50% range. Efficiency is standard labor-hours divided by actual labor-hours. If historical averages are used, the calculation effectively becomes [Historical Average divided by Actual]. Efficiency always approximates 100% ... but undeservedly. If descriptions are not correct and time distribution is not complete and accurate, the averages will not be reliable. They will reflect the current environment, methods, and tooling rather than standard methods and procedures with proper preparation through planning, coordination, and scheduling.

- Adjusted Averages:

They require a base period of perhaps six months during which time averages are collected for repetitive maintenance jobs and activity sampling is performed concurrently. Sampling establishes the average efficiency of each crew. If a given job averaged ten labor-hours and the crew averaged 70% efficiency during the base period, 7.0 labor-hours becomes the adjusted average. This methodology is fairly expensive due to the Cost of sampling, and require several months before measures are available for deployment.

- Analytical Estimates:

Analytical estimates are recommended as the appropriate level of work measurement sophistication.

- Job Slotting and Labor Libraries:

Job slotting and labor libraries are effective work measurement techniques recommended for use in combination with Analytical Estimates.

- Universal Maintenance Standards:

Although they are the most accurate method by which to develop maintenance standards, such standards are too time consuming and expensive to set-up as well as maintain. Consequently they are not generally recommended. However, development of these standards did spawn the three techniques that are recommended (Analytical Estimates, Job Slotting, and Labor Libraries).

#### Which methodology best serves the several applications of work measurement?

The key to effective work measurement is to establish standards and measure current efficiency relative to the standards.

- Backlog Weeks: should be calculated on current efficiency.
- Schedules: people work at a pace that is based partially on the amount of work they are given. Ideally, jobs are quantified within the schedule based on standard labor-hours (expectancy of how long a job should take).
- Efficiency: should be based upon a true standard (expectancy of how long a job should take), and should never be used for discipline (as a crutch to cover-up for a lack of proper supervision and leadership).
- Efficiency Reports: should be developed weekly for the total crew or team responsible to a given supervisor. Using a one-week time frame means that the average efficiency for each crew is based on several dozen jobs, thereby balancing abnormally difficult jobs with unusually trouble free jobs.

#### Building an estimate

There is no substitute for task knowledge when it comes to estimating. Regardless of the measurement technique, familiarity with operating equipment and the jobs required to maintain them is essential. Craft background is the ideal starting point because it enables a Planner to “visualize” how the job should be performed.

Tremendous advantages accrue when planners are seen to be involved in proper preparations for effective job performance.

Nine elements of planning (description, scope, job steps, parts, tools, access, information, permission, skill sets) come into play within the estimating process. If not properly addressed within the planning process and provided for within the associated estimates, a defect in any of the nine elements can sink a job and cause it to run over estimate and into overtime.

### Job creep

This is what happens when the scope of work changes as the job progresses. Often the time increase is not incurred on the planned job but on other jobs the customer may request while the technician is in the area.

Given proper scope, there are several essentials that make estimating easier, more accurate, and more consistent between those who estimate - planners. These include:

- Breaking large jobs into steps. Long, complex jobs cannot be estimated accurately as a whole.
- Not trying to estimate with “pinpoint” accuracy.
- Relative comparison of new jobs to common known jobs — “benchmarks”. The new job need not “match” the benchmark. It is necessary simply to determine which benchmark is the closest comparison.

## ***Chapter 11 - Analytical Estimating.***

### A recommended approach to maintenance work measurement ...

The purpose of analytical estimating is to quickly develop reasonably accurate and consistent time estimates. The technique is simple and based on the following principles:

- Experience: for persons who have had practical experience performing maintenance jobs, it is relatively easy to visualize and establish a time requirement for simple, short duration jobs. Because of their experience, ex-craftsmen usually make the best planners.
- Job breakdown: long, complex jobs cannot be estimated as a whole. Estimation of such jobs is easier and more accurate when the job is broken down into separate steps or tasks and estimated at that level, then summarized into an estimate for the total job.
- Accuracy: pinpoint accuracy in estimating is not justified or achievable because all the variables in maintenance work cannot be known until after the job is completed. In maintenance we therefore look for  $\pm 15\%$  accuracy.

All maintenance jobs can be broken down into the sequence shown in annex 11.

### Travel Time Table

It might be wise to devote a little up front effort to develop a traveltime table (not unlike a point-to-point distance chart on a road map).

A simple travel-time table should look like this: see annex 12.

### Miscellaneous Provision Table

All the steps coded "Fixed Provision Table" are assembled within the miscellaneous provision table. Appropriate estimates must be developed for the plant involved.

### The Labor Library

A Labor Library (annex 13) is developed for each piece of equipment and/or nature of work. It addresses the pure work that takes place at the job site (wrench time) broken down by job step or task.

All maintenance departments do (at least occasionally) define job steps, perform material take-offs, locate and reference prints and drawings, prepare clarifying sketches, and make labour-hour and job duration estimates. The historical problem has been that all these preparatory efforts expended through the years have not been retained. The planning information is commonly discarded upon job completion.

Catalog planning efforts in a retrievable format.

### Allowances

Direct work standards (labor library, travel time table, miscellaneous provision table) do not include provision for activities such as authorized breaks and wash up, fatigue, unavoidable delays, and crew balancing on multi-person and multi-crew jobs. Such activities are inherent in maintenance work and must be provided for by addition of allowance factors.

A typical table of allowances is shown in annex 14.

Allowances are typically added to the total accumulated labor-hours (direct work, miscellaneous provisions, and travel time).

### Comparative Time Estimating

(Making sure everybody compares their estimates to the same standard)

Absolute accuracy is neither possible nor necessary to establish a proper expectancy for control of maintenance. What is essential for control is consistency.

There are basically four means of structuring comparative maintenance job estimate files:

- Systematic card files, by: Skill, Nature of work, Crew size, Duration, Labor-hours.
- Catalog of standard data for building job estimates
- Labor Library
- Slotting Table of Benchmark Jobs

Best practice tests between the later two structures.

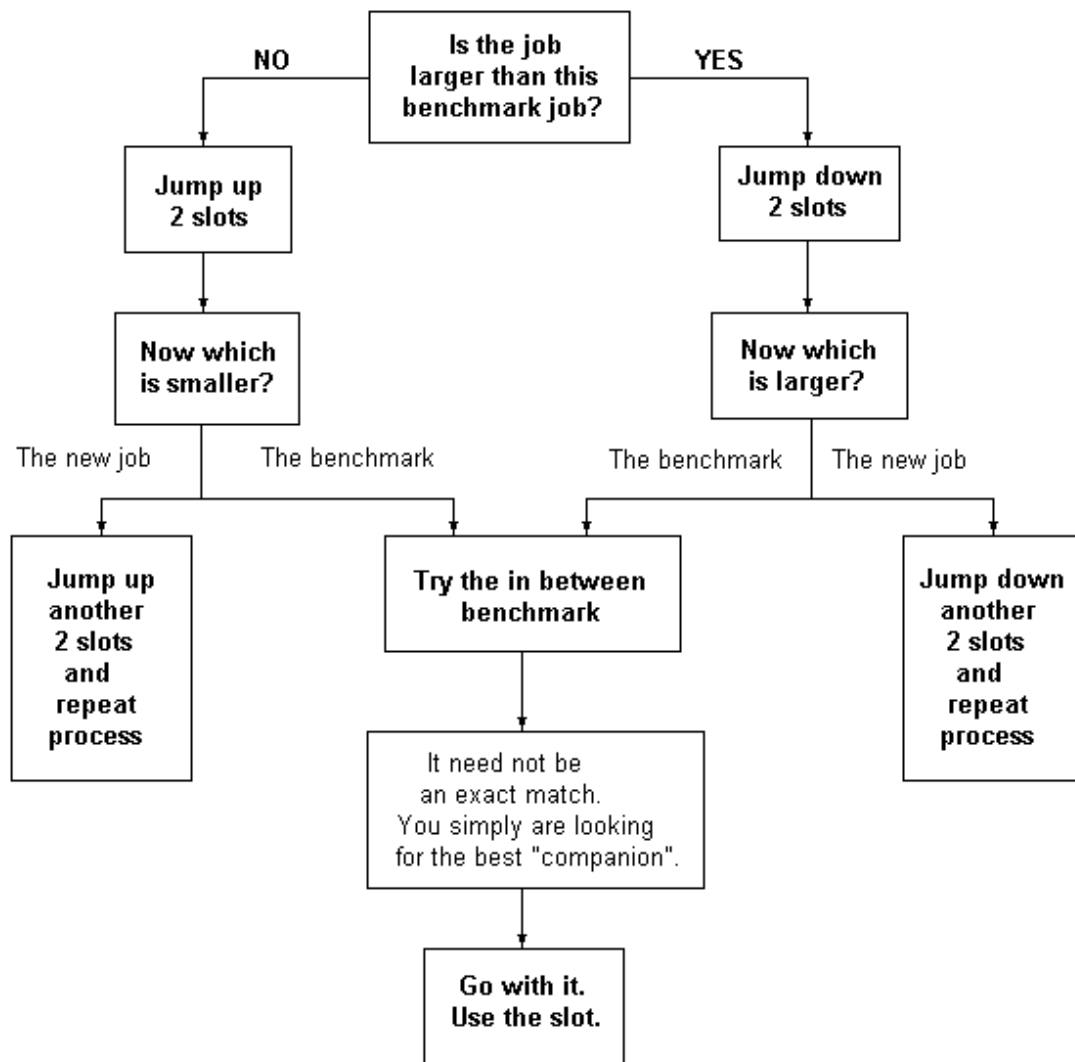
Regardless of the comparative approach used, the basic form of work measurement must still be selected (Gross Estimates, Analytical Estimating, etc.).

### Slotting Tables

Slotting compares jobs to be evaluated with a group of jobs that are well known, and have been carefully described and estimated. Usually it is easier to determine whether a job is bigger or smaller than another, than to determine, in isolation, how long the job will take.

To make a comparative estimate, a planner must first define the scope of the job to be performed and must prescribe the method to be used.

Back at his workstation, the planner's next step is to consult the appropriate section of the benchmark library to locate a benchmark job of similar nature and level of labour intensity through a bracketing process. Using the process illustrated (see below) he makes a judgment as to which slot the new job best fits.



Notice that the increments in the slotting table (annex 15) are consistent with a desired accuracy of  $\pm 15\%$  and remember that the technique of comparative estimating involves the comparison of jobs with those in the library, not the matching of jobs. This distinction is important because a few hundred carefully selected benchmark jobs in the library will enable an experienced Planner to produce consistent estimates for most maintenance work.

Annex 15 presents the slotting concept visually, but actual Slotting Tables commonly take another form, which contains a spreadsheet of benchmarks cataloged by required skills within the nature of the task.



### Development of Slotting Tables

Maintaining the reference library is a central function requiring the assembly of contributions from all planners to cover the various classes of equipment.

Initial Slotting Tables can be developed in the following manner:

1. Solicit up-front input from the organization (perhaps involving all the planners and supervisors as well as the technicians).
2. Explain job slotting and its usage.
3. Then enlist participation with the technique explained in annex 16.

### Slotting Table Cataloging

The objective is to develop families of Slotting Tables. Use of this technique means that estimates will improve progressively as the planning process matures.

### Job Estimating Worksheet

One of the most important considerations in the preparatory process is consistency of job estimates. Without consistency, the labor force will feel that estimates are unfair and will fight their usage. The worksheet in annex 17 will help the planner maintain a consistent approach.

## **Chapter 12 - Coordination with Operations.**

The objective is to agree on the most important maintenance jobs to be completed with the available resources during the coming week. For those jobs requiring equipment to be out of service, times must be found and agreed to when Operations can release the asset and maintenance can make the necessary resources available.

Maintenance work should be scheduled to optimize the balance between minimal adverse impact on the operating schedule and effective utilization of maintenance resources. This optimization requires communication, collaboration and coordination with production planning to link the maintenance schedule with the operating schedule.

In a production environment where up-time is essential, coordination maximizes the use of "windows of opportunity" to accomplish work whenever and wherever equipment is not in use. Where opportune windows do not present themselves, downtime for planned maintenance must be scheduled to minimize disruption of production.

Planners should view liaison with operations as a permanent relationship.

In selecting jobs for the Weekly Master Schedule, it must first be ensured that all preventive and predictive routines are scheduled at their predetermined frequencies. The PM's, together with approaching PM's, should be performed early to take advantage of scheduled downtime agreements to avoid another shutdown in only a matter of a few weeks.

Next, the various parties should be aware of all jobs approaching requested completion dates. Any jobs that cannot be scheduled to meet those dates should be discussed with the Requestor in the context of other job priorities established by all attendees. Conflicts must be considered from all perspectives. Conflicts between internal customers must be resolved by their common manager in the optimal interest of the overall operation.

Planners return to their workstations to layout detailed schedules for next week that reflect agreements reached.

- Operations agree to make the equipment available in the agreed state, so that work can be performed as scheduled.
- Maintenance agrees to perform the work as scheduled, starting on time and finishing on time. Reliable estimates of outage duration must therefore be made.

Compliance with schedule requires that resources designated for given jobs should not be diverted to unscheduled work except for true emergencies. The ultimate Operations approver of the schedule is the logical authority regarding any urgency constituting a "schedule-break".

Planner preparation for the weekly coordination meeting ...

- Upkeep of Backlog.
- Issuance of Backlog Reports.
- Resolution of Conflicts.
- Available Resources.
- Grouping for Optimization.
- Ready to go. The meeting reviews all work orders that are “Ready to be scheduled.”
- The meeting also affords participants the opportunity to request that certain jobs in other status be expedited into the “Ready” state as soon as possible.

Requesting organizations also have responsibility to prepare for the meeting. They should reach accord regarding which of their requested Work Orders are most important for Maintenance to perform during the coming schedule week. It is best if this agreement is reached prior to the coordination meeting so that the meeting can be focused upon reaching accord between, not within, the several requesting organizations.

As the coordination process is streamlined, the meeting requires less than one hour per week and all participants find that their time and attendance is very worthwhile. Participants realize that the best way to get more work performed properly and in a timely fashion is through the formal planning, coordination, and scheduling process.

Agenda for the weekly coordination meeting

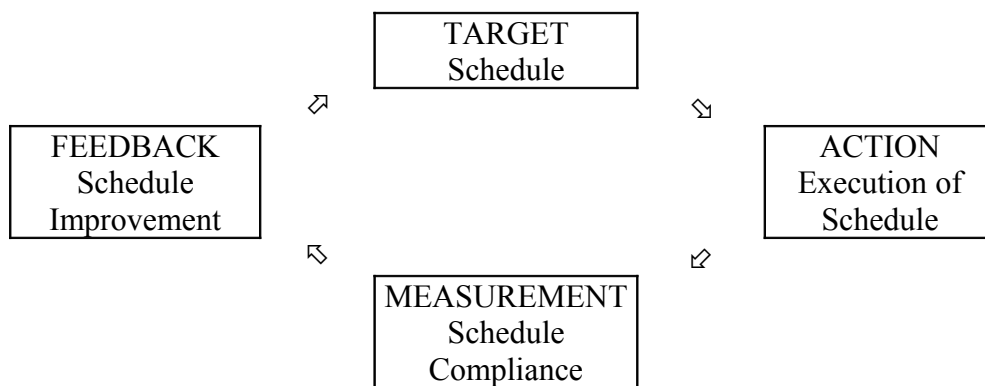
1. The preliminary cut of next week’s schedule should be shared, showing resources available and demands already established (PM’s, Corrective Work, Carry-overs, Project commitments, etc.)
2. Next, the Production Schedule should be presented to clarify any operational support required from maintenance (set ups, changeovers, change-outs of production expendables, etc.) as well as equipment access windows that can be utilized by Maintenance.
3. At this point all parties are ready for the give and take as to whose job is next most important in the optimal interest of the overall operation. This continues until all available resources are committed in general terms. Some changes are inevitable when the scheduling process addresses the specifics.
4. If participants continue to lobby for more support, overtime and contractor support is the next consideration. This requires approval and funding.
5. Finally, review critical jobs that are delayed for lack of parts, engineering, approval, budget, or other reasons and consider possible expediting.

## **Chapter 13 - Scheduling Maintenance Work.**

### The Weekly Expectation

Scheduling is the locus from which all maintenance activity is executed. When any new maintenance management system is started up, scheduling should be viewed as the “point” function and “marketing arm” of the system because it yields the earliest tangible results (often within weeks of start up).

All individuals and groups perform better and accomplish more with clearly established, communicated and published expectations. When the maintenance function is managed without a weekly schedule, there are no specific expectations as to what is to be accomplished with the resources for which payroll checks will be drawn. Instead, whatever reactive demands are made is what will be done.



The fundamental requirement target (the schedule) against which to control, followed by action (execution of the schedule) to achieve the target. The results, measured against the original intention (called schedule compliance), provide feedback for correcting deviations. (improving future schedule compliance). Managers must schedule precisely, proceed positively, and persistently pursue weekly targets.

Using the results and reports such as those showing schedule compliance, the planner, the supervisor, the maintenance manager, and internal customers can continuously improve the planning, coordination and scheduling function.

The schedule is a device for lining up jobs waiting to be performed so that operations are best served while maintenance also makes optimal use of its resources. Four abilities, as listed below, are necessary for maintenance schedules to meet the challenge:

- Determine priorities mutual to the involved parties
- Focus on the target reflective of those priorities
- Concentrate on execution to schedule
- Persevere to achieve “Proactive Maintenance Excellence” supportive of World-Class Operation.

One way or another, maintenance resources have a job to be performed. Urgency alone (without consideration of importance) cannot be allowed to determine how vital resources will be consumed. Excellence is best described as performing the right things properly (by planning), selecting the most important things to be done (by coordination and scheduling) and accomplishing them 100% correctly (by execution) without wasting resources (by planning).

The scope of Scheduling includes:

- Bringing together in precise timing the six elements of a successful maintenance job: labor; tools; materials, parts and supplies; information, engineering data and reference drawings; custody of the unit being serviced; and the authorizations, permits, and statutory permissions.
- Matching next week's demand for service with resources available after accounting for all categories of leave, training, standing meetings, and indirect commitments, plus consideration of individual skills.
- Preparation of a "Weekly Schedule" that represents the agreed upon expectation regarding planned work orders to be accomplished with available resources. The schedule also assures that all preventive and predictive routines will be accomplished within established time limits.
- Consideration of alternative assignment strategies where the schedule assigns specific jobs to specific people (allowing second-string players into the game to gain experience ... as feasible).
- Ensuring that responsible supervisors receive and understand the planned job packages for scheduled jobs.

#### Backlog management is a prerequisite for effective scheduling

Effective scheduling requires adherence to proven principles of backlog management and established procedures:

- Lead-time - work to be done must be identified as far in advance as possible so that the work backlog is known and jobs can be plan effectively and completely prior to scheduling.
- Accurate evaluations should be made of the priority of each job, given the perspective of the overall operation. Each job in backlog must be force ranked so that the most important jobs are always scheduled and where possible, executed first.
- Backlogs must be kept within a reasonable range. Backlogs below minimum do not provide a sufficient volume of work to ensure smooth scheduling and effective utilization of all resources. Backlogs above maximum turn so slowly that it is impossible to meet customer needs on a timely basis. Consequently, they loose faith in the proactive approach and slip back into the reactive quagmire.
- Special or heavy demands resulting in excessive backlog cannot be scheduled unless additional resources are authorized or expected completion dates are relaxed.

### Scheduling Techniques

- GANTT Bar Chart. This technique shows the time relationship of job tasks in terms of their chronology and simultaneousness. Such charts are useful, but do not convey task relationships, because it is not clear which activities must finish before others can begin. This is the technique to use for weekly maintenance scheduling. As such it is the focus of this chapter.
- Network Arrow Diagrams. This technique takes two basic forms; Critical Path Method (CPM) or Project Evaluation and Review Technique (PERT). By identifying the “critical path”, both these forms depict the shortest elapsed time feasible for completion of major projects. The importance of scheduling in this manner increases as project complexity increases and on-time completion within budget constraints become critical.

This last unique form of planning, scheduling and control is covered in Project Management (Chapter 18).

### Instructions for preparing schedules

Experience shows that increased productivity is achieved when maintenance personnel know tomorrow’s assignments before they leave work today.

Scheduling principles are simple, but their effective application is not quite so easy because three separate procedures must be performed concurrently to produce a viable schedule. These procedures are:

- Job loading, to set forth jobs to be completed during the schedule period. Scheduling of these jobs stems from coordination between maintenance and operations to assure that the near term operating needs and the long-term assurance of asset and capacity reliability are both served.
- Job scheduling, to sequence the loaded jobs through the schedule week based on meaningful estimates of the required duration and agreed upon equipment access.
- Manpower commitment, to ensure optimal utilization of resources.

An effective schedule, therefore, consists of three sections corresponding to the three procedures, as shown progressively in annex 18 and annex 19.

### Job loading

Jobs should be listed in sequence of agreed upon importance during the weekly coordination meeting. This sequence may not be chronological within the week.

### Job schedule

The careful selection of your most logical schedule week will contribute significantly to schedule compliance.

When laying out the schedule, the important considerations are the duration of the job, when it is to be performed (start and finish), and what crew member(s) should be assigned to it. Start and finish dates and times are particularly important when shutdown of production processes and coordination of multiple resources are involved.

Using a recognizable key, insert notes at the ends of bars and at the beginnings of succeeding bars where shutdowns and support crafts are required (electricians must complete line item 11 before mechanics can begin line item 12).

#### Labor deployment scheme

As jobs are aligned to individuals on the Job Schedule, those individuals must be committed to their assigned jobs within the Labor Deployment Scheme, thereby cross-referencing resource to assigned job.

A master schedule template should be established for each crew or team responsible to a specific supervisor or team leader (approximately ten people).

Should any team resource have a fixed commitment to indirect activities such as training, the pre-committed capacity should be indicated on the master template.

Each assignment should be cross-referenced to the appropriate job. In the interest of conserving schedule space, reference should be to the line item number (one or two digits), rather than the work order number (four or five digits).

- When all three sections are brought together on a single form, a complete picture is provided for the coming week that assures: Nobody is scheduled to more than one job at any given time.
- Available resources are fully utilized without voids or overloading.
- Internal customers receive the promised support.

#### Completing the scheduling process

The following scheduling guidelines and techniques are offered: annex 20.

## **Chapter 14 - Job execution**

### The supervisor is responsible for job execution

The progress of each job relative to the schedule is continually reviewed to determine if the situation basis changed in any material way.

This requires timely information to determine when projects and other jobs are progressing unfavorably. An accurate schedule helps supervisors to judge when exceptions fall outside of reasonable boundaries and intervention is in order.

Effective supervisors also assure that team members reference their planned job packages to minimize exceptions before they occur.

When a time-line is included within the planned job package, the supervisor can make a well-informed judgment. If the amount of work completed is within reasonable boundaries, no intervention is needed. Intervention while the job is still in process can make a real difference in downtime and equipment availability.

When jobs go awry, materials, parts, and tools are the most common culprits. Obviously, there were shortfalls in the planned job package, provide feedback to the planner. Feedback after job completion enables the planner to improve the planned job package, thereby precluding such delays in the future.

The above scenario reflects true management. Explanation of variances after the fact (horse out of the ban) does not.

### Three important functions

- During the schedule week, the supervisor checks preparedness for each day's work.
- Supervisors make the actual job assignments to specific team members.

#### 1. Daily schedule adjustment.

The schedule requires adjustment after each day, to provide a recasting for the balance of the week.

During daily schedule adjustment, the supervisor:

- Follows schedule progress and coordinates schedule adjustments as dictated by "real" operating needs and changing resource constraints. Urgent interruptions will occur regardless of how well schedules are constructed and coordinated, and will change the framework of work for the week.
- Supervisors should always strive to optimize schedule compliance, despite essential "schedule breaks."
- Adjustments to schedules should always be made in such a way that the most important jobs are completed by end of the week. Extended or delayed jobs must be carried over to the next day ... particularly if they are already started. Schedule adherence or protection is usually a cost effective use of overtime. Selected scheduled jobs should sometimes be sacrificed to take advantage of downtime windows of opportunity to perform planned jobs listed on the contingency schedule.
- Team members must always be kept fully aware of alterations in assignments and their timing, and Production Supervisors also must be kept abreast of revisions.



## 2. Planner support of job execution.

- Support of Job Execution - ensures that the responsible supervisor receives and understands the planned job package for each scheduled job.
- Follow-up coordination ensures that all agreed-up actions of others are performed as planned.
- Schedule Follow-up - determines the level of schedule compliance and reasons for non-completion. This “constructive” responsibility works toward future improvement. At the end of the schedule week, Superintendents should review schedule compliance with all supervisors for whom they are responsible.

## 3. The morning meeting.

A well-thought-out schedule provides a framework for achievement of weekly targets, but problems do occur and changes need to be made on a daily basis. All parties must be involved in discussions related to course corrections. The morning meeting is such a forum and is often effective, especially when the maintenance function is still operating in a reactive environment.

The meeting focuses on immediate problems while protecting as much of the weekly schedule as possible. Tactics are therefore discussed and resources realigned as necessary.

Once the cultural transition from a reactive to a proactive environment has been achieved, emphasis is switched to the weekly coordination meeting between maintenance and operations. The daily meeting then has less prominence and superintendent approval becomes a requirement prior to any change of the weekly schedule.

## **Chapter 15 - Job Close Out and Follow Up**

The job is not complete without comprehensive feedback regarding the work performed. In the case of planned jobs it need be only to exceptions, additions and deletions from plan. If planning was effective, such need should be minimal.

The most basic feedback is labor hours charged, which should be reported via the Labor Distribution System. The second basic is any materials and parts, which the team had to requisition themselves. Feedback on the Work Order itself would be expanded or corrected description and job steps; additional special tools required, and interruptions encountered, etc.

Historians say, unless we study history we'll be doomed to repeat it. Maintenance jobs are similar. Thousands of dollars are spent doing a particular job, but it seems to be difficult to spend even \$50 to close it out in such a way that we can take advantage of the detailed knowledge gained from doing the job in the first place.

In performance of his close out responsibilities, the assisted planner must:

- Collect completed work orders and enter them or direct them to be entered into the CMMS. He or she must ensure that all fields are filled in, comments are readable (contact the writer if not) and that there is enough detail to support future analysis.
- Close work orders, as soon as completed, to equipment history and charge them to the proper accounts, thereby avoiding inappropriate charges after jobs are complete.
- The planner also verifies that all essential feedback entries have been made.

### Schedule compliance

The maintenance supervisor keeps the planner abreast of schedule compliance throughout the course of the schedule week.

The planner calculates Schedule Compliance ratios each week and prepares associated reports. The calculations determine the level of schedule compliance and reasons for non-compliance, not to place blame but to identify constructive actions to improve future performance.

The schedule is not rigid, but represents the most desirable target for the supervisor to pursue. At the same time, supervisors must have flexibility to make necessary tactical decisions as true emergencies arise.

### Reasons for non-compliance

Schedule compliance highlights areas where mechanics can not do their job due to problems outside their control. These reasons should be recorded, reported, and studied for trends. The following coding structure is offered as an example.

## Reason for Schedule Non-Compliance

Operations may fail to release equipment as previously agreed to.	FR
Excessive emergencies.	PA
Poor assignment of technicians.	EE
Insufficient technician capacity.	IC
Stock-outs are frequent	SO
Planning packages do not reflect reality. Parts are incorrect, job steps are incomplete or wrong, and lockouts, specifications and regulations are not documented.	PP
Failure to meet estimated job durations means that some scheduled jobs are not completed by end of the scheduled week.	DU
Excessive absenteeism and simultaneous peak loads.	EA

Calculation of schedule compliance

Schedule Compliance measures the percent of scheduled labor-hours completed during the schedule week.

Schedule Compliance = Scheduled Labor-Hours Completed / Scheduled Labor-Hours Scheduled

Supplementary metrics

Schedule Performance measures the percent of labor-hours available to be scheduled that were indeed scheduled and completed during the schedule week.

Schedule Performance = Scheduled Labor-Hours Completed / Total Labor Hours Available

Schedule Effectiveness measures the percent of total labor-hours worked that were scheduled to direct work (vs. indirect work) and completed during the schedule week.

Schedule Effectiveness = Schedule Performance x % of Labor-Hours Completed that were direct versus indirect work

Effectiveness is the most complete metric.

The three metrics combined provide a comprehensive picture of scheduling success.

## **Chapter 16 - Planner and Scheduler Metrics**

Measurement of Maintenance effectiveness requires the use of a family of metrics with related benchmarks (a few dozen in total). However, only a handful can act as measures of a Planner's efforts.

The planner's job is not to predict results but to establish expectation (superficial goals lead to superficial results).

Expectations influence outcome and create transformations in people. Pursue things that will make a difference rather than seeking the safe path of mediocrity.

### Direct measures of planning effectiveness

Most of the measures listed below should be looked at monthly and plotted on a chart to allow trends to be detected. The most meaningful and appropriate measures of planner effectiveness are:

- Percent of Work Orders covered with Planned Job Packages
- Percent of Work Orders covered with art Estimate of Required Labor-hours
- Reliability (accuracy, currency and completeness) of Backlog by Status
- Mean Time from Work Order Request to Ready To Be Scheduled Status (other people and functions also influence this metric)
- Mean Time between Job Completion and Job Close Out
- Steady and meaningful expansion of Planner Reference Libraries
- Customer Satisfaction with Planner Communication, Coordination, and Feedback
- Supervisory Satisfaction with Planner Support on Plannable Work Orders (periodic survey)
- Crew Satisfaction with thoroughness of Planner Preparation for the smooth execution of planned jobs. Thoroughness can be measured by application of "the Job Plan Survey" included among the appendices (periodic survey).
- Timely posting and distribution of Weekly Schedules together with distribution of associated Planned Job Packages
- Timely and accurate preparation, distribution, and/or posting of those control reports and trend charts for which the planner is responsible

### Indirect measures of planning effectiveness

All other measures of planner contributions are qualitative measures of maintenance functional performance, the credit or criticism for which belongs to the entire maintenance department and indeed to the entire local organization.

### The follow-up critique

Planning quality is best measured by post completion feedback and critiquing.

This process should take place on an ongoing basis as an agenda item within the Weekly Coordination Meeting. Questions such as the following should be addressed:

- Was the schedule successfully completed?
- What was schedule compliance?
- Were any of the schedule shortfalls due planning?
- What was the problem?
- Could it have been avoided?
- What can we do differently next time?
- What changes must be made?

### Activity sampling

The final means of measuring planning quality is through periodic activity sampling. This technique statistically samples the workweek of the maintenance work force to determine the portions spent at direct work (on-site use of tools/wrench time) and that consumed by specific forms of delay (avoidable and unavoidable). It is the avoidable delays that quantify planning shortfalls. This topic is covered in more detail in the introduction.

## **Chapter 17 - Using CMMS to Aid Planning and Scheduling**

Effective planning, coordination, and scheduling of the maintenance function can be, and for many years was, accomplished without computer support. However, in these days of high technology and rapid, economical data communication, job preparation is accomplished far more efficiently with the support of a sound Computerized Maintenance Information Management System (CMMIS).

A CMMIS accomplishes nothing in isolation, but must be integrated with the other twenty building blocks of the “Maintenance Arch” (see Introduction). Bottom-line impact results from actions taken on the basis of information provided by the system, not directly from the system itself.

It is no longer an economically sound decision to manage a function as critical as maintenance without on-line informational support.

Computerization of the work order system allows easier access to large amounts of data enabling analyses too time consuming to perform manually.

A popular phrase regarding many CMMIS’s on the market is that they “are not user-friendly.” The statement is true. It is also true that the functions and persons to which the systems are least user-friendly are the planner-schedulers.

The maintenance planning system is generally part of a much larger maintenance information system.

To effectively support the functions discussed throughout this book, the chosen CMMIS (hardware and software) must offer the following characteristics. The selected CMMIS must be a sound, comprehensive, on-line, real-time, user-friendly, computerized work order control system. If it is not real time, the maintenance staff (planners and clerks) must perform all administrative input and output. A preferable strategy is for all parties to do their own share of informational input and retrieval.

If these responsibilities are not shared, all too often, planners become little more than clerks. It is a sound investment to take a skilled mechanic off the tools to become a planner but it is a poor investment indeed to take a planner off planning and relegate that person to clerical data entry. The design of the system should take advantage of all available technology to minimize the time required for input and retrieval.

Good backlog management features relate essentially to effective coding regarding:

- “Job Status” to facilitate the planner’s efforts to keep all work orders moving to completion rather than allowing them to bog down in a state of limbo.
- “Assigned Team” to facilitate the preparation of a weekly schedule fully deploying the resources reporting to each given supervisor.
- “Asset/Equipment” to facilitate the assembly of all ready-to-go backlog that might be performed during access to a given asset.
- “Requester” to keep internal customers apprised as to the current status of their requests. Ideally, requesters should be able to access this information themselves, on-line.
- “Planner” so that each planner is able to separate his or her work batch from the complete backlog.

- “Condition required” because there is regularly a need to separate work that is doable at any time versus that requiring asset down time, of various duration.

Features in CMMIS that support effective planning and estimating include:

- Macro-planning to keep resources in balance with the workload.
- System capability to store, retrieve, modify, and copy previously developed job plans and estimates from history or planner libraries.
- When planning a job on a specific asset, ready access to related information without backing out of the planning module.
- System linkage to current drawings and other reference documents with provision for automatic attachment to planned job packages.

Effective materials management features are essential. Problems in area are common and constantly threaten mechanic’s productivity.

- Cross references
  - Bill Of Materials (BOM) of components by asset.
  - Conversions between manufacturer’s part numbers, vendor’s part numbers and storeroom item numbers.
- Reservation (allocation) of inventory item units to specific planned jobs and release (de-allocation) of same as needed.
- Reliable replenishment of authorized stock.
- Prompt processing of purchase order requests for direct purchases.
- Prompt and reliable notification of receipts.

Effective scheduling procedures:

- Annualized levelling of PM/PdM’s with notification as they come due
- Ability to call forward approaching PM’s to take advantage of known asset access.
- Weekly scheduling for each crew by job, day of the week, and individual to whom job is aligned.
- Linkage to project management software.
- Good reporting features including Backlog Status, Work Programs, Schedule Compliance, Crew Efficiency, and Age of Reserved Inventory.

## ***Chapter 18 - Planning and Management of Projects***

Planning and Management of Major Maintenance Shutdowns and Management of Projects

This chapter does not belong in this book, but a short content of it can be found in annex 21.



## **Annexes**

### **Annex 1: The rush job**

#### *The Rush Job*

*I am a rush job.*

*I belong to no age, for man has always hurried.*

*I prod all human endeavours.*

*Men believe me necessary – but falsely.*

*I rush today because I was not planned yesterday.*

*I demand excessive energy and concentration.*

*I override obstacles, but at great expense.*

*I illustrate the old saying “Haste makes waste.”*

*My path is strewn with the evils of overtime,  
mistakes, and disappointment.*

*Accuracy and quality give way to speed.*

*Ruthlessly I rush on ... I am a rush job.*

*Anonymous.*

**Annex 2: Worksheet for determining the ratio of craftsmen to planners**

<u>Planning and scheduling structure:</u>	
Separate from material coordinating (vertical structure)	1 point
Combined (horizontal structure)	2 points

<u>Numbers of crafts coordinated:</u>	
One	1 point
Two	2 points
Three	3 points
Four	4 points

<u>Level of planning:</u>	
Craft and general description with schedule	1 point
Craft, general description, special tools and major materials with schedule	3 points
Craft, specific instructions, tools, materials, prints and schedule	5 points
All the above plus work methods described	7 points

<u>Level of estimating:</u>	
Estimates or historical averages	1 point
Slotting against benchmarks or labour library	3 points
Analytical estimating	5 points
Engineered Standards	7 points

<u>Inappropriate Responsibilities (additive)</u>	
Sourcing	1 point
Procuring	1 point
Expediting	1 point
Receiving	1 point
Stocking	1 point
Picking and kiting	1 point
Staging and securing	1 point
Delivery to scheduled job site	1 point

Total points:	
---------------	--

<u>Conversion Table:</u>	
<u>Total points</u>	<u>Craftsmen : Planner Ratio</u>
4 to 7	30 : 1
8 to 12	25 : 1
13 to 17	20 : 1
18 to 22	15 : 1
23 to 26	12 : 1
27 to 30	10 : 1

### **Annex 3: Check-list for Backlog Integrity**

- Jobs that are completed, but nobody has bothered to close them out
- Duplicate jobs under different names
- Jobs over six months old?
- Jobs for which no one recognizes the originator or why the job was needed in the first place
- A poorly described job (no one can figure out what to do to what)
- Job status not filled in and nobody recalls what the status is. Were parts required? Were they ordered? Were they ever delivered, and if so, where are they now?
- Jobs that needed to be done that are not listed in the backlog.

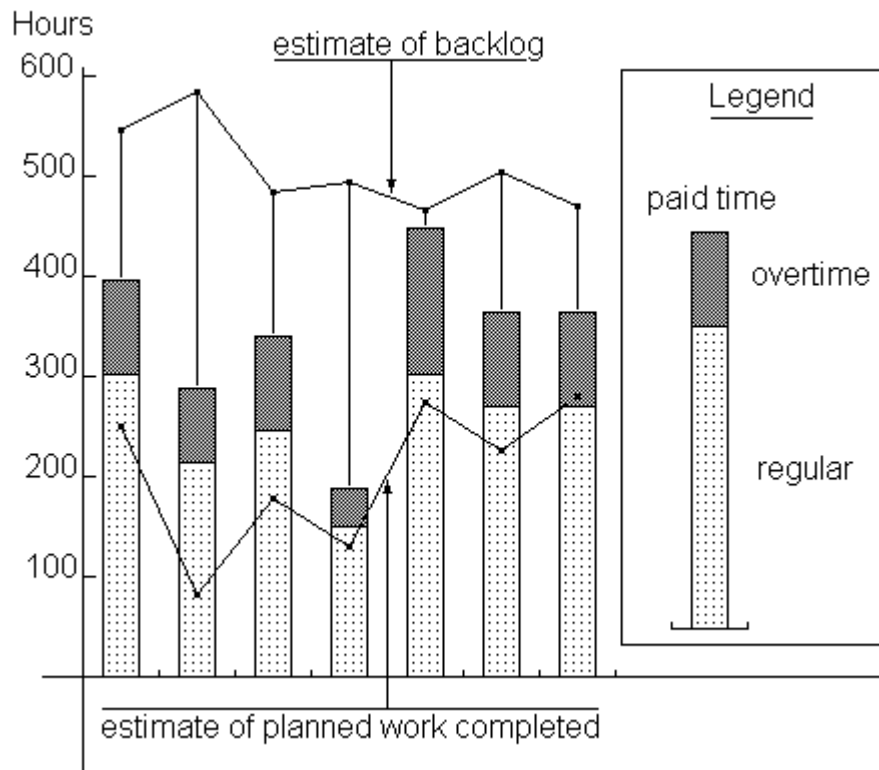
**Annex 4: A weekly example of a Work Program**

WORK PROGRAM

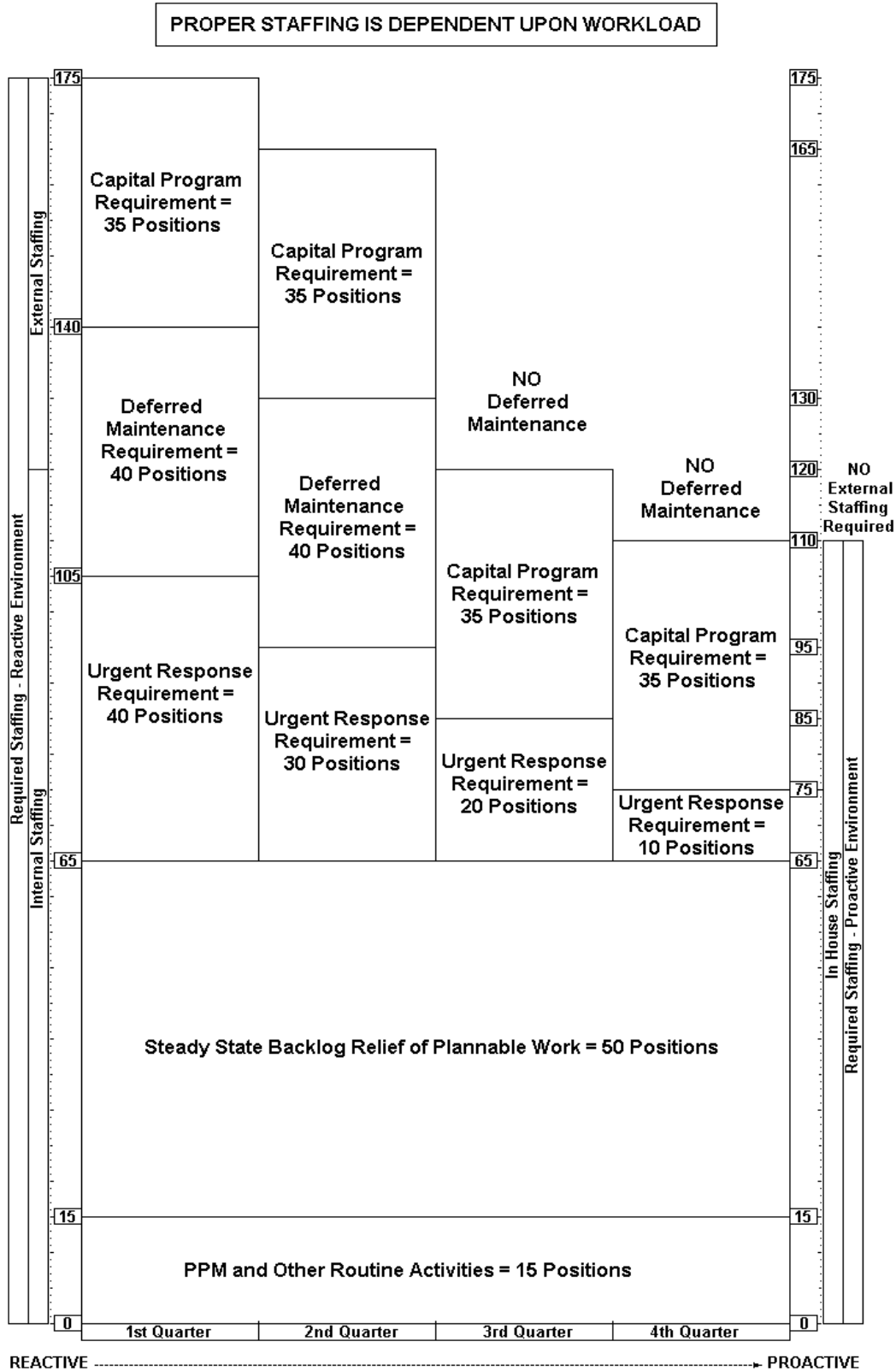
CREW _____	Period Ending _____
<b>AVAILABLE RESOURCES</b>	
Crew Size _____	
Straight Time Man-Hour Available Per Week	800
Planned Overtime Per Week	96
Man-Hour Contracted or Borrowed Per Week	<u>0</u>
<b>Total Man-Hours Available Per Week</b>	<b>896</b>
<b>LESS INDIRECT COMMITMENTS (Weekly Averages)</b>	
Lunch (if paid)	0
Vacation	120
Absence	24
Training	56
Meetings	40
Special Assignments	40
Average Man-Hours Loaned to Other Areas	40
Other Indirect	<u>10</u>
<b>Total Indirect Man-Hours Projected per week</b>	<b>330</b>
<b>Total Man-Hours Per Week Available For Direct Work</b>	<b>566</b>
<b>COMMITMENTS OTHER THAN BACKLOG RELIEF</b> (Weekly Averages)	
Emergency/urgent (Unschedulable)	100
Routine PPM	120
Other Fixed Routine Assignments	<u>0</u>
<b>Sub Total</b>	<b>220</b>
<b>Net Resource Available For Backlog Relief</b>	<b>346</b>

<b>Backlog Data</b>	<b>Current</b>	<b>Backlog Weeks</b>	<b>Current</b>	<b>Target</b>
Backlog Man-Hours in Ready Status	3200	Ready	9.2	2 to 4
Total Man-Hours of Backlog	4800	Total	13.9	4 to 6

**Annex 5: Backlog Weeks Trend Chart**



### Annex 6: Required Maintenance Staffing Based Upon Workload.



## **Annex 7: Job Assessment and Scoping Check-list**

- ❑ Confer with the requester to clarify the desired result. By clarifying the end objective, the means to get there can often be simplified or the job can be expanded to solve several problems at once.
- ❑ Refine the description accordingly.
- ❑ Clarify the specific job location (building, floor, bay, etc.)
- ❑ List what needs to be done (job content).
- ❑ Define start and finish points (job scope).
- ❑ Finalize priority.
- ❑ Visualize job execution and outline requirements.
- ❑ Record the steps necessary to execute the job.
- ❑ Prepare sketches or take photos to clarify the intent of the work order for assigned mechanics or simply as a reference during detailed planning.
- ❑ Take minor measurements (exactly). Complex measurements should be left to the assigned technicians.
- ❑ Determine required conditions. Must this job be coordinated with Operations?
- ❑ Is it necessary for equipment to be down?
- ❑ Define involved control loops.
- ❑ Determine if other equipment in adjacent areas will be impacted by performance of this job.
- ❑ Check for safety hazards.



## **Annex 8: Job Planning Survey**

1. Were job instructions clear?
2. Was the estimate within 15% (total hours and hours by craft)?
3. Was the work performed as specified?
4. Did unusual problems occur on this job?
5. Were trips for tools, parts or supplies needed after the job was started?
6. Were there delays due to problems with permits or permissions?
7. Were there delays relating to equipment access?
8. Were there delays caused by lack of craft coordination?
9. Allow space for explanations ...

**Annex 9: List determinable materials, parts and special tools required.**

- ❑ Prepare the Bill of Materials.
- ❑ Establish the acquisition plan.
- ❑ Determine what items are in stock and reserve them.
- ❑ Identify those items, which must be direct, ordered.
- ❑ Prepare acquisition documents.
- ❑ Consider disposal issues.
- ❑ Prepare Purchase Order with Maintenance Work Order reference for contractors and outside equipment rental.
- ❑ List special tools and equipment required.
- ❑ Arrange for ladders, scaffolding, rigging, etc.

**Annex 10: Questions to ask about tools and equipment.**

1. What tools and equipment are needed for this job?
2. Do we have the necessary items in-house or do we go outside for it?
3. If we have it in-house, who is responsible for insuring that it will be available?
4. If we go outside for it, who is the preferred vendor?
5. If not currently owned, should it be purchased or rented?
6. Can we reserve it with reasonable assurance that it will be available?
7. What is the lead-time if not immediately available?
8. Is the cost included in the job estimate?
9. Do we rent it “wet or dry” (with or without an operator and insurance)?

**Annex 11: Common Job Sequence**

<u>Source</u>	<u>Task</u>
Fixed Provision Table	Get ready and receive instructions for doing the job (includes job instructions from the supervisor, collecting personal tools, obtaining parts from storeroom and gathering required special tools and equipment).
Travel Time Table	Travel to job site (outbound).
Fixed Provision Table	Listen to production input regarding symptoms.
Fixed Provision Table	Make preliminary diagnosis and troubleshoot prior to shutdown.
Fixed Provision Table	Shutdown and Lockout. This procedure is done jointly with the line supervisor, control room technician and/or line operator. Equipment must be stopped in the proper sequence with proper lockouts.
Labour Library	Partial or total dis-assembly to reach the problem area.
Fixed Provision Table	Determination of full extent of problem.
Fixed Provision Table	Identification of necessary replacement parts, obtaining them from the storeroom or initiating a direct purchase for parts not held in inventory.
Labour Library	Reassembly of equipment using the replacement parts as needed.
Fixed Provision Table	Check proper job completion, test operability of equipment, clean up the job site and put away tools.
Travel Time Table	Travel back to shop (inbound).
Fixed Provision Table	Report on job and return unused parts, special tools and equipment.
Allowance Table	Allowances

**Annex 12: Travel-time table**

Travel-time table.

From Shop to	Round Trip Hours	Allowed Hours per Person		
		Simple	Average	Complex
Area A	0.5	0.5	1.0	1.5
Area B	0.4	0.4	0.8	1.2
...	...	...	...	...
	Round trips provided	1	2	3

**Annex 13: Labor Library**

Equipment Name:				Equipment No:					
Sequential Task		Craft:							
No.	Description	Mechanic		E&I		Construction		Labour	
		Crew:	MH	Crew:	MH	Crew:	MH	Crew:	MH
0.10									
0.20									
0.30									
...									

**Annex 14: Typical table of allowances**

		<b>Level of Inherent Fatigue</b>		
<b>Nature of Allowance</b>	<b>%</b>	<b>Light</b>	<b>Average</b>	<b>Heavy</b>
Personal time (breaks)	5	5	5	5
Fatigue	5-10	5	7	10
Unavoidable Delay	5	5	5	5
<b>Subtotal</b>	15-20	15	17	20
Crew Balance – Multi Person	0-3	0-3	0-3	0-3
Crew Balance – Multi Craft	0-2	0-2	0-2	0-2
<b>Total</b>	15-25	15-20	17-22	20-25

## Annex 15: Slotting Table Concept

Category	Median Labour Hours	Range of Labour Hours		
		From	To	
A	0,1	0,00	0,15	
B	0,2	0,15	0,25	
C	0,4	0,25	0,50	
D	0,7	0,50	0,90	
E	1,2	0,90	1,50	
F	2,0	1,50	2,50	
G	3,0	2,50	3,50	
H	4,0	3,50	4,50	
I	5,0	4,50	5,50	← Fewer Labour Hours
J	6,0	5,50	6,50	← Slot Here
K	7,3	6,50	8,00	← More Labour Hours
S	26,0	24,00	28,00	
T	30,0	28,00	32,00	



## Annex 16: Instructions for recommending benchmarks

1. Identify some jobs performed by your own crew that occur frequently and are familiar to you.
2. Determine the most effective crew size.
3. Record each selected job in the appropriate interval on the Benchmark Solicitation Form (see figure below). Put the job in the appropriate crew size column and in the increment row representing your best judgment. Work in pencil, as you may wish to change an estimate based on the relativity of one job to another. Use of this relativity is the concept behind the slotting techniques.
4. Offer a recommended benchmark job in as many slots as possible, but do not force a job into a wrong slot. It is better not to use a job or to leave an increment blank, than to force a job into an improper increment.
5. Submissions will be compared to those from other participants and as necessary will be spot-checked by work measurement. Therefore, do not hesitate to offer your best insights.

This approach provides a quick start-up with reasonable initial accuracy and consistency. Resultant benchmarks are subsequently refined as the planning and estimating process matures. The refinement process incorporates the following technique:

- Each week an exception report is generated via the CMMS. For each planner, it lists the top ten jobs for which actual labor-hours differed from his estimated labor-hours by the largest percentage, regardless of sign (plus or minus).
- The involved planner should evaluate those ten jobs to determine if adjustment of the estimate is necessary. If the planner decides that he/she was wrong, the estimate should be changed in the database for future application. On the other hand, if it is decided that the source of variance was poor performance by crew or supervisor, or some avoidable delay that should not repeat in the future, then the estimate should not be revised.

Using Foreman Estimates to Building the Slotting Library

<b>Craft:</b>		<b>Elapsed Time</b>				<b>Maintenance Management Program Benchmark Development Sheet</b>			
		Allowed Hours	Range of Labour Hours From To	Units	<b>Suggested Benchmark Job</b>				
Slot					One Person Crew	Two Person Crew	Three Person Crew	Four Person Crew	
A	0,3	0	20	Min.					
B	0,5	20	40	Min.					
C	0,7	40	50	Min.					
D	1,0	50	75	Min.					
E	1,5	1,25	1,75	Hours					
F	2,0	1,75	2,5	Hours					
G	3,0	2,5	3,5	Hours					
H	4,0	3,5	5	Hours					
I	6,0	5	7	Hours					
J	8,0	7	9	Hours					
K	10,0	9	11	Hours					

## Annex 17: Maintenance Job Estimating Work Sheet

### Maintenance Job Estimating Work Sheet

Planner: _____	Request #: _____ WO #: _____	Date: _____ Date: _____
----------------	---------------------------------	----------------------------

Equipment Number Performed Upon: \_\_\_\_\_

Description: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Work Group: _____	Travel: _____
Characteristics: _____ Simple   Average   Complex	Fatigue Factor: _____ Light   Average   Heavy
Crew Size: _____	Skill Required: _____
Crew Balancing Required: _____ Yes   No	Multi-Craft Allowance Required: _____ Yes   No

<u>Build Up of Detailed Estimates</u>				
<u>Step</u>	<u>Activity</u>	<u>Required</u>		<u>Time Estimate</u>
		<u>Skill</u>	<u>Crew Size</u>	
1.				
2.				
3.				
4.				
5.				
6.				
Total Direct Work (Elapsed Time):				_____
(Carry to below summary)				

<u>Normal Time x Allowance Factor = Estimated Time</u>	
Direct Work Time: _____	
Job Preparation & Wrap Up: _____	
Travel Time: _____	
Total Normal Time = _____ x Allowance Factor of _____ = Estimated Duration _____	
	x Crew Size _____
	= Total Estimated Manhours _____
Estimate Developed by: Slotting <input type="checkbox"/> Detailed Estimate <input type="checkbox"/> Historical Average <input type="checkbox"/> Gross Estimate <input type="checkbox"/>	

### Annex 18: Job loading and scheduling

Line Item	WO #	Job Description	Job Loading		Crew Size	Clock Hours	Man Hours	Assigned Crew	Thursday		Friday		Saturday	
			Req. Skill	Man Hours					OT	OT	OT	OT		
1	10010	Daily PM Line #2	M3	1	1	1	F							
2														
3														
4														
5	10340	Replace limit switches	E4/E1	2	4	8	A & B							
6														
7														
8		Repl. limit switches - Ln #1	E4	1	2	2	C							
9														
10														
11	10362	Connect Power to Line #3	E1/E4	2	4	8	C & A							
12	10362	Check Run Line #3	M1/M3	2	4	8	G & F							
13														
14														
15														
16														
17														
18														
19														
20	10020	Clean & Inspect Load Centers	E4/E1	2	4	8	A & B							
							<b>Total Man-Hours Scheduled:</b>							
Add 10% Provision							"A"							
21														
22														
23														
24														
Jobs ON Contingency Schedule														
25														
26														

### Annex 19: Labour Deployment Scheme

Team:		WEEKLY MAINTENANCE SCHEDULE														
		Supervisor:							Manpower Deployment Scheme							
		Skill		Friday		Saturday		Sunday		Monday		OT		OT		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O		
Joe Adams	Sam Butler	E4	E1	E1												
Doug Chase	Bob Doig	E1	I1													
John Edwards	Charles Farmer	M4	M3													
Howard Goode	Homer Harvey	M1	M3													
Frank Ivanhoe	Bob Jenkins	M3	W3													
Lou Kennedy	Len Larson	K1	H1													

## **Annex 20: Scheduling guidelines and techniques**

- Prepare a schedule form for each supervised unit by entering the week beginning date, the name of the responsible foreman and the organizational unit involved.
- The Planner should determine (by discussion with the foreman, reference to vacation charts, and other means), known absences for the coming schedule week and subtract them from the resources expected to be working during the schedule week.
- Review all jobs in the backlog starting with incomplete jobs from current or previous schedule(s).
- Review Planned Job Packages, to make certain they are sufficiently complete for scheduling and assignment. This work includes final confirmation of material, parts, and special tool availability required for execution, safety instructions, and permit requirements.
- Plan strategy on a weekly basis. Rigidly enforce the rule that weekly schedules must be prepared for each supervisor by Thursday Noon of the preceding week (if the schedule starts Friday). The schedules are to show how team resources are to be utilized throughout the schedule week.
- Work scheduled must be balanced against available man-hours, and sufficient jobs must be posted to the schedule to consume all available labor-hours. Schedule what can be done, not necessarily what needs to be done.
- Each available mechanic should be scheduled for a full day of productive work for each day of the schedule week. The duration should be indicated in the job section of the schedule. In the man power deployment section, indicate labor-hours, to avoid confusion.
- The majority of the crews should be scheduled for important work, which needs to be started and completed without interruption. Make a conservative provision for urgent schedule breaks. Assign jobs that can be interrupted or delayed, to “a few good people” who are flexible. Flexible means that they can stop and resume jobs, be re-instructed and reassigned to “emergencies” with minimal loss of efficiency and without a drop in morale. Approximately 10 to 15% of scheduled labor-hours should be on low priority jobs that can be sacrificed when necessitated by urgent demands. Personnel assigned to such jobs are the ones to be pulled in response to schedule breaks (urgencies).
- Do not schedule any job until all needs (parts, materials, tools, special equipment, asset access, the item to be worked, any special support) are available in the quantity required and at the time necessary.
- List jobs in descending order of importance until all available man-hours are committed (PMs listed first), based upon agreements reached during the weekly coordination meeting.
- Determine most logical time of day to schedule PPM’s. Often, the early part of the day is the period of heaviest breakdowns so is not a good time to schedule PM’s. On the other hand, it is not advisable to leave them until the end of the day because then they may not get done at all. Late morning or early afternoon are advisable times to schedule PM’s time.

- Add jobs equal to 10 or 15% of scheduled labor-hours (Line Item 21—24) as provisional jobs to be substituted when scheduled jobs are unavoidably delayed or completed in less than the estimated time.
- Establish a contingency section of the schedule (Line Items 25-27) for jobs of high desirability, but that require equipment access not expected within the schedule week. Should availability occur, it is more important that these jobs be performed than some jobs on the primary schedule, but only if the provisional jobs have been properly planned. The provisional strategy is proactive and should be classified as schedule compliant.
- Avoid duplicate shutdowns by scheduling all work requiring common equipment access as appropriate.
- Save minor indoor jobs for severe temperatures and inclement weather.
- Eliminate unnecessary trips. Look for opportunities for assignments to take advantage of jobs in the same location, jobs using the same tools or materials, jobs needing the same skills, and other ways to improve efficiency.
- Schedule multi-person jobs as the first job in the morning whenever possible so that everyone is available to start the job at the same time.
- When scheduling multi-person jobs later in the day, consider previous assignments. Don't assign one person to a one-hour job and the helper to a two-hour job because both will not be available to start the two-person job concurrently.
- Think about crew balancing delays on multi-man jobs. All four members of a crew are seldom required for the entire duration of a job. Often another small job in the same area can be worked concurrently.
- Allocate people to specific jobs with supervisor's approval. Pick the people for the jobs based on knowledge and aptitude, required skill or equipment and on the basis of individual training needs. Experience shows who is skillful in certain job types and who needs more exposure to them. Balance equipment specialization with broad facility knowledge. Utilize individual skills to the greatest extent possible. Craftsmen should be provided with a challenging environment and the opportunity to grow.
- Schedules for the forthcoming week for each supervisor's team must be finalized and posted prior to the end of the previous week. All preventive and predictive maintenance inspections must be incorporated at their predetermined frequencies and the timely completion of all identified corrective maintenance must be scheduled.
- Associated "Planned Job Packages" must be delivered to and reviewed with responsible supervisors to assure that nothing falls through the cracks due to misinterpretation of intent or meaning. These consultations form the point at which responsibility transitions from planner to supervisor. Nothing can be allowed to be lost within the transition. In turn, the same level of transition must take place between supervisor and technician at the time of assignment.
- Operations are to be provided with copies of schedules to confirm and document that all agreed upon commitments are acceptable and understood by both operations and maintenance departments.

- It is vital that schedules be studied and approved by everyone concerned. Approval means that a contract has been reached between operations and maintenance to comply with “their joint schedule” for the deployment of maintenance resources in support of operating plans.
- At this point, the Weekly Master Schedule becomes a document of which all parties, through mutual contribution, accept ownership.
- When urgent work is done at the expense of scheduled jobs, a schedule overload results. A scheduled job will be displaced and carried over to the next schedule period, unless the problem is addressed by a temporary increase in capacity (overtime or contract labor). The displaced job is one of those scheduled for the organization that initiates the schedule break. Therefore, requests for schedule breaks require the sanction of the Maintenance and Production Manager.
- Finalize tactics on a daily basis when the schedule is being executed. The weekly schedule must be updated each evening during the week it is in force for the balance of that week. While the transition from reactive to proactive maintenance is taking place, updating will be burdensome and will have to be performed by the planner. However, as schedule compliance matures, the required updating becomes minimal and can be performed by the supervisor.
- Operations must advise planners at the earliest possible moment if they are unable to release equipment as scheduled. Similarly, the maintenance department must advise production management if the reverse situation is likely to occur. Planners must ensure the coordination.
- Planners must keep abreast of schedule status, and detect when a job runs into trouble before it misses a milestone.
- Maintenance must notify and consult with customers about any pending interruptions or disruptions.
- When a job is complete, maintenance must collect the planned job package with appropriate feedback, record the results for schedule compliance, and confirm that the job is closed out. Feedback includes what actually happened, what failed, and ideas for improvement.
- Maintenance must verify that the job was done according to the plan. When a job deviates it is vital to learn why. Verify that the job used the materials listed in the Bill of Material. Verify that all specialized tools and equipment were accounted for in the plan. Verify that drawings were correct and that no additional permits or permissions were needed. Finally, on larger or disruptive jobs verify that all people who should have known about the job were notified and all processes were shut down appropriately.
- Finally, update the planning package in all the areas mentioned.



## **Annex 21: Project Management Process**

### STEPS OF THE PROJECT MANAGEMENT PROCESS

#### **Phase One — Project Definition**

- 1. Create a vision for the project.** Chose the project management team. Establish a physical structure and chain of command to manage the project. Make sure that each member knows his or her role in the overall project. Train the team in project management and related software.
- 2. Identify and involve the stakeholders** to ensure that all essential expectations are considered during project development to avoid scope changes after project initiation.
- 3. Determine the general scope of work** from the engineering schedule and from preventive maintenance inspections. Review all drawings, specifications and other available documentation.
- 4. Develop a summary statement of the turnaround or project objective** and distribute for concurrence ... by signature.
- 5. Define the deliverables** constituting project completion.

#### **Phase Two — Preliminary Engineering**

- 6. Determine pre-shutdown and other preparation.** Initiate associated work orders.
7. Determine the extent of partial or complete shutdown of associated processes and adjacent areas.
- 8. Gather all PM's and backlog jobs that may be candidates to be performed during the shutdown** or while project work is being performed in an area. Look forward for PM's that might be accelerated. Reference the previous shutdown in the given area as a starting template, paying close attention to activity sequencing and problems encountered. Do not repeat the same mistakes.
- 9. Break the project into jobs and individual activities** comprising the jobs. There are rules for setting up an activity
  - An activity has a defined beginning and ending. The better defined, the easier it is to manage the activity.
  - No subsequent activity can originate from the middle of a prior activity. If one really can, the earlier activity must be split into two activities.
- 10. Determine general manpower requirements and skill sets,** defined by in-house versus contract personnel.
- 11. As contractors are chosen, check that they can meet their commitments.** Contractors go to great length to make a sale. Look at the depth of their organization, the time of year (is it a busy time even without your job). The contractor needs only to win a string of proposals to become over committed. When good contractors are found, the project manager must be a fair customer and avoid negotiating deadlines, milestones and budgets that are unreasonable. Reliable contractors should be regarded as and treated as partners.
- 12. List all heavy or specialized equipment likely to be required,** such as cranes, forklifts, scaffolding, compressors, welding machines, or torque wrenches, and assure their timely availability.

**13. Estimate elapsed time needed for each activity.** Depending on the risk associated with schedule delinquency, three estimates may be made (optimistic, probable and pessimistic). Studies show that the more pessimistic estimates best reflect actual. This may be so in the first instance of a given turnaround. But as planning improves the “probable” should become reliable. Most overruns occur as a result of preparatory shortfalls.

**14. Identify prerequisites for each activity.** Determine what activities must be completed before each activity can be started. Block walls cannot be laid-up until footers are cured. A particular activity may be dependent upon completion of several other activities.

**15. Post the required data to the CPM software.** From this information the software builds a “model of the project” in the form of a critical path network with time-line bar chart, resource demand chart, and projected cash flow. Determine how long the project will take. The activities constituting the longest path through the project are the critical path. Slippage in any critical path activity will result in the project being completed late.

For many activities, late starts will not affect the overall project completion date. Time before a delayed activity becomes critical is called “float”. Until float is consumed, the late activity is not critical. When float runs out, non-critical path activities become critical and alter the critical path.

This is the opportunity to work the project through, on paper. Assuring that the movement of materials, people and equipment is safe and reasonably efficient. Find the shortfalls in this paper exercise, not during live execution.

The first planning pass is done in relative time (elapsed days from day one). When ready to plug in an actual start date, the software will automatically post dates to the time-lines.

**16.** From labor estimates, contractor requirements, material and parts estimates, and required equipment **establish a comprehensive budget for the overall project.**

**17.** When the first cut of the project is established, **risks are identified and quantified** for inclusion in the forthcoming request for authorization and funding.

### **Phase Three — Justification and Funding**

**18. In the case of capital projects, a return on investment is established** and added to the risk analysis. They are jointly presented for comparison to ROI hurdles prior to authorization.

### **Phase Four — Detailed Project Planning**

**19. Decide on need and status of materials**, such as valves, internals, etc., and make sure that the parts and materials will arrive in sufficient time for checkout prior to use.

**20.** When the workload has been established, **define supervisory needs and responsibilities.**

**21. Identify other staff support requirements** such as clerical, data and timekeeping.

**22. Initiate Purchase Orders and Work Orders** for contractors, rental equipment, etc.

**23. Arrange for temporary office space** with required support equipment (phones, copy machine, etc.).

**24. Make transportation arrangements** for supervisors and crews.

**25. Arrange for material and tool trailers** if needed.

- 26. Make arrangements with Production for temporary storage** (lay-down space) of large equipment sections temporarily removed in the turnaround process.
- 27. Arrange for dumpsters for collection of waste material.**
- 28. Order portable toilets** if needed.
- 29. Secure a list of all contract workers and arrange for their safety orientation.**
- 30. Assemble drawings, wiring diagrams, shop drawings and other reference documents.** Add them to appropriate Planned Job Packages.
- 31. Secure permits covering safety, fire, and regulatory requirements** (local, state and federal).
- 32. Summarize the project responsibilities of each individual supervisor.** Provide them with the associated Planned Job Packages. The package should include:
  - Turnaround objectives
  - Turnaround schedule
  - Detailed Work Orders for all jobs to be supervised
  - Copy of the turnaround organizational chart
  - List of responsibilities by supervisor
  - Progress report forms with instructions for their use
  - Instructions regarding contractor daily time reporting
  - Set of craft work rules
  - Telephone and beeper list
  - List of helpful reminders
- 33. Provide a list of telephone and beeper numbers** to all personnel key to the project.
- 34. Go over this list again to verify that preparation is complete.**
- 35. Distribute the final project schedule** to all appropriate parties.

### **Phase Five — Project Execution**

- 36. Begin to receive and stage parts, materials and equipment.**
- 37. Execution of the projector turnaround is now ready to begin.**
- 38. Continuously monitor and post progress relative to plan.** This enables the software to provide real-time alerts when activities fail behind or expenditures exceed budget. Identify slippage promptly and take corrective action. Expedite as necessary. Add resources (overtime or additional contract support) to overcome the shortfalls in order to return to plan.

Focus on and protect the critical path, but keep an eye on the other paths. Make sure they do not exceed their available float.

**39. Change Orders — Scope creep should be resisted.** Some changes won't go away, but the overall project must be protected. Protect the boss from adverse surprises. Protect the team from disruptions that changes create. Manage the changes. A change order process should be created at the beginning of the project. How many times has it been said, "While we are doing this, it would be easy to also do this other thing"? If change is accepted, everyone up the ladder should sign off on it and accept the consequences in terms of extended duration and increased cost.

### **Phase Six — Project Completion and Close-Out**

**40. Complete cleanup of the site**

**41. Punch list completion**

**42. Turn-over, quality assurance, life safety testing**

**43. Start-up**

**44. Delivery of "As Installed" drawings** and other contracted deliverables (recommended PM routines, BOM and recommended spare parts)

**45. End-user acceptance**

**46. Post completion review.** This is a debriefing to establish lessons learned in order preclude their repetition.

**47. Project Closeout Report should be written as soon after completion as possible.** It documents what happened, what didn't happen, and how problems were fixed. It contains a set of project documents.

### **Phase Seven — Project Review (six months after completion)**

**48. Actual financials realized should be compared to projection.** Failure to deliver expectations damages credibility, which appropriately influences approval of future capital requests.