UNIT 3 PREPARATION OF MAINTENANCE PLANNING AND SCHEDULING

Objectives

After studying this unit, you will be able to:

- understand objectives and benefits of maintenance planning and scheduling,
- forecast and analyze the maintenance workload of a plant,
- understand principles and procedure of maintenance planning,
- understand principles and procedure of maintenance scheduling.

Structure

3.1 INTRODUCTION

Planning and scheduling are the most important aspects of sound maintenance management. Planning is the process by which elements required to perform a task are determined in advance of the job start time. Scheduling deals with specific time and phasing of planned jobs together with the orders to perform the work, monitoring the work, controlling it, and reporting on job progress. Good planning is a prerequisite for sound scheduling. However, for successful planning, feedback from scheduling is necessary. The principle objectives of planning and scheduling include:

- Minimizing the idle time of maintenance work-force,
- Maximizing the efficient use of work time, material, and equipment, and
- Maintaining the operating equipment at a level that is responsive to the need of production in terms of delivery schedule and quality.

Effective planning and scheduling contribute significantly to the following:

- Reduced maintenance costs,
- Improved utilization of the maintenance workforce by reducing delays and interruptions,
- Improved quality of maintenance work by adopting the best methods and procedures and assigning the most qualified workers for the job.

An essential part of planning and scheduling is to forecast future work and to balance the workload between different categories. The maintenance management system should aim to achieve over 90% of the maintenance work planned and scheduled in order to reap the benefits of planning and scheduling. Effective planning and scheduling requires consideration of the following aspects:

a) the operational and structural complexity of a large industrial plant
b) the dynamic nature of the relationship between production and maintenance, and
c) the relationship between maintenance strategy, maintenance workload and resource availability.

3.2 FORECASTING MAINTENANCE WORKLOAD OF A PLANT

Forecasting of maintenance workload of a plant is essential for carrying out proper planning and scheduling. Any industrial plant consists of different units, each unit has number of items, and each item has number of components (*Figure 3.1*).

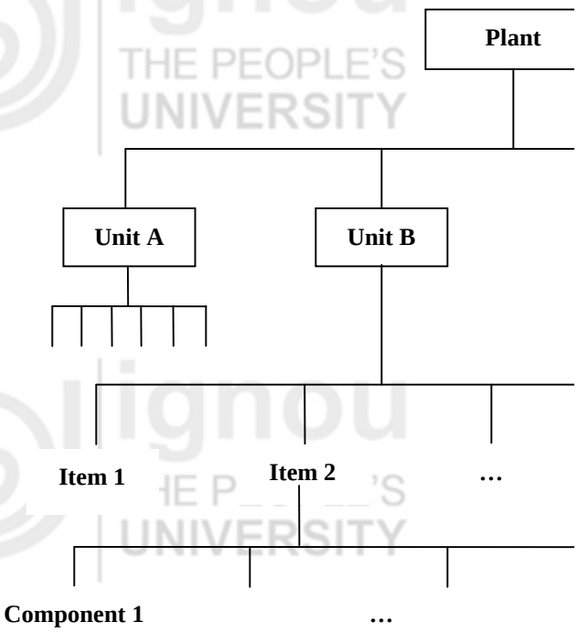

Figure 3.1 : Details of Hierarehy in an Industrial Plant

Maintenance work is generated because a component is unable to perform its desired function. This section gives methodology for forecasting and analyzing maintenance workload of a plant.

a) **Understand Plant Operation**

Unit Criticality

It is necessary to understand the nature of the process and construct process flow diagrams, which show relationships between the various units of the plant. Where possible such diagrams should indicate unit capacities, raw material storage, interstage storage and final product storage.

Once the process flow diagrams are known, the production operating policy for the plant should be identified. This includes identification of the plant operating pattern (*e.g.* number of shifts per day, number of working days per week, seasonal variations, etc.) and expected plant output (i.e. expected performance and availability). Similarly identify the operating patterns and expected availabilities of various plant units. Determine how other production factors, such as catalyst changes, raw materials supply, etc. and any external factors, such as statutory safety regulations, influence the operating pattern. Estimate the cost of downtime for the plant and determine whether this is constant or variable over a period of time.

Using the above information consequence of failure analysis (in terms of safety and downtime cost) should be carried out. Classify and rank the units according to criteria of criticality, *e.g.*

Level I : Unit failure causes immediate loss of production and/or a serious safety hazard and/or loss of quality.

Level II : Unit failure cause loss of production and/or a serious safety hazard, say, 4 hours off-line.

Level III : Unit failure does not affect production or cause a safety problem.

Maintenance Scheduling Characteristics

Using the above information following maintenance scheduling characteristics are identified:

i) Maintenance windows:
   - Windows for the whole plant caused by seasonal, monthly, weekly or daily variations in the demand for the product.
   - Windows for units (in particular critical units) or groups of units caused by production scheduling.
   - Windows arising for the whole plant, or for units, due to other production changes (such as tool changes, catalyst changes, equipment cleaning etc.). These tend to have poor predictability.
   - Windows for major sections of plant, or for units, that can be created by the use of standby or redundant plant, or interstage storage.
   - Windows arising for the whole plant, or for units, as a result of statutory safety work.

ii) Interchangeable or independent units where off-line maintenance could be carried out without affecting the operation of any other unit. This allows flexible maintenance resource scheduling.

iii) Situations where the effects of off-line maintenance on a unit 'Knock on' down a batch process. This spreads the maintenance for the line over a longer period.

iv) 'Process chains' where, in order to maintain a single unit, a whole process involving many units needs to be taken off-line. This either causes maintenance resource peaks or excessive planned downtime for maintenance.

b) **Set Maintenance Plan for Each Unit**

Based on the above information, preventive maintenance requirements for critical units are decided as explained in the following steps. For less critical units the information given in the manufacturers manual may be sufficient.

i) Analyze the units into their maintenance causing items and those items needing maintenance are identified.

ii) Determine best maintenance procedure for each item identified. It is necessary to determine the required trade or trades, the approximate duration of the work and whether the work is online or off-line. The estimated time available for repairing or replacing such items before plant output or safety is affected should also be indicated.

iii) Divide the maintenance work into online and off-line. Online jobs are independent of production and should be considered for scheduling on a plant or area wide basis. Off-line jobs are grouped by trade and periodicity of the jobs. Establish the instructions and time for the jobs.

A maintenance plan for an unit contains list of jobs, with instructions, of all such work. In most cases a plan for an unit is provided by the manufacturer of the unit, but such a plan normally considers only the simple, short life, items. This may be good enough for the less critical units, a full analysis is necessary for critical units.

Activity A

What major considerations are taken while 'planning for maintenance' for a manufacturing unit/machine/equipment?

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c) **Prepare Maintenance Schedule for Plant**

The basic problem is how best to schedule large number of individual jobs, considering the effect of off-line work might have on plant production and on the maintenance resources. It is always to be kept in mind that this should lead to minimizing the lost output and high utilization of maintenance resources.

i) Prepare a plant listing by unit and list all the maintenance work identified for each unit. Arrange the list in order of the process flow.

ii) Establish an online schedule by grouping the jobs according to trade, geographical area or plant type, and frequency. Such work can be scheduled independently of production. The main consideration is a schedule making the best use of resources and providing the right information to trigger major off-line work.

iii) Establish an off-line window schedule for jobs, which can be carried out in the known, or expected, maintenance windows. If there are numerous windows, the schedule can be based at unit level, with the main aim of making the best utilization of resources, e.g. smoothening of the resource demand. If there are relatively few windows and if the cost of lost production is high, careful consideration must be given to linking work across units and trades. This will minimize downtime but cause peaks in resource demand.

iv) Establish an off-line shutdown schedule for remaining jobs on the main list exceeding the time available in the windows. In order to carry out such work the plant needs to be taken off-line and production loss incurred. These type of jobs can only be scheduled in agreement with production. This is the most difficult scheduling problem, especially where the cost of production is high and where many jobs need to be scheduled.

The simplest situation is where most of the jobs, or main job are time based. The periodicity of plant shutdown can be based on the job with the shortest period (the critical jobs) and, as far as possible, other preventive jobs fitted into this period and integral multiples of this period. Corrective maintenance work can also be fitted into the shutdown. Some corrective maintenance work will have been identified before the shutdown (via failure or inspection) and some as a result of inspection during the shutdown. Scheduling the plant shutdown in this way has considerable advantages in organizing the labor to match large peaks. Shutdown jobs can be planned using a master network, using bar chart planning for individual task comprising each job or group of jobs.

It is often possible to extend the period between plant shutdown without increasing the likelihood of plant failure, if the timing of the critical job(s) is condition-based. However, the disadvantage is the difficulty in resourcing large and uncertain work peaks.

Most difficult situation is one in which major work, resulting from a randomly occurring plant failure, still occurs despite preventive maintenance. In this situation such failure might be taken as the trigger for the plant shutdown. Online inspection can be used to predict and plan other jobs in such a shutdown and off-line inspection to establish any other necessary shutdown work. The difficulty lies in resourcing such variable and unpredictable workload.

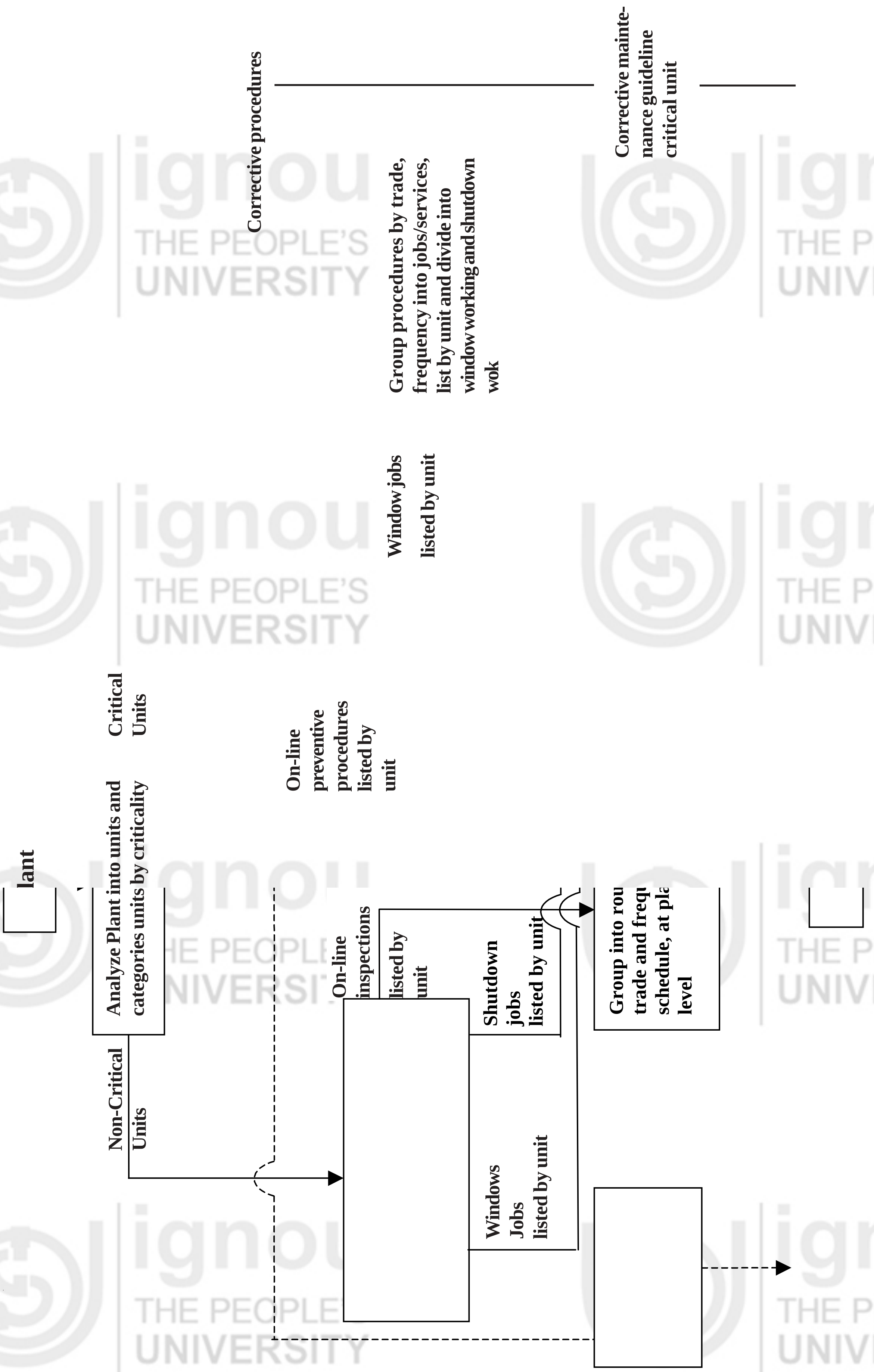

Figure 3.2 Schematic diagram

In practice, and particularly with large integrated plants the schedule will be made up of mix of online routines, window schedules and shutdowns. Thus the online routines influence what is carried out in windows and shutdowns, and the inspections carried out in windows influence the length of the period between the shutdowns. A shutdown is often chosen to coincide with, and be an extension of, a major window. It may again be noted that the sales/production likage has considerable influence on maintenance schedule.

The above analysis helps in identifying the maintenance workload. It also identifies the need for spare parts and for reconditioning. Figure 3.2 gives a schematic diagram of the methodology for forecasting maintenance workload of a plant.

Activity B

Visit a nearby manufacturing set up. Critically study their maintenance planning and scheduling activities. Explain what linkages the maintenance department has on its production or sales activities while planning and scheduling takes place?

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3.3 MAINTENANCE PLANNING

Planning in the context of maintenance means the process by which all the elements required to perform a task are determined and prepared prior to starting the job (Figure 3.3). Planning is a process of detailed analysis that determines and describes the work to be performed, the sequence of associated tasks, methods to be used for their performance, and the required resources – including skills , crew size, man-hours, parts, special tools, and equipment, and an estimate of total cost. It also includes identification of safety precautions, required permits, communication requirement, and reference documents such as drawings and wiring diagrams. It addresses essential preparation, execution and start-up efforts. Work estimates (the setting of job duration and labor estimates) and activation of required procurements, are parts of the planning process.

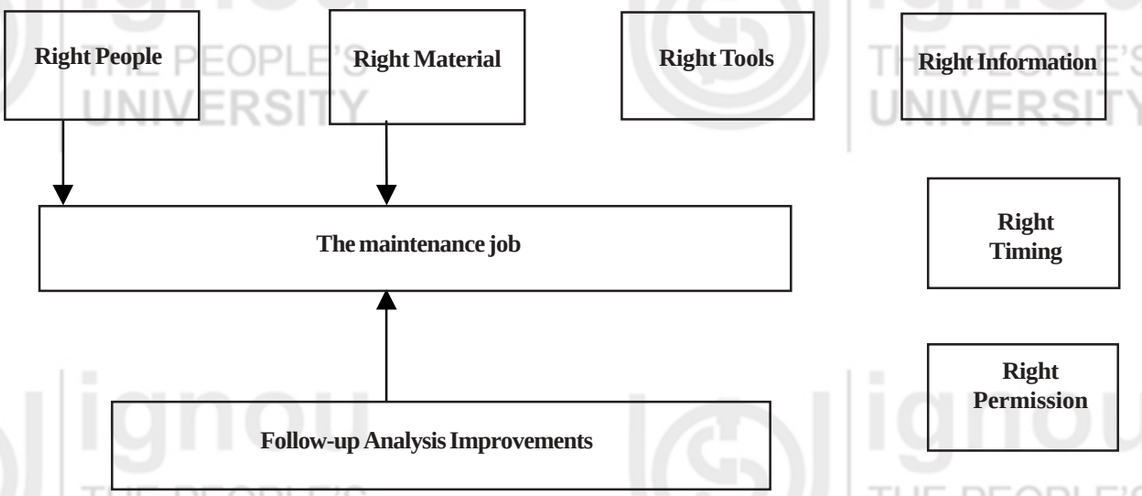

Figure 3.3 : Role of Planning

Basic maintenance planning principles are as follows:

i) The planners are organized into a separate department from the craft maintenance crews to facilitate specializing in planning techniques as well as focusing on future work

ii) The Planning Department concentrates on future work (work that has not been started) in order to provide the Maintenance Department at least one week of work backlog that is planned, approved, and ready to execute. This backlog allows crews to work primarily on planned work. Crew supervisors handle the current day's work and problems. Any problems that arise after commencement of any job are resolved by the craft technicians or supervisors. After every job completion, feedback is given by the lead technician or supervisor to the Planning Department. The feedback consists of any problems, plan changes, or other helpful information so that future work plans and schedules might be improved. The planners ensure that feedback information gets properly filed to aid future work.

iii) The Planning Department maintains a simple, secure file system based on equipment tag numbers. The file system enables planners to utilize equipment data and information learned on previous work to prepare and improve work plans, especially on repetitive maintenance tasks. The majority of maintenance tasks are repetitive over a sufficient period of time. File cost information assists making repair or replace decisions. Supervisors and plant engineers are trained to access these files to gather information they need with minimal planner assistance.

iv) Planners use personal experience and file information to develop work plans to avoid anticipated work delays and quality or safety problems. As a minimum, planners are experienced, top level technician that are trained in planning techniques.

v) The Planning Department recognizes the skill of the crafts. In general, the planner's responsibility is "what" and the craft technician's responsibility is "how". The planner determines the scope of the work request including clarification of the originator's intent where necessary.(Work requiring engineering is sent to plant engineering before planning). The planner then plans the general strategy of the work (such as repair or replace). The craft technicians use their expertise to determine how to make the specified repair or replacement. This arrangement does not preclude the planners from being helpful by attaching procedures from the file for reference.

vi) Wrench time is the primary measure of workforce efficiency and of planning and scheduling effectiveness. Wrench time is proportion of available-to-work time during which craft persons are not being kept from productively working of a job site by delays such as waiting for assignment clearance, parts, tools, instructors travel, coordination with other crafts or equipment information. Work that is planned before assignment reduces unnecessary delays during jobs and work that is scheduled reduces delays between jobs.

The planning process comprises all the functions related to the preparation of the work order, bill of material, purchase requisition, necessary drawings, labor planning sheet, job standards, and all the data needed prior to scheduling and releasing the work order. An effective planning procedure should include the following steps:

i) Determine the job content (may require site visits)

ii) Develop a work plan. This gives the sequence of activities in the job and establishing the best methods and procedures to accomplish the job

iii) Establish crew size for the job

iv) Plan and order parts and material

v) Check if special equipment and tools are needed and obtain them

vi) Assign workers with appropriate skills

vii) Review safety procedures

viii) Set priorities(emergency, urgent, routine and scheduled) for all maintenance work.

Table 3.1 explain the priorities used for maintenance work

ix) Assign cost accounts

x) Complete the work order

xi) Review the backlog and develop plans for controlling it

xii) Predict the maintenance load using an effective forecasting technique.

Table 3.1 : Priorities used for Maintenance Work

Priority Code	Priority Name	Time frame work should start	Type of work
1.	Emergency	Work should start immediately	Work that has an immediate effect on safety, environment, quality, or will shutdown the operation.
2.	Urgent	Work should start within 24 hours	Work that is likely to have an impact on safety, environment, quality, or will shutdown the operation.
3.	Routine	Work should start within 48 hours	Work that is likely to impact the production within a week
4.	Scheduled	As scheduled	Preventive maintenance and routine, all programmed work
5.	Postponable	Work should start when resources are available or at shutdown period.	Work that does not have an immediate impact on safety, health, environment, or the production operations

The maintenance work order usually does not provide enough space to perform the details of planning for extensive repairs, overhauls, or large maintenance projects. In such case where the maintenance job is large and requires more than 20 hours, it is useful to complete a maintenance planning sheet (Figure 3.4). In the maintenance planning sheet, the work is broken down into elements. For each element, the crew size and the standard times are determined. Then, the content of the planning sheet is transferred to one or more work orders. In filling out the planning sheet or the work order, the planer must utilize all the expertise available in the maintenance department. Thus, consultations with supervisors, foremen, plant engineers, and workers should be available and very well coordinated. Therefore, the planning and scheduling job requires a person with the following qualifications:

i) Full familiarity with the production methods used throughout the plant

ii) Sufficient experience to enable him/her to estimate labor, material, and equipment needed to fill the work order

iii) Excellent communication skills

iv) Familiarity with planning and scheduling tools

v) Preferably with some technical qualification.

Sheet ..... of			Filled by		Date	
Equipment Identification No.:			Approval		Priority	
No.	Completion Date	Work Order No.	Unit	Work Description	Crafts	Estimated time

Figure 3.4 : Maintenance Planning Sheet

The planning office should be centrally located and its organization will depend on the size of the company.

The planning process can be divided into three basic levels, depending on the planning horizon:

i) Long range planning (covers a period of 5 years or more)

ii) Medium range planning (1-month to 1-year plans)

iii) Short range planning (daily and weekly plans).

For long and medium range planning, the planner needs to utilize the following methods-

i) Sound forecasting methods to estimate the maintenance load

ii) Reliable job standard times to estimate staffing requirements

iii) Aggregate planning tools such as linear programming to determine resource requirements.

The long-range plan covers a period of 3 to 5 years and sets plans for future activities and long-range improvements. The medium- range plan covers a period of 1 month to 1 year. The plan will specify how the maintenance workforce will operate and will provide details for major overhauls, construction jobs, preventive maintenance plans, plant shutdowns, and vacation planning. This plan balances the need for staffing over the period covered and estimates required spare parts and material acquisition. Short-range planning concerns periods of 1 day to 1 week. It focuses on the determination of all the elements required to perform industrial tasks in advance.

Activity C

What do you mean by maintenance planning? What considerations are important in planning stage looking ahead that it should not create any hindrance in scheduling?

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3.4 MAINTENANCE SCHEDULING

Maintenance scheduling is the process by which jobs are matched with resources and sequenced to be executed at certain points in time. Basic maintenance scheduling principles are as follows:

i) Job plans providing number of persons required, lowest required craft skill level, craft work hours per skill level and job duration information are necessary for advance scheduling.

ii) Weekly and daily schedules must be adhered to as closely as possible. Proper priorities must be placed on new work orders to prevent undue interruption of these schedules.

iii) A scheduler develops a one week schedule for each crew based on a craft hours available forecast that shows highest skill levels available, job priorities, and information from job plans.

iv) The one week schedule assigns work for every available work hour. The schedule allows for emergencies and high priority, reactive jobs by scheduling a

sufficient amount of work hours on easily interrupted tasks. Preference is given to completing higher priority work by under-utilizing available skill levels over completing lower priority work

v) The crew supervisor develops a daily schedule one day in advance using current job progress, the one week schedule and new high priority, reactive jobs as a guide. The crew supervisor matches personnel skills and tasks. The crew supervisor handles the current day's work and problems even to rescheduling the entire crew for emergencies.

vi) Wrench time is the primary measure of work force efficiency and of planning and scheduling effectiveness. Work that is planned before assignment reduces unnecessary delays during jobs and work that is scheduled reduces delays between jobs. Schedule compliance is the measure of adherence to the one week schedule and its effectiveness.

A reliable schedule must take into consideration the following-

i) A job priority ranking that reflects the urgency and the criticality of the job

ii) Whether all the materials needed for the work order are in the plant (if not, the work order should not be scheduled)

iii) The production master schedule and close coordination with operation

iv) Realistic estimate and what is likely to happen rather than what scheduler desires

v) Flexibility in the schedule (the scheduler must realize that flexibility is needed, especially in maintenance; the schedule is often revised and updated).

Planning the maintenance work is a prerequisite for sound scheduling. In all types of maintenance work, the following are necessary requirements for effective scheduling:

i) Written work orders that are derived from a well-conceived planning process. The work order should explain precisely the work to be done, the methods to be followed, the crafts needed, spare parts needed, and priority.

ii) Time standards that are based on work measurement techniques

iii) Information about craft availability for each shift

iv) Stock of spare parts and information on restocking

v) Information on the availability of special equipment and tools necessary for maintenance work

vi) Access to the plant production schedule and knowledge about when the facilities will be available for service without interrupting the production schedule

vii) Well defined priorities for the maintenance work. These priorities must be developed through close coordination between maintenance and production

viii) Information about jobs already scheduled that are behind schedule (backlogs).

The scheduling procedure should include the following steps:

i) Sort out backlog work orders by crafts

ii) Arrange orders by priority

iii) Compile a list of completed and carryover jobs

iv) Consider job duration, location, travel distance, and the possibility of combining jobs in the same area

v) Schedule multi-craft jobs to start at the beginning of every shift

vi) Issue a daily schedule (except for project and construction work)

vii) Authorise a supervisor to make work assignments.

The maintenance schedule can be prepared at three levels, depending on the horizon of the schedule:

i) The long-range or master schedule, covering a period of 3 months to 1 year,

ii) the weekly covering one week, and

iii) the daily schedule covering the work to be completed each day.

The long-range schedule is based on existing maintenance work orders, including blanket work orders, backlog, preventive maintenance, and anticipated emergency maintenance. It should balance long-term demand for maintenance work with available resources. Based on; long-term schedule, requirements for spare parts and material could be identified and ordered in advance. The long-range schedule is usually subject to revisions and updating to reflect changes in plans and realized maintenance work.

The weekly maintenance schedule is generated from the long-range schedule and takes into account current operations schedules and economic considerations. The weekly schedule should allow for about 10% to 15% of the workforce to be available for the emergency work. The planner should provide the schedule for the current week and the following week, taking into consideration the available backlog. The work orders that are scheduled for the current week are sequenced based on priority. Critical path analysis and integer programming are techniques that can be used to generate a schedule. In most small and medium sized companies, scheduling is performed based on heuristic rules and experience.

The daily schedule is generated from the weekly schedule and is usually prepared the day before. This schedule is frequently interrupted to perform emergency maintenance. The established priorities are used to schedule the jobs. In some organizations, the schedule is handed to the area supervisor, who assigns the work according to the established priority.

Activity D

Visit a maintenance department. Prepare a weekly maintenance schedule for the manufacturing set up. Explain how your weekly schedule has implications for long range scheduling *i.e.* 3 month maintenance scheduling.

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3.5 SUMMARY

Planning and scheduling are the most important aspects of sound maintenance management. Planning is the process by which elements required to perform a task are determined in advance of the job start time. Scheduling deals with specific time and phasing of planned jobs together with the orders to perform the work, monitoring the work, controlling it, and reporting on job progress. Effective planning and scheduling contribute significantly to reduced maintenance costs, improved utilization of work-force and improved quality of maintenance. An essential part of planning and scheduling is to forecast future maintenance workload. Methodology for forecasting and analyzing the maintenance workload of a plant has been discussed. Planning process is a prerequisite for scheduling. Basic principles and elements of effective planning have been discussed. This is followed by a description of scheduling.

3.6 KEY WORDS

Planning: It is the process by which elements required to perform a task are determined in advance of the job start time.

Scheduling: It deals with specific time and phasing of planned jobs together with the orders to perform the work, monitoring the work, controlling it, and reporting on job progress.

3.7 SELF ASSESSMENT QUESTIONS

1) What do you understand by maintenance planning and scheduling?
2) How can Unit Criticality be classified?
3) What are the maintenance scheduling characteristics?
4) What do you understand by maintenance windows?
5) How can you forecast and analyze the maintenance workload of any plant?
6) What are the basic principles of maintenance planning?
7) What are the steps in effective planning procedure?
8) What should be the qualifications for a good planner and scheduler?
9) Explain the basic levels of planning commonly used?
10) What are the methods used in long and medium range planning?
11) How are the priorities specified for maintenance work?
12) What are the basic principles of scheduling?
13) What are the necessary requirements of effective scheduling?
14) What are the considerations for a reliable schedule?

3.8 BIBLIOGRAPHY AND SUGGESTED READINGS

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