CHAPTER II

THEORITICAL CONSIDERATIONS

This chapter discusses theoretical aspects which include tools, techniques and rules which can be applied to project management effectively. Special emphasis will be given to repetitive manufacturing project.

2.1 Project Management

A project may be defined as a one-time definable start and completion activity with a well-defined set of desired end results as its objectives. Every project has some elements that are unique. It must be carefully planned/coordinated with several management techniques to achieve these desired objectives.

Project management is the overall planning, co-ordination and control of a project team from inception to completion, aimed at ensuring its completion on time, within the budget, and to achieve the intended technical requirement of form, quality performance. Project management is a blend of art and science: the art of getting things done through and with people in formally organized groups; and the science of handle large amounts of data to plan and control so that project duration and cost are balanced, excessive and disruptive demands on scarce resource are avoided.

2.1.1 Project Management Techniques

There are many project management techniques which can be applied in different situations such as network planning, Program Evaluation and Review Technique (PERT), Line of Balance (LOB), etc..

Network planning technique presents in diagrammatic forms all the activities, which must be carried out, and their mutual time dependencies. Network diagram is simple and effective for communicating complex activity relationships. It also serves as a basis for the calculation of work schedules and provides a mechanism for controlling project time as the work progresses. Network planning can be classified into two major groups namely Activity-on-Arrow (AOA) and Activity-on-Node (AON) systems as will be discussed later.

PERT is based on network planning technique also. But it uses probabilistic activity-time estimates to aid in determining the probability that a project could be completed by a given time. It has primarily been employed for research and development projects.

LOB is a management-oriented graphic charting technique for scheduling, monitoring, controlling and presenting progress against established targets, relating to time and accomplishment. It is an appropriate technique for the steady state of repetitive production activities to deliver a quantity of the completed products according to schedule. LOB graphically depicts the cumulative results for repetitive processes which have been completed as of the progress review date.

2.1.2 Project Management Techniques for Repetitive Manufacturing

There are some projects, such as manufacturing project, in which a predominant feature is that of repetition. Batch production in repetitive manufacturing project traditionally proceeds in a series of discrete steps - that is, the work on the whole batch being completed in any one stage before the batch is passed to the next stage.

For this type of project, control is always lost during the transition phase between one-time planning activity and repetitive activities of production. Therefore, the PERT/LOB technique is developed to effectively manage this type of project.

In the past, there was no effective management approach to be applied during the transition from the phase of development to production. Because transition phase, which contains both one-time activity of development and repetitive activities of production, is difficult for either PERT or LOB to handle effectively. Thereby, some of the effectiveness of planning and control system is generally lost during this transition phase. For this reason, the technique of PERT/LOB was developed to provide better control during the critical transition phase.

PERT has proved successful mainly in planning and controlling a large, complex project of a non-repetitive nature, such as construction; and, whereas, LOB has proved to be a successful and effective management tool for steady state production activities. PERT/LOB is a technique, which integrates the planning elements of PERT with the control element of LOB. It aims to provide closed project control during the transition phase by allowing inclusion of repetitive activities in the network.

In the case of non-repetitive activities, PERT/LOB is equivalent to the basic PERT technique but, in the case of repetitive activities, PERT/LOB is equivalent to the basic LOB technique. Hence, it is possible to use PERT for planning and then to employ LOB for controlling sub-sequential batch production. The integration of PERT/LOB greatly extends the potential of PERT and LOB for planning and control. The application of PERT/LOB is not limited to simply transition phase. But it is applicable wherever and whenever PERT or LOB can be employed.

2.2 Work Breakdown Structure

Work Breakdown Structure (WBS) is a systematic and disciplined approach for breaking down a project into its many components and sub-components. The work of a project is divided and subdivided through increasing levels of details rather than breaking the work into a low level of details in a single step.

Developing the work definition in a structured way provides better results in management and control. It provides a clear picture of the work elements to be performed. Thereby, WBS may be considered as the backbone of the project management. It is a primary tool which can provide the coordinating framework necessary to integrate all the different forms of information in a project. WBS can be used to ensure that equal emphasis is given to work in different areas.

With WBS, every activity which must be carried out to complete the project, is listed in a systematic, hierarchical, and structured way. Hence, the project manager is able to visualize the whole project altogether - with all of its major sub-projects including minor activities and their interrelationships - in merely a single project activity diagram. WBS can also be used as the basis for making estimates of either task durations or costs.

The project can be logically subdivided by considering many categories such as location, company departments, technical requirements, project phase, task and so on. However, the three basic structures for WBS are Organizational Structure, Product Structure and Process Structure.

1) Organizational Structure

Organizational Structure breaks the project organization down into teams which are involved in the project similar to an organization chart. However, it is different in that it focuses on the work to be performed in each organization and on inputs to the project from each organization. The organizational structure implies the flow of the process and the development of the final product. Therefore, it is excellent for organizational changes.

2) Product Structure

Product Structure breaks the work into packages similar to that of Bill of Material (BOM). It is an appropriate structure for hardware items. The structure starts with the final product and then breaks into its major components and sub-components, respectively. This breakdown continues into the parts. This structure implies organizational responsibility and the time-phasing of the workers. It is excellent for emphasis on quality.

3) Process Structure

Process Structure breaks the work into time phase. It uses the list of all work on assemblies, sub-assemblies, components and parts in each phase to highlight where each work is taking place in the process. Thereby, this structure implies organizational responsibility and the structure of the product. Process structure is excellent for emphasis on schedule.

In practice, the different structures are not mutually exclusive. A WBS can incorporate one of the others. There is no universal agreement on labels applied to the level in a WBS. For military, the term "programme". is typically used to refer to an exceptionally large, long-range objective, which is broken down into a set of "projects". Next, these projects are further subdivided into "tasks", which are, in turn, split again into "packages" which are themselves comprised of "work units".

There is no right or wrong WBS. A structure may fit perfectly for one discipline but it also may be an awkward burden for another. Experience is the significant factor to structure the project task. Translation of tasks from the WBS to the network diagram can be nearly one for one, if the WBS is carefully constructed.

WBS must include the whole project. It should start with the whole project and then breaking down these overall tasks into tasks with little missing as possible. The proper level of details in WBS would be to make each work package small enough to be considered as a separate work element for the activity duration estimating purposes. Generally, the selected task should be similar in time scales. However, all primary items do not have to be broken down to the same level of details. The more broken down the tasks, the shorter the durations. Besides an activity duration should be related to the update cycle. The lowest level should be appropriate for not only estimating but also for controlling by considering many factors such as the present stage in the project management life cycle, the type, size and duration of the project, the requirement of effective control.

It is useful to identify each element in the WBS by a short but informative and unambiguous description, in order that all participants are able to understand which parts of the project this specific element represents. Although the length of the description may be restricted, the meaning must be clear. When the element description is not clear enough, much confusion always occurs. Misunderstanding of the work element content causes problems in assessing durations, and progress monitoring becomes confused. For these reasons, the activity descriptions, which are defined, must be capable of explaining as much as possible about the work. Additional notes may be used if it is necessary.

WBS can take a wide variety of forms , which in turn, serve a wide variety of purposes. WBS may be described as a hierarchy structure, which is designed to logically subdivide all the work elements of the project into a graphical presentation as a vertical tree diagram.

WBS can be in the form of an indented outline which uses the indentation to signify levels of the WBS - with the first level tasks being at the left most, and successive level appropriately indented. When using an out-line, a plan can be created starting with main sections of the work. Then each section is broken down into subsections, which are further broken down into subsections and so on. Then activities are grouped into headings and subsections. The whole plan can be shown in all its details, or some sections within their headings may be collapsed to show merely a heading level. This method is convenient and enables the report to be concentrated on a certain aspect of the project. The suitable report for high level management can be produced as a summary of the whole project by collapsing all tasks into their headings.

2.3 Network Planning System

Since a project containing a number of activities is very difficult to manage, the risk of overlooking some which are tasks necessary to complete a project is high. Therefore, tasks made up the project and their technological dependencies upon one another should be defined and shown explicitly in the form of a network diagram. It is necessary to list all the tasks in the sequence of time and to determine those that can be carried out simultaneously and those that must be carried out sequentially. The identification of the project tasks and their interconnections requires a thorough analysis of the project and many decisions regarding the resources requirement and the sequence of the various elements of the projects.

The whole project should be represented by a hierarchy of network levels, with increasing details but the scopes decrease as the control descends the hierarchy. Different levels of the network are employed by different users. A network of several hundred tasks reduced into one of a few dozen activities, as a summarized picture of the project, may be presented for review by top management, a customer, or other interested audience.

Which tasks should be included in the network and which tasks should be left out or combined with others are normal problems for project planners. The useful guidance is that the need of the user to know when one task has finished and the other has started. For instance, if the user needs to know when activity A has finished and activity B has started so as to take an action or to make a decision, the network could be diagramed as in Figure. 2.1.

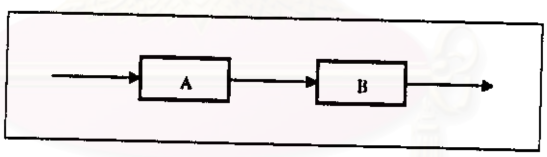

Figure 2.1 *Both start and finish of A and B are of concern*

On the other hand if the user is simply interested in the completion of the A+B pair, a single node should be represented as Figure. 2.2.

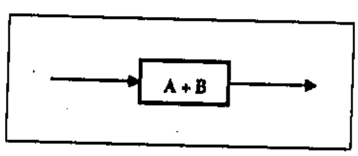

Figure 2.2 *Only completion of A+B is of concern*

Task duration should relate to the update cycle. Listing of tasks with durations which merely amount to a very small fraction of the overall expected time scales should be avoided, particularly, if they do not require resources. In case of the very short activity, it will be difficult to determine what is critical for completion. Conversely, if the activity is much too long, there almost will be no change when reporting progress.

For these reasons, the concepts of expanding and condensing tasks as mentioned earlier are beneficial in improving accuracy and in eliminating excessive details in the development of the detailed network.

2.3.1 Ladder Technique

Some types of project may comprise long series of repetitive tasks which entail many parallel strings of continuing operation. These repetitive tasks must proceed simultaneously with one another.

The concept of "Ladder Technique" for representing task - which one is dependent upon a continual flow of work or information from the others - is suitable for repetitive projects. Since considering a whole project as an integration of many sub-projects is convenient to build up a complex plan from smaller parts. Therefore, project with repetitive tasks is appropriate to be viewed as the integration of many sub-projects or smaller batches. With the ladder technique, which breaks down the whole project into many smaller sub-projects, task of the second sub-project can start before the first sub-project is completed by overlapping tasks. The network planning with ladder technique is shown in Figure 2.3.

With the concept of ladder technique, a plan for repetitive tasks could be made for each batch or lot size, which can range from a single unit to the entire production quantity. The consideration of the batch size should involve the required number of items, processing time, line balancing, resource availability and other factors.

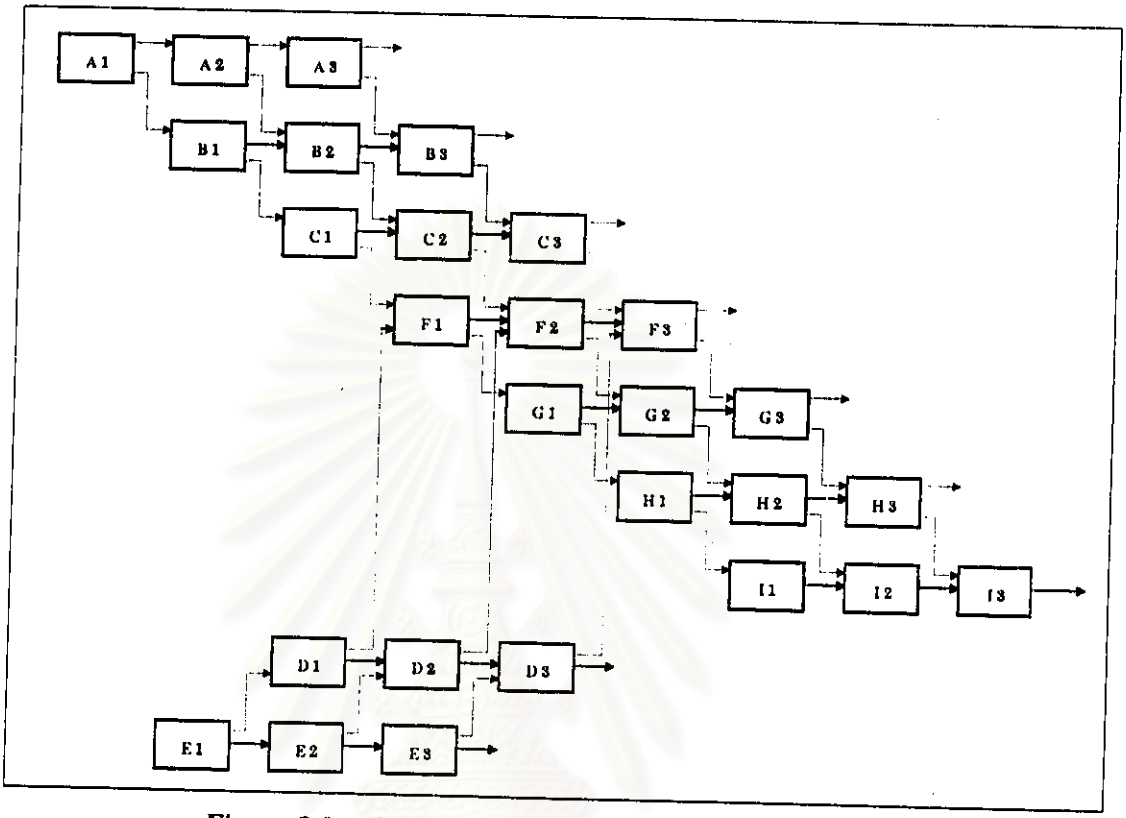

Figure 2.3 Network planning with the ladder technique

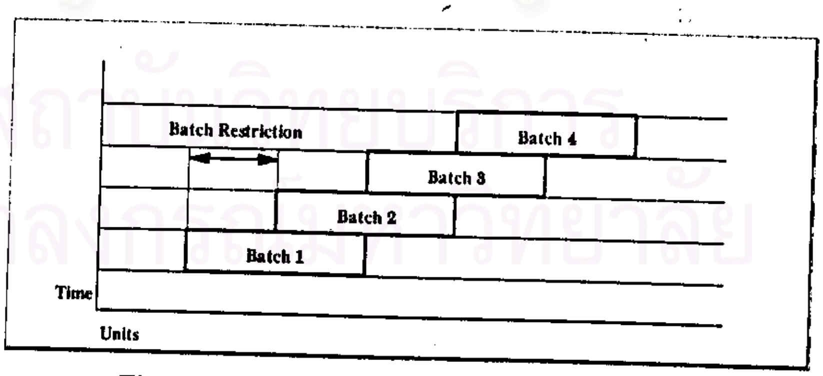

Figure 2.4 Overlapping batch planning

Besides it should be taken into account the elapsed time for each batch or the minimum time between successive batches, too. This time between batches is called "batch restriction", because it obviously restricts the start of the successive task as shown in Figure 2.4. Determination of the batch restriction should include the set up time, material availability, storage space, capacity limitation and so on also.

2.3.2 Activity-on-Arrow and Activity-on-Node System

There are two major groups of network planning system namely Activity-on-Arrow (AOA) and Activity-on-Node (AON) system.

The Activity-on-Arrow system, or merely called arrow network or sometimes referred to as arrow diagraming method or the i, j method, uses arrows to represent tasks and uses nodes as event to link tasks. Arrow networks tend to be the more widely used because it has been introduced since 1950s for the early work.

Another family of networking systems is well known as Activity-on-Node system. One of the first proponents, J.W. Fondahl of Stanford University had developed the AON scheme in 1958 almost simultaneous with the publication of the first AOA reports. However AOA is more popular because of earlier publication.

AON network notation is the complete reverse of the arrow scheme. It graphically represents the activity by a node usually drawn as a rectangle or a box instead of an arrow. While, the logical dependencies of one activity upon another is shown by an arrow linking the two nodes together. Arrow heads show the direction of the flow of activities and their precedence to one another.

The major advantage of the node scheme is the eliminating of need for special dummy* arrows to correct false dependencies, which always occur in the arrow and event schemes of AOA due to difficulties in learning to appropriately use of dummies. All the arrows in the node scheme are dummies in effect, there are not subtle false dependency problems requiring the use of special dummies. This advantage makes the scheme not only more efficient but also easier to learn. Besides, it is more natural to represent work with a box. Drawing AON network is more flexible. All boxes can be drawn on one page and then the logical dependencies are linked later. While this is impossible for the arrow network because the activities must be defined by two nodes.

2.3.3 Precedence Diagraming System

An important extension to the original AON concept appeared around 1964 in the Users Manual for an IBM 1440 Computer Program. J. David Graig, one of the principal authors of this technique, first used the term "Precedence Diagraming Method" (PDM) to refer this node scheme. In the present, PDM is accepted by many as the most effective of the network planning techniques currently being used. Moreover PDM is gaining wider preference, popularity and acceptance among project management software manufacturers.

PDM provides both a graphical portrayal of the interrelationships among the elements of a project and an arithmetic procedure, which identify the relative importance of each element in the over all schedule. PDM uses the AON diagraming technique to provide clear illustration of activities whose starts and finishes are not coincident with the starts and finishes of their immediate

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* Dummy is a logical link, a constraint which represents no specific operation. In calculations it is most usefully regarded as an activity which absorbs neither resources nor time. Dummy is usually represented by broken arrow.

predecessors and successors. It is capable of showing activities which should be allowed to overlap each other or, conversely, must be separated by a time delay on many specified a "lag time" associated with precedence relationship. Similar to the traditional AON scheme, PDM uses a box to represent an activity. The size of box bares has no relationship to duration. It is not necessary to be a box, other figures such as triangle, circle, pentagon and so on can be used also, but boxes are the norm.

The sequence of activities and their logical dependencies are represented by arrow connecting the nodes together to show how they depend on each other. The length of the arrow has no significance because it indicates merely the dependency of one task to another. The flow of time is typically from left to right. PDM does not need to use event except to represent situations where there are more than one "start" or more than one "finish" activity by employing two "collector" nodes, a "start" node and a "finish" node to show the start and the end of the entire project.

In PDM convention, the left-hand end of the box represents the start of the activity while the right-hand end represents the finish of the activity. The "exit" and "entry" position of the arrows from and into the nodes have no any special significance in the traditional AON scheme. On the other hand, these positions are extremely important in PDM.

The traditional network system both AOA and AON is based on two vital assumptions. One is that a task can not start until all of its immediate predecessors have been completed or linked in a Finish-to-Start relationship. The other is that once all preceding activities have been finished, the following activities start immediately thereafter.

But in practice, not everything in the real world is as simple as this relationship. Sometimes it is not necessary to wait for an activity to be finished before starting the next. The following activity, frequently, can be started after starting an activity and waiting a bit and, then, the two activities are carried out in parallel. For instance in a pipe laying project, after having started the digging task for a few days, the pipe laying can be started. Then they are working always in parallel. For this reason, the conventional AOA and AON modeling techniques do not really duplicate real-life situations. In the real world, overlapping activities always take place whenever it is possible to start a job after a certain percentage of the preceding activity has been completed or a certain duration has been passed. To represent these "overlapping" activities, modifications to PDM were developed.

PDM scheme is especially designed to represent overlapping activities and should be employed when these relationships are expected to occur frequently in the project. Since, besides the basic Finish-to-Start dependency relationship in the traditional network system, PDM extends the simple logic of the basic node scheme to four types of logical dependency between activities, namely Finish-to-Start (FS), Finish-to-Finish (FF), Start-to-Start (SS) and Start-to-Finish (SF) dependency relationships. With these relationships, PDM is much different from traditional network, which shows the dependency relationship among the project activities by employing only simple logic that all activities preceding a given activity must be completed before the given activity may begin. Hence, the activity can be linked together in many logical dependency relationships. Sometimes these logic links maybe referred to as constraints because they impose a constraint on the start or finish of the task to which they are connected. The meaning of these constraints can be described as follows:

1) Finish-to-Start (FS) :

The FS constraint is the most common relationship which is used in the traditional network plan. It represents the relationship between the finish of an activity and start of another. The start of a successor is constrained by the finish of a predecessor. The following activity can not start until the preceding activity is finished.

2) Start-to-Start (SS) :

This constraint links the relationship between the start of the two activities. The start of a successor is constrained by the start of a predecessor. But the finish of the predecessor is not important to the successor. The following activity can not start until the preceding activity has started regardless of when either is finished.

3) Finish-to-Finish (FF) :

This type of constraint is capable of linking the relationship between the finish of the two activities. The finish of a successor is constrained by the finish of a predecessor. The following activity can not finish until the preceding activity is finished regardless of when either is started.

4) Start-to-Finish (SF) :

This constraint represents the relationship of the start of the preceding activity and the finish of the following activity. The finish of a successor is constrained by the start of a predecessor. The following activity can not finish until the preceding has started. However, a serious need for SF relationship is rare.

Furthermore, PDM also employs "hammock activity" to facilitate the network. Hammock is an activity for which there is no work out for the duration. It is used to link into the plan at relevant points without specifying the durations. The durations of hammocks themselves are deduced by calculating the timing of all non-hammock activities. Hence, a hammock can fill up all the time available between its start and finish. It is used to summarize a number of activities into one activity and is useful for milestone reporting to senior management who simply wants to know the important issues at a summary level. A sample of hammock activity is shown in Figure 2.5.

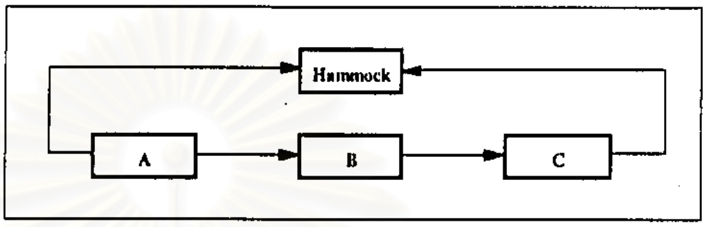

Figure 2.5 *Hammock activity*

However, the dependencies connecting the activities in PDM usually have zero duration. The addition of lead/lag times or positive or negative duration to these precedence relationships offers more flexibility to this approach. Lead is the amount of time by which one activity precedes the following activity. Lag is the amount of time by which one activity follows the preceding activity. These delays are called lead time before the activity and lag time after the activity. A predecessor leads a successor but a successor lags a predecessor. With lead and lag time, the delay may be added to the start or finish of an activity to further develop the more realistic relationship of dependency for more complex situations in a more accurate way. All constraints and their lag time are depicted in Figure. 2.6.

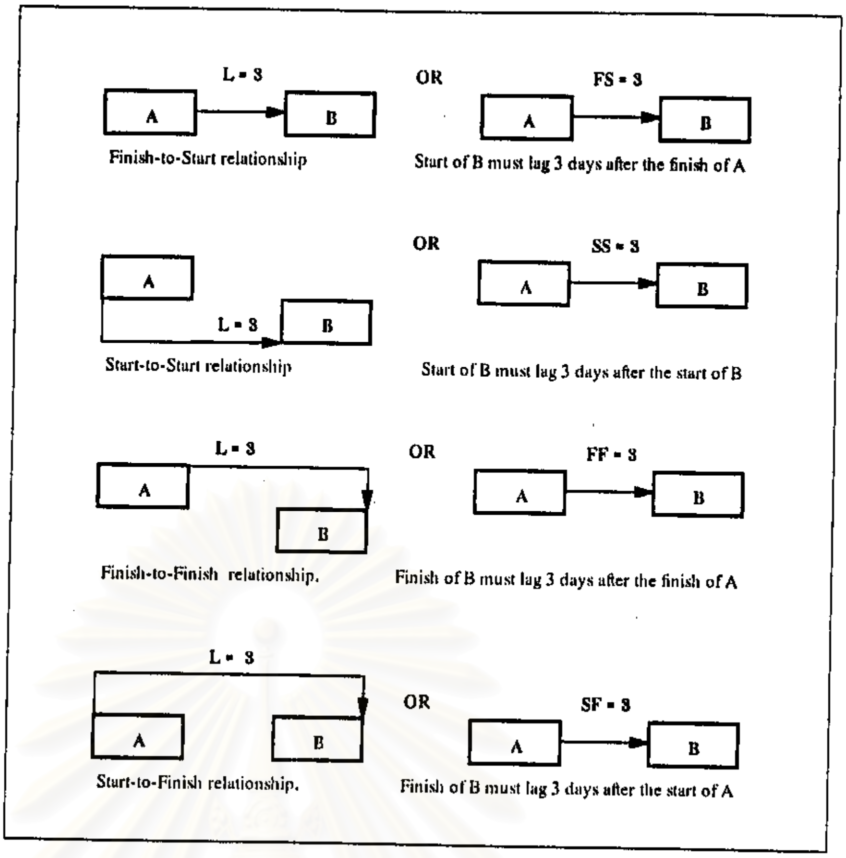

Figure 2.6 *PDM dependency relationships with their lag time*

In practice, all of these relationships must be mixed up together in the precedence diagram to build up the most effective plan. FF and SS constraints are the most natural and allow overlaps of succeeding work elements in time. They always can be used to represent a fast tracking type of situations in which the project duration is compressed by concurrent working of the activities.

Since these four dependency relationships as constraints are interchangeable They give the same result by changing lead/lag time. However, generally there is only one relationship which is the easiest to understand and to be employed in practice. In order to assign the best relationship to this study, three cases are applied to illustrate criteria for selecting the type of constraint for each task as follows:

CASE 1: Overlap allowed; Duration of predecessor is shorter than successor.

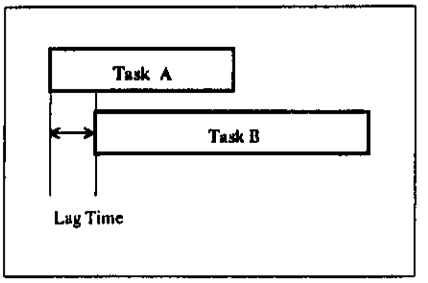

Figure 2.7 *Overlap allowed; duration of predecessor is shorter than successor*

Refer to Figure 2.7, Task A is predecessor of Task B. With the same batch size in repetitive manufacturing, duration of Task A is shorter than Task B. That means Task A is faster than Task B. Therefore, in practice Task B can start immediately after Task A delivers one unit of intermediate product to it. After that Task B can work continuously without interruption until the whole batch is completed. Because, Task A which is faster can deliver its work to Task B in time.

With this situation, Task B can not start until Task A has started and Task B must finish after the finish of Task A by nature because of the longer duration of Task B. That means the start of Task B is constrained by the start of Task A regardless of the finish time. Therefore, Task B should be linked to Task A with SS constraint.

The lag time of SS constraint should at least be equal to the processing time for one intermediate product of Task A in order to allow Task A to have time to work on the first unit before delivering to Task B. However, this minimum lag time is less flexible and high in risk in that project may not be able to start Task B as planned because Task A must start and work exactly as planned.

CASE 2 : Overlap allowed; duration of predecessor is longer than successor.

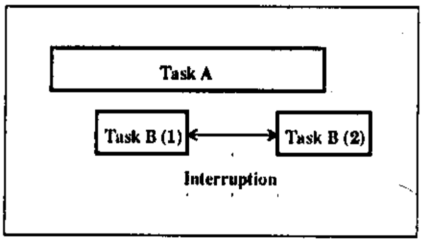

Figure 2.8 *Overlap and split allowed; duration of predecessor is longer than successor*

From Figure 2.8, Task A is a predecessor of Task B. With the same batch size, the duration of Task A is longer than of Task B. Because Task B is faster than Task A.

In practice, Task B should not start immediately after Task A has delivered one unit of work to it. Because, in this case, after finishing work on the first intermediate product, Task B must be stopped or interrupted as shown in Figure 2.8. Task A, which is slower, cannot deliver its work to Task B in time. Therefore with this planning approach, there are many periods of interruption during Task B. Task B must alternately work and stop. This working method is difficult to monitor and control. Furthermore, there are many disadvantages, especially for the set-up process.

For this reason, Task B should be linked to Task A with FF constraint in order to allow Task B to have enough intermediate products from Task A, as an work in progress inventory to work continuously without interruption as shown in Figure 2.9.

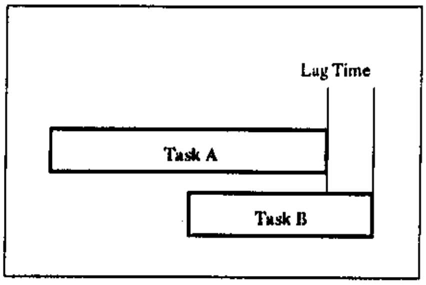

Figure 2.9 *Overlap and non-split allowed; duration of predecessor is longer than successor*

The lag time of FF constraint between Task A and Task B can be at least equal to the processing time for one unit of intermediate product of Task B in order to allow Task B to have time to work on the last unit. However, this lag time is less flexible and has a high risk of having no intermediate product from Task A to be delivered to Task B. Task B must be interrupted in the case of Task A being slower than estimate or Task B being faster than estimate. Therefore, this minimum lag time should be employed only when requiring to shorten project duration.

CASE 3 : Overlap not allowed; regardless of task duration

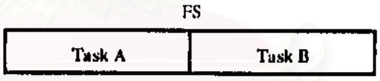

Figure 2.10 *Overlap not allowed; regardless of task duration*

Refer to 2.10, Task A is a predecessor of Task B. This case is the most common relationship. The start of Task B must begin after Task A finishes completely. That means the start of Task B is constrained by the finish of Task A. Therefore Task B is linked to Task A with FS dependency relationship. Task B can start immediately after Task A finishes completely.

In the case that there are more than one predecessors. The successor must be linked to every predecessor by considering each predecessor case by case.

2.3.4 Algorithm and Computational Procedure

PDM computational procedure consists of forward pass calculation and backward pass calculation. But it is considerably more complex than tradition network scheme.

Forward pass is carried out from left to right, in the direction of the flow of work, to calculate the early dates for each activity, in which it can be started or finished. Once the forward pass calculation is made, backward pass is made from right to left in logic network to calculate for the late dates, which are the latest start and finish dates each task can have without jeopardizing the project completion date.

Moreover, as a by-product, the computational procedure identifies the critical path through the network. It also indicates the amount of the float time associated with the non-critical path.

PDM planning can be classified into three fundamental cases - regarding the task splitting - as follows:

CASE I *: Activity splitting is not allowed on any activities.*

CASE II *: Activity splitting is allowed on all activities*

CASE II *: Combination of Case I and II; activity splitting is allowed merely on designated activities.*

The manual computational procedure, where activity splitting is allowed was developed by Keth C. Crandell, Professor of Civil Engineering, University of California, Berkeley, and published in 1973 (1973 : pp. 18-27, cited in Moder, Phillips and Davis, 1983). After that the version, in which the activity splitting is allowed, was also supplied by Crandall. However, nowadays these complex computational procedures are normally carried out by a computer, and there is no need to have a deep knowledge of the techniques.

For all of the above three cases, for forward pass calculations, INITIAL TIME is applied to prevent the situation in which the calculation gives negative start time. INITIAL TIME is set equal to zero, or else to an arbitrarily specified (non zero) project scheduled start time.

Similarly the backward pass computational procedure needs TERMINAL TIME to prevent the situation of a late finish time exceeding the scheduled project completion time. Generally TERMINAL TIME is set equal to the maximum of all activity early finish times.

The other nomenclatures and assumptions to be used in computational procedure are depicted in Figure2.11 and described as follows:

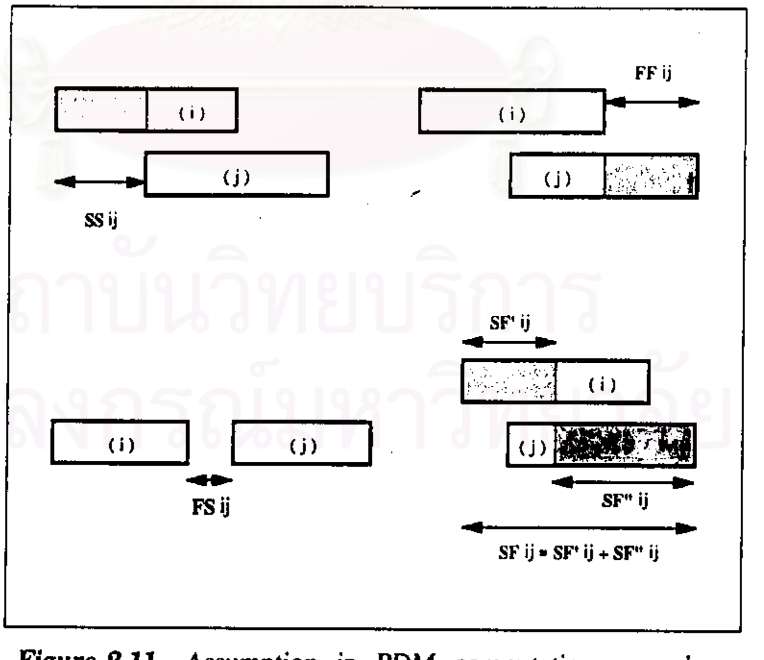

Figure 2.11 *Assumption in PDM computation procedure*

FS_{ij} denotes a finish-to-start constraint. It is equal to the minimum number of time units that must transpire from the completion of the predecessor (i) prior to the start of the successor (j).

SS_{ij} denotes a start-to-start constraint. It is equal to the minimum number of time units that must be completed on the preceding activity (i) prior to the start of the successor (j).

FF_{ij} denotes a finish-to-finish constraint. It is equal to the minimum number of time units that must remain to be completed on the successor (j) after the completion of the predecessor (i).

SF_{ij} denotes a start-to-finish constraint. It is equal to the minimum number of time units that must transpire from the start of the predecessor (i) to the completion of the successor (j).

CASE I : Activity splitting is not allowed on any activities.

Forward Pass Computational Procedure

The forward pass computational procedure consists of two steps, which are applied to each project activity in topological-consequences. The INITIAL TIME is required to be set equal to zero, or to an arbitrarily specified project scheduled start time. Then

Step 1 *: Compute the early start time of the activity (j) or* ES_j.

ES_j is the latest (maximum) of the set of start times including the INITIAL TIME and one start time computed from each constraint going to the activity (j) from predecessor activities indexed by (i).

$$ES_j = MAX_{all\ i} \begin{cases} \text{INITIAL TIME} \\ EF_i + FS_{ij} \\ ES_i + SS_{ij} \\ EF_i + FF_{ij} - D_i \\ ES_i + SF_{ij} - D_j \end{cases}$$

Step 2 : *Compute the early finish time of the activity (j) or EF_j.*

EF_j of each activity can be computed with the formula.

$$EF_j = ES_j + D_j$$

Backward Pass Computational Procedure

The backward pass computational procedure consists of two steps which are applied to each project activity in the reverse order of the above forward pass computational procedure as follows:

Step 1 : *Compute the late finish time of the activity (i) or LF_i.*

LF_i is the earliest (minimum) of the set of finish times including TERMINAL TIME and one finish time computed from each constraint going from activity (i) to successor activities indexed by (j).

$$LF_i = MIN_{all\ j} \begin{cases} \text{TERMINAL TIME} \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_j \\ LF_j - SF_{ij} + D_i \end{cases}$$

***Step 2** : Compute the late start time of the activity (i) or LS_i.*

LS_i of each activity can be computed with the formula.

$$LS_i = LF_i - D_i$$

CASE II : Activity splitting is allowed on all activities

Forward Pass Computational Procedure

The forward pass computational procedure, in the case where splitting allowed, consists of three steps with complete computational algorithms, which are applied to each project activity in topological sequences.

***Step 1** : Compute the early start time or ES_j of the activity (j)*

ES_j is the latest (maximum) of the set of start times including the INITIAL TIME and one start time computed from each start time constraint of the form FS_{ij} and SS_{ij}, going to activity j, from predecessor activities indexed by i.

$$ES_j = MAX_{all\ i} \begin{cases} \text{INITIAL TIME} \\ EF_i + FS_{ij} & \text{(for each } FS_{ij} \text{ constraint)} \\ EF_i - D_i + SS_{ij} & \text{(for each } SS_{ij} \text{ constraint with } \alpha_i < SS_{ij}) \\ ES_i + Ss_{ij} & \text{(for each } SS_{ij} \text{constraint with } \alpha_i \geq SS_{ij} \\ & \text{or where } \alpha_i \text{ was not required)} \end{cases}$$

***Step 2** : Compute the early finish time or EF_j of the activity (j)*

EF_j is the latest (maximum) of the set of finish times including the early start time plus the duration of the activity j ($ES_j + D_j$), and a finish time calculated from each finish-time constraint of the form FF_{ij}, or SF_{ij}, going to the activity j, from predecessor activities indexed by i.

$$EF_j = MAX_{all\ i} \begin{cases} ES_j + D_j & \\ EF_i + FF_{ij} & \text{(for each } FF_{ij} \text{ constraint)} \\ EF_i + D_j + SF_{ij} & \text{(for each } SF_{ij} \text{ constraint with } \propto_I < SF'_{ij}) \\ ES_i + SF_{ij} & \text{(for each } SF_{ij} \text{ constraint with } \propto_i \geq SF'_{ij} \\ & \text{or where } \propto_i \text{ was not required)} \end{cases}$$

Step 3 *: Compute* $\propto$ *for activity j if* $EF_j > ES_j + D_j$

$$\propto_i = \begin{cases} D_j - FF_{ij} & \text{if } EF_j \text{ was set by an } FF_{ij} \text{ constraint} \\ D_j - SF''_{ij} & \text{if } EF_j \text{ was set by an } SF_{ij} \text{ constraint} \end{cases}$$

Backward Pass Computational Procedure

The backward pass computational procedure in case where splitting allowed consists of three steps with complete computational algorithm, which are applied to each project activity in reverse topological sequences.

Step 1 *: Compute the late finish time of activity (i) or* LF_i

LF_i is the earliest (minimum) of the set of finish times including the TERMINAL TIME and a finish time calculated from each finish time constraint of the form FS_{ij} or FF_{ij}, going from activity i, to successor activities indexed by j.

$$LF_i = MIN_{all\ j} \begin{cases} \text{TERMINAL TIME} & \\ LS_j - FS_{ij} & \text{(for each } FS_{ij} \text{ constraint)} \\ LS_j + D_j - FF_{ij} & \text{(for each } FF_{ij} \text{ constraint with } \beta_j < FF_{ij}) \\ LF_j - FF_{ij} & \text{(for each } FF_{ij} \text{ constraint with } \beta_j \geq FF_{ij}, \\ & \text{or where } \beta_j \text{ was not required)} \end{cases}$$

***Step 2** : Compute the late start time of the activity (i) or LS_i*

LS_i is the latest (minimum) of the set of start times including the latest finish time minus the duration of activity i ($LF_i - D_i$), and a start time calculated from each start time constraint of the form SS_{ij} or SF_{ij}, going from activity i, to successor activities indexed by j.

$$LS_i = MIN_{\text{all } j} \begin{cases} LF_i - D_i & \\ LS_j - SS_{ij} & \text{(for each } SS_{ij} \text{ constraint)} \\ LS_j + D_j - SF_{ij} & \text{(for each } SF_{ij} \text{ constraint with } \beta_j < SF''_{ij}) \\ LF_j - SF_{ij} & \text{(for each SFij constraint with } \beta_j \geq SF''_{ij} \\ & \text{or where } \beta_j \text{ was not required)} \end{cases}$$

***Step 3** : Compute β for Activity i if $LS_i < LF_i - D_i$*

$$\beta_j = \begin{cases} D_i - SS_{ij} & \text{if } LS_i \text{ was set by an } SS_{ij} \text{ constraint} \\ D_i - SF_{ij} & \text{if } LS_i \text{ was set by an } SF_{ij} \text{ constraint} \end{cases}$$

CASE III : Activity splitting is allowed merely on designated activities

The computational procedure in this case only amounts to the application of the CASE I or the CASE II procedure to each activity, which in turn, depends on whether the activity is designated as one where splitting is not allowed, or is allowed, respectively.

2.4 Expected Resources and Activity Duration Estimates

Since the project planning is based on the best activity duration estimates, which are obtained for each activity, then the estimate of the resources and the duration required to perform each of the network activities should be carefully made.

Activity duration is the amount of time, which is most likely needed for completion of an activity. It means the elapsed time between the start of the activity and the end of the activity. It is assumed to be carried out in a "normal" way by "normal" man-powers under "normal" conditions by using a "normal" level of resources, which will be available for each activity throughout the project. The normal efficiency of the workforce also must be carefully taken into account, because people always take time off or work at the reduced efficiency for a variety of reasons such as illness, machine breakdown, idle time through poor work scheduling, etc. An estimate made for a skilled workforce would be very different to that of an unskilled workforce due to learning ability. Therefore the allowance for these factors should be added to identify the actual duration. Besides, machine capacity and machine loading must be considered.

The objective in obtaining time estimate should be to get the most realistic one. The times assigned to activities must be realistic by taking into account all local circumstances. Then, it is quite inappropriate to use the standard time from work study, because most actual work do not performed at the standard conditions. In this case, "actual" or "observed" times are much more appropriate.

Besides, the estimate should provide the prerequisite information at an acceptable accuracy. The degree of estimating accuracy achieved can determine not only the element of risk taken in planning and scheduling of any project but also the effectiveness of subsequent working and resource schedules. That means the accuracy of the scheduling information, which is received from the network, is proportional to the accuracy of the activity duration data used.

Generally, the accuracy of the time estimate for activity depends largely upon the historical data or on information available from previous projects.

Estimating without studying the history of the previous projects are always at risk of repeating the same making poor estimates and delay.

Moreover, in estimating, each estimate should be independently taken into account of activities preceding or succeeding. For instance, it should not say that a particular activity will take longer than usual because the parts needed for the activity are expected to be delivered late. The delivery should be viewed as a separate activity, for which the time estimate should reflect the realistic delivery time. Besides, these times should neither include uncontrollable contingencies, for instance floods, power blackouts, accidents nor should safety factors be applied for such contingencies.

The estimated time for each task should be estimated by those who are most experienced for that particular task. These time should be accepted by those hold responsible for their achievement. The most knowledgeable supervisory person should have a vital role in estimating each activity duration.

According to the concept of WBS, the planner can develop a more accurate estimate of the project duration by breaking down the job into smaller time-consumming elements in order to get a precise time estimate of each element. This method when applied to the smaller work elements makes it more difficult it is to overlook some activities. Besides, this estimation still benefits in sequencing the elements into a plan that would show which elements must be done in series or which can be done in parallel.

Due to the impossibility of predicting various future uncertainties as mentioned earlier, after receiving the best estimates of the activity duration available at the time, these estimates should be updated later when more accurate information becomes available. Furthermore, the present project can provide valuable estimating information for future projects. Hence, occurrences in the project must be recorded and documented.

2.5 Resource Management

During planning process, it is necessary to consider other constraints, too. Resource constraint is the most critical. Thus, the tasks of resources loading can not be divorced from that of scheduling. The feasibility of the plan must be checked with respect to the resource requirement. Since the activity can not be performed if there are inadequate resources.

The standard traditional practice of initial network planning was normally analyzed without considering the resource constraint under the assumption of resource loading that are normal. This approach made no real sense. In practice, the project manager should have a responsibility to schedule the activities in such a way that the available amounts of resources are sufficient. Therefore, network planning should comprise a way of relating the project schedule to the level of physical resources allocated to the project.

Primarily, resources must be carefully planned to release them in advance in order to ensure the most efficient completion of the project. The scheduled dates of the project can be calculated only after the resource requirements for every activity are identified. The critical path in a resource constrained schedule may not be the same continuous chain of activities as in the case of unlimited resource schedules. The continuous chain of zero float may exist but may comprise different activities because the start times of many activities are constrained by resource availability.

Usually resources include manpower, equipment, raw materials, financial fund and so on. Since there are a number of resources required in a project, it does not make sense to list every resources - that will result in hundreds of activities on a network. Only key resource types are necessary to be included on a network and tracked. This can be as crude as lumping all the workers together.

The use of the word "adequate" in resource management implies that the necessary resources must be available when they are needed and in the correct amount. Too few organization will be ineffective and the project will be flounder; too many organization will be inefficient. The ideal situation of resource utilization, which resource requirement equals to the resources available, is seldom to happen, because it is difficult to adjust supply with demand.

While at any given time the firm has a fixed level of various resources available for completing project tasks such as machine hours of various types of machinery or instrumentation, labour-hours of various types of special professional or technical services. Therefore, when determining the resource availability, both project manager and resource providers must have the same understanding of how much time is actually required to complete tasks. Besides, resources must be planned under the normal conditions. There must be an allowance for the fact that personnels working full time on a project are not available five days each week for 52 weeks of the years. There are times lost through group meeting, training, sickness, holidays, etc.

There are many tools for resource planning. Resource calendar is a primary but necessary tool. It is a calendar which identifies working days and non-working days with the number of hours worked per day during the life of the project. The resource calendars may be provided for the project as a whole or for individual resource or for specific resource as special calendar within it, and for different geographical locations. Activities and resources can be associated in a calendar.

Resource loading diagram is powerful for resource management, too. It is the profile of resource usage or histogram over time describing the amounts of individual resource related to an existing schedule required during specific time periods. It is extremely important in project management to provide a general understanding of the demands a project will make on a company's resources by highlighting the period-by-period resource implications of a particular project schedule. Resource loading diagram is the first step in attempting to reduce excessive demands on certain resources and to provide the basis for improved scheduling decision to achieve maximum resource utilization by pushing resources overload to resource valleys.

2.5.1 Material Planning

Material needs for manufacturing project are taken into account as a critical part of the resource needed also. Delay due to the late arrival of important materials is one of the obvious problems most project organizations face. Because, unavailability of materials makes it impossible to proceed the plan. Workers are unable to use machines to carry on with their work until the material shortage has been corrected.

Not only is there a problem from material shortage but material arriving too early before needed is also a major problem. The possibility of damages and losses because of re-handling, deterioration and pilferage is much higher when the materials are on the site. Besides, the cost due to interest on their payment is incurred, too. For these reasons, the ideal situation is Just-In-Time (JIT) delivery.

Although delay in many cases are the result of factors which are beyond the control of the project managers. If sufficient information is available, this delay can be compensated for by emphasizing some other parts of the project. Hence, the efficient material planning is important to avoid project delays due material shortage.

Primarily, the network planning and scheduling arrangement should include material requirement as milestones*. The delivery may be scheduled in batch with target date used on purchase schedules derived from the project critical path network. When the planner has obtained the quantities and required dates from plan of delivery and operation, information must be sent to the purchasing department to negotiate with suppliers. The delivery date of the last item needed to complete the materials requirement of a particular activity - upon the receipt of the item with the longest lead time in the batch - is used as the determinant for materials available date. However, one should consider economic purchasing arrangements in terms of quantity and time, also.

To achieve material planning, Bill of Material (BOM), which is a complete list of all materials showing the quantity for each to be used in the project, is fundamental information. Moreover, it is necessary to take into account up-to-date in-house inventory of stocked materials because each time that a material is requisitioned from the stock, the quantity of that material in stock is reduced. Some companies may have a policy to maintain materials in consistent supplies in stock. Thereby, the quantity after each batch consumption must be checked to ensure that it is not below the minimum. If the stock is lower than this level, it must be

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*Milestone - A clearly identifiable point in a project or set of activities that commonly denotes a reporting requirement or completion of a large or important set of activities.

replenished. Materials on delivery must be considered before calculating net requirement, also.

Furthermore, scrap rate must be included in procurement. Because, generally, every process generates some waste. Procuring materials exactly equal to the requirement is at a high risk to be inadequate due to waste. Therefore, allowance for some waste should be included.

2.5.2 Heuristic Approaches

There are two fundamental approaches to constrain resource allocation problems namely heuristics and optimization models. Although the optimization approach is capable of seeking the best solution, there are far more in their ability to handle complex situations and large problems.

Hence, some rules must be set up as a form of resource allocation to confine the task to manageable proportions. Heuristic approaches are merely feasible approaches of attacking the large, nonlinear complex problems which tend to occur in the realistic situation of project management.

A heuristic approach is simple and easy to use as a guide. It aids in problem-solving situations and works well to reduce the amount of effort required in coming up with a solution. It attempts to seek better solutions, although they may not always produce the best solution of resource profile in every case. Hence, they may be viewed as decision rule.

With network planning, the early/late start/finish, float of each work element and critical path can be calculated. The float along each network path can indicate where certain activity schedule can be moved forward or backward in time without effecting the completion time of the project. Heuristic approach analyzes resource usage resource by resource, and period by period. In a period when the available supply of a resource is exceeded, the heuristic examines the tasks in that period and allocates the scarce resource to them sequentially, according to some established priority rules.

In the case where resources are insufficient, activities requiring those resources are slowed or delayed until the next period when resources can be re-allocated. The adjustment of time scale to reduce the requirement may be possible by consuming some float on non-critical activities without any extension. However, if the peaks and valleys of the resource demand are large, the variation may not be significantly changed by adjusting only non-critical activities. It may be necessary to adjust the timing of all activities including critical activities. Delaying a task until resources are available may cause other tasks to become delayed. Furthermore, if this process delays a critical activity, the duration of project will be extended by pushing out the project completion date.

Simple heuristic approaches, for instance "minimum float first" or "shortest activity first" can be effectively employed to assist in establishing activity priorities for many types of limited resource scheduling problems.

The first step in building a priority list for resource assignment by heuristic approaches is the sequencing of the priorities. The priority order can be in several patterns. The priority rules are the major difference among the heuristic approaches. More complex heuristic approaches, which comprise combination of heuristic and modifying rules, always provide a better solution. Thus, the usefulness of heuristic approaches in seeking the better solutions with a minimum effort is based upon an experience and research studies. Each organisation can set up its own set of rules, which can be modified if found unsatisfactory. Besides, the priority list can be altered to accommodate internal and external pressure during the life of project.

As discussed earlier, heuristic approaches such as resource allocation rules are decision rules and not optimizing rules. Although, there is no optimum priority list for the optimum result, it is typically accepted that a set of decision rules will always provide a better schedule than an "ad hoc" approach.

2.6 Floats and Critical Path

Having completed the forward and backward pass calculation procedure, earliness and lateness are next employed to calculate two crucial types of scheduling information, namely float and critical path.

If the early start and the late start are different, there is flexibility about when the activity can start. "Float" or "Slack"is the difference between the late start and the early start. It is the amount by which each activity can be slid without affecting the completion time of the project. Schedules between early start and late finish can be used tc either smooth the resource usage or to show the most likely output. There are many kinds of float as follows:

1) Total Float

Total float is the time by which an activity can expand. The total of float available is accounted for when all preceding activities take place at the earliest possible time and when all following activities are allowed to occur at the latest indicated times. As the total float is absorbed at the planning stage, the floats in both previous and subsequent activities may be reduced.

2) Free Float

Free float is the time by which an activity can expand without affecting subsequent activities. The term free indicates only that use of the float will not affect any following activities. The amount of free float available is accounted for when all preceding activities take place at the earliest possible times and when all following activities also take place at the earliest possible times. If free float is absorbed at the planning stage, the float in only earlier activities will be reduced. Free float can be used without affecting subsequent activities.

3) Independent Float

Independent float is the time by which an activity can expand without affecting any other either previous or subsequent activities. The amount of independent float available is accounted for when all preceding activities take place at the latest possible times and when all following activities take place at their earliest possible time. Therefore, independent float can be used without re-planning any other activities. Where the absorption of float affects neither earlier nor late activities, the float is then said to be independent. The incidence of independent float is rare. The result is always either zero or negative.

An activity with zero float is critical and its duration determines the project's duration. A series or string of these activities with zero float is known as "Critical Path". It represents the longest path through the network and the project can not be completed any sooner than its critical path. Such activities should be claimed priority for resources and for management attention to ensure that they are finished without delay.

Activities which have float with some scheduling leeway are called non-critical tasks. Activity with large float is called bulk activity and should be used to smooth forecast resources usage by filling gaps in the demands in the critical path. While activities with very small float, are near critical and should receive so much attention as the critical path. However, in practice there is a more curious phenomenon, which generally is the result of the use of constrained starts and finishes - namely the negative float.

4) Negative Float

Negative float is the time by which an activity must be reduced for the project to meet a target date. It indicates the reduction in duration time required to meet a target date. Negative float takes place when the task durations are too long to fit between constraining dates. Hence, it is impossible to achieve scheduled target dates. This condition may be referred to as supercritical because the project can not be completed in time with this plan. With negative float, the definition of the critical path is extended to the path which has the least floats.

If float is negative, the work and actions re-planning is essential to remove the negative float to achieve project completion date. This may be done by reducing activity durations, increasing resources, increasing overlap, doing more activities in parallel and changing the constraint of the start or the finish and so on.

2.7 Project Scheduling

A scheduling is the conversion of a project action plan into an operation time table. The time schedule is a series of dates against the work elements in the plan to indicate when the work should be done and when is actually done. It is an important tool for project management as a fundamental basis for monitoring and controlling project activities because project environment typically lacks the continuity of day-to-day operation and has many complex problems of co-ordination.

Schedule should be developed for each major task in the plan. Dates and time allotments for each work package must be in precise agreement with those set forth in the action plan with the same units of time. However, it is not necessary to schedule all project activities at the same level of detail.

A rolling-wave is one of the modern approach which is appropriate for detailed activity planning. With this approach, full detailed activity plans are merely derived and maintained for those work packages that are current or about to start. The detail of later work package is left until it is needed or it is known likely to be done before expanding the effort on detail.

Although the detailed activity planning is an rolling wave basis, it may be necessary to prepare some definition of the scope of some work packages, which must be started in time, such as long lead time activity, at an earlier stage (eg. material procurement). Besides, schedule should be published to allow employees know what they have to do in order to develop employee participation and morale, too.

2.8 Monitoring and Control System

Monitoring means to keep track of and to check systematically all project activities. Therefore, key issue in the monitoring system is to create an information system, which can provide required information to make timely decision that will keep project performance as close as possible to the project plan. It includes collecting, recording, and reporting information concerning any or all aspects of project performance, which concerned people in the organization, especially project managers, wish to know. Besides, the monitoring system must provide the evaluation, examination and appraisal of how things are going on the project, in order to allow the project manager to anticipate problems or to catch them just as they begin to occur.

Control, which is the last element in the cycle of planning-monitoring-controlling, is a necessary and inherent part of project management. Planning-monitoring-controlling is a closed loop cycle that uses feedback as a control process. In project management, the term "control" is used in a special sense. It does not mean supervision or direction. But it means the structured process of comparing those activities which occur to those that have been planned to occur. It is the process of monitoring, evaluating and comparing desired results with actual results, which are collected about project performances in order to determine the project status such as cost, schedule, technical performance objectives and so on. The project controller, then, may take necessary actions if the desired performances differ enough that he/she wishes to decrease the difference and to bring the actual into reasonably closed congruence with the plan established for attaining the objectives. The purpose of control system is to act on data.

The monitoring system is a direct connection between planning and control. A poor correspondence between the planning and the monitoring system is a vital problem. Control can be faulty or missing if the monitoring system does not collect and report information on some significant elements of the plan. Thereby, good monitoring system can provide better control of the work scope.

To link monitoring and control to objectives, monitoring system should be closely and directly related to specific performance outcomes. Hence, identification of the key factors in the project action plan as criteria for monitoring and control is the first step in designing any monitoring system. Typically, the fundamental criteria to be planned, monitored, and controlled are time (schedule), cost (budget), and performance (specification). Moreover, it is necessary to precisely define which specific characteristics of these performances should be controlled. Then performance criteria, standards and data collection procedure must be established for each of the factors to be measured.

The good monitoring system should be capable of developing data streams, which indicate variances yet to come. Because these variances obviously are apt to be statistical or trend in nature. This benefits in preventing problems rather than curing them. Monitoring and control can serve to maintain high morale on the project team as well as to alert team members to problems, which will have to be solved. Placing the control as close as possible to the work being controlled with the desired simplest possible mechanism is a good rule to achieve in monitoring and control.

2.8.1 Data Collection

Precise determination of which of all the available data should be collected is the fundamental problem of monitoring system. "Gather everything" is inappropriate as monitoring policy. Focusing too much weight on easy-to-measure and too little weight on difficult-to-measure rather than the important, or concentrating on criteria which are easily defined at the lower expense rather than on the subjective data which may be more valuable for control should be avoided. The nature of required information typically is dictated by the objectives of the organization, the needs of the client and so on.

The effective project manager should not be primarily interested in how hard their project team work. They should be interested in achieving the results rather than activity. For this reason, it is better to start by defining the desired result as precisely as possible. Information to be collected also must be identified. Not only is it necessary to define what pieces of information should be collected but also when.

Monitoring should concentrate primarily on measuring various facets of output or result rather than intensity of activities. Focusing on results instead of activities offers more benefits or a more stable plan. Because, as the project is carried out and new information is available, the work required to reach a result can change. While the objectives and intermediate products will still remain fixed if the project definition does not change.

Besides, the point for gathering information must be identified. Key point is an important method to identify this point. Since, in any production process, there are a lot of key, nodal or gate points arising from either the graphical layout of the production process or the production method itself. These key points can be used as finishing or inspection points .

Information can be received in many ways - each of which is suitable for some types of measure. However, data collection procedure should usually set up for the life of project as follows:

1) Mechanically

Mechanical or electronic or electrical counting and/or recording device may be employed in case that a process consists of a machine or conveyer to record all products passing a checking point.

2) Operator's work record.

The operator has a responsibility to show which operations and how many of each he/she has carried out. This record should be done in a very abbreviated form, involving simply little writing. It is probable most satisfactory in repetitive work. Usually, the information should be verified by the supervisor.

3) Job card.

Job card is a variation of the work record by presenting the operation with a card specifying the work to be done. This card may be prepared by production control department.

4) Walk-and-count.

This method is the most primitive which assigns the progress chaser's walking around his own sphere of activity and counting the work he/she sees.

2.8.2 Measurement Determination

It is important for any measurement or data capture to be at appropriate level of accuracy. It should be identified where high accuracy measurement is needed and where low accuracy measurement is tolerable. Because the precision of measurement generally can be increased by an increase in the cost of making such measurement.

It may not be necessary for measurement to be too accurately made - particularly in the case where it is cheaper to accept a measuring technique which is known to be inaccurate but consistent than to attempt to obtain a very high accuracy. Typically, a higher level of accuracy is required on critical activities. Because, any delay on these activities will extend the project's duration.

A simple count of the number of products would provide the answer how much had been achieved. It can be done easily in term of Equivalent Unit (EU). Therefore, the number of identical items that go into the final end item must be determined. This number equals one EU; for example, three trucks per tank equals one EU.

For large project, error in Work In Progress (WIP) assessment will have little overall effect because it accounts for merely a small proportion of the whole project. However, the impact of work in progress is more for short-term projects, where the proportion of work in progress at any time is rather high - especially, in cases where the project contains large individual activities due to insufficient work breakdown. This structure leads to huge work in progress because it takes correspondingly longer to cross of the completed activities. Thus, work in progress should be taken into account or the project should be broken down to many smaller sub-projects.

2.8.3 Report

After having completed data collection, they should be digested to generate reports on project progress and presented in as a simple form as possible including project status reports, time/cost reports and variance reports, among others.

Report should be designed in some kind of a form and sent out regularly. This form lists the task which might be involved and leaves some spare space for comments. Report should be simple and friendly tools. That means it should be a single-paged document, which reports against the plan, against the defined criteria for control, and requires simple numeric or yes/no answers and is easy to use to ensure accuracy. If the submitting reports takes an excessive amount of time, workers will not only complain but will also be distracted from productive work. Thereby, the reports should be designed in the way that allows workers to spend as little time as possible filling in them. Reports should be made at defined intervals. It will be better to negotiate the design of reports with the people who will use them so as to ensure commitment.

The frequency of the reporting period depends upon many factors such as the length and the stage of the project, the risk and consequence of failure, and the level of reporting. The report should be available in time to be used for effective project control. The timing of reports should correspond to the timing of the project milestone. It is essential that performance be measured while there is still time to take corrective actions. The reporting cycle must be longer than the time basis of the plan. It is not necessary to issue reports periodically - except for progress reports for senior management or except for those weekly, monthly, quarterly, etc., publications.

Reporting against set questions should be answered honestly. If they are reported dishonestly, it will become obvious at the second or third reporting period. Report should not be of the same depth or at the same frequency for each level. Too many reports, too many details, or the distribution of report, charts, table and so on to many people should be avoided. Generally, unnecessary details result in the report not being read. More details make more work in tracking progress. On the other hand, less details may fail to track certain problems.

Lower level personal requires detailed information about individual task and the factors affecting such task. Usually, this reporting frequency is high. While, the senior management level prefers overview reports describing progress in more aggregated terms with less individual task details. Reports are, hence, issued with lesser frequency. These reports show project status - what has been accomplished - at a specific time. If accomplishments are inadequate or late, these reports serve as shorting points for remedial planning. Significant differences from the plan or standard should be highlighted or flagged so that they can not be overlooked by the controller. The use of coloured pencils is helpful for the notation.

In addition, reports should be presented graphically so as to allow the overall status to be seen at a glance. Because the data are rarely comparable if the interface of the report is poor. The ability to use charts properly is important among the tools of the production controller.

2.8.4 Baseline Plan

For effective control, measuring progress against a fixed baseline is very crucial. Measuring progress against the most recent update of plan leads to lose control. If the plan is updated to reflect current progress, it will be impossible to calculate variances, and control will be lost. Many projects will always seem on time and within budget since the plan has just been updated for the latest progress and no one can remember what the original targets were.

The reports should be the comparison of the actual activity to the plan and of the actual output to the desired output. This desired plan should be held constant throughout the duration of project. This frozen measure is called the baseline. Comparing the difference between baseline and actual performance level is useful as a basis for action to indicate trends and to further account for why such difference exists.

Since, control is also aimed to predict what may take place in the future in case the present conditions still continue without any improvement. Therefore, not only should the baseline be maintained but the current also be estimated. The baseline is used for control while the current estimate is used to predict the out-turn and to manage the scheduled work.

Although, the baseline should be maintained constant as far as possible, it may need to be revised in some situation. For instance, if the project becomes significantly delayed, the baseline can not represent a sensible measure for control. Continuing to use it is unrealistic for control and can, then, actually be demotivating. Hence, it may be necessary to revise the baseline. However, this should be treated as a serious exercise.

Baseline plan of the control process benefits project manager who initiates control decision actions as needed to bring the project back into line. Since, the control is the act of reducing the difference between plan and reality.

In case of comparing with the standards themselves, these standards may not be constant over the life of project. They can be changed as a result of altered capabilities within the organization or factor, which are not under the control of the project manager. Comparing with standard is helpful for the monitoring to carry out some data analysis.

2.8.5 Line Of Balance Technique

Line of Balance (LOB) is a management-oriented graphic charting technique for scheduling, monitoring, controlling and presenting progress against established target in relation to time and accomplishment during repetitive production activity.

LOB technique was first put forward by the US Army in March, 1952, and then it was explained and restated by the US Department of the Navy in February, 1959. LOB is based upon the establishment of a requirement to maintain the delivery programme for complete units. From this delivery requirement and the dependency relationship of foregoing activities on it, a schedule can be prepared to manufacture the various parts which will go to make up the whole project for delivery.

Hence, LOB is an effective management tool for steady state of production activities to deliver a quantity of the completed products according to schedule. Since repetitive work of batch production generally proceeds in a series of discrete steps, the work on the entire batch being completed in any one stage before the batch is passed to the next stage. Thereby, in repetitive projects, it is not known whether the work carried out in such stage is in balance with the work in other processes or not. Supposedly, the volume through one process is excessive, this will cause necessary investment in work in progress; whereas, if the volume is too low, production is chocked off.

The delivery of product may be stated very straightforwardly, such as week-by-week schedule, giving the number of units to be delivered during each separate week. Therefore, to achieve an effective control, LOB should be determined for each control point in the network of the single unit of product.

LOB graphically depicts the cumulative results for each control point, which has been completed as of the progress review date. It can show the progress, status, timing, and phasing of the interrelated activities of a project; these interesting data support management with a method of comparing actual performance with the planned whether or not the objectives of the whole project are being met. Hence, LOB enables the project manager to compare the actual with planned progress against each other, in order to pinpoint activities deviated from the plan and to show which activities are not in balance (behind schedule) with the rest of activities in order to determine the severity of these deviations. Besides, LOB allows management to attend to potential problems and delays, to determine the magnitude of corrective actions needed to put the project back on schedule.

2.8.6 Project Monitoring Indicators

Overall project performance must not be overlooked, too. Therefore, performance of the entire project should structure the reporting information which executives can make meaningful comparison of the project and re-allocate corporate resources where necessary. However, it is not easy to directly measure performance of the project. Therefore, some indicators should be developed as indirect measure of project performance.

1) Percentage Completion

An approach for measuring overall performance is the use of an aggregate performance measure called earned value. Earned value is the basis for the approach used in Cost/Schedule Control System Criteria (C/SCSC), which focuses on the value of the work performed over time as opposed to the cost incurred, commitments, or the time elapsed. The earned value provides a management tool, which can aggregate individual performance in order to get the overview of the project performance. Its concept is a mechanism to compare the work value of the physical actually performed with that of the work which should have been completed at a given point in time. This is achieved by using cost curves and the completion estimate of the activities that are still in progress.

It is very easy to compute the value of task in terms of already completed or not yet started. For the finished work, obviously the earned value is the based unit (the baseline cost) of that element of work. While in the case of task not yet started, the value is zero. Task in progress are more difficult to evaluate. This problem is more significant if the plan comprises a lot of long tasks. Therefore, the estimate of percentage completion must be taken into account for work in progress or intermediate product also.

It is not easy to estimate the "Percentage Completion" of each task especially the overall project. However, basically, the estimate of percentage completion is easier by having rather more short tasks in the plan. Many conventional approaches can be used to aid in estimating percentage completion as follows:

- By making visual inspection. Visual inspections are subjective. Experience has shown that an accurate answer is never received from the question of what percentage of the ongoing task is completed. Besides, when making visual inspection, people always have bias and tend to overestimate the percentage completion.

- By using the effort accrued and the effort remaining to calculate percentage completed. This can be done with the following formula:

$$\textit{Percentage Completion} = \frac{\textit{Effort to Date}}{(\textit{Effort to Date} + \textit{Effort Remaining})}$$

Effort in this formula maybe activity duration, man-hour and so on. This formula uses the sum of effort to date and effort remaining as the denominator, instead of the original estimate, in order to obtain a better estimate of percentage completion. This is valid in cases where effort to date is already greater than the original estimate. However, the estimate of effort remaining can be subjective, and may be calculated by simply subtracting the original estimate by effort to date (until the effort to date is the greater).

- By using the 50-50 estimate. This approach assumes 50 percent is completed when the task is begun, and the remaining 50 percent is when the work is complete. Therefore, all work in progress is on average 50 percent complete.

- By using the 0-100 percent rule. This approach is very convenient in that it does not assign any credit for work in progress until the task is completed.

Earn value analysis even weights task in accordance with their work. More work (effort), more valuable tasks have a greater effect than those less valuable. Typically, the closest approximation of the percentage of completion of the entire project in overview takes the familiar form of S-shaped curve, which gives a pictorial representation of whether the project's progress is on schedule, ahead of schedule or behind schedule. If the total value of the work accomplished is in balance with the baseline plan, it is not necessary for senior management to analyze individual task in detail. In cases where the entire project performance is not sufficient, going down a level will always highlight the offending activities.

2) Performance Ratio

Converting the variance to percent variance or ratio is capable of reducing the distortion caused by the size of the project. Therefore, the ratio of the actual to the target performance can be used to reduce this distortion. The performance ratio can be measured by the following formula:

$$\textit{Performance Ratio} = \frac{\textit{Actual Performance}}{\textit{Expected Performance}}$$

If the performance ratio is greater than one, it is good. On the other hand, it is bad whenever it is less than one.

Besides, control limits may be established as the threshold variances to flag problem areas and assist the decision-making function. This control limits may be set as a percentage such as +/- 10% to indicate early an undesirable trend. However, it is not necessary for the range of control limits to be systematic around 1.0. Moreover different tasks can have different control limits for instance progress on the critical path should be closely monitored than on non-critical path with narrower control limit.

3) Forecasted Project Duration

Establishing a project forecast is a way to construct an early warning system. From the concept of earned value, forecast duration completion is calculated using the schedule variance as a revised prediction of how long the project will complete. At each point in time, any new projection from the actual data or progress can be used to forecast what should occur period by period in the future if it is not intervened. The forecast can be calculated at both the project and work package levels with one of two assumptions:

1) All remaining activities will be done at baseline schedule.

Duration at Completion = *Original Estimate + Schedule Variance to Date*

This forecasting approach is based on the assumption that the value of the variance at completion will still be the same as monitoring date. With this assumption, it is presumed that the actual performance of the project team will be close to or on targets, within budget and on schedule.

2) Delay will continue at the current rate

$$\text{Duration at Completion} = \text{Original Estimate} \times (1 + \%\ \text{Schedule Variance to Date})$$

$$\%\ \text{Schedule Variance to Date} = \frac{\text{Schedule Variance to Date}}{\text{Earned Value to Date}}$$

This forecasting approach is based on the assumption that the past performance of the project team will still be continuing at the same rate of efficiency.

All of these project monitoring indicators can be applied not only for a project overview but also for each task and for total groups of tasks.

2.9 Computer Based Project Management Information System

Personal computers have not only changed the face of project management over the 1980s and 1990s but also have continued to do so into the next century with more and more crucial role. Today, a number of powerful but inexpensive project management softwares are readily available for the personal computer. The high speed digital computers have immense power for handling large and complex projects. It is capable of processing large volumes of data with not only short space of time but also with low risk of error. Currently, managing project is nearly impossible without the computer's help.

Project management software requires simple activity information. While it is capable of applying reasonably sophisticated project management techniques (eg. resource levelling, project tracking, and updating) to projects of reasonable size with multi-project capability and with a reasonable set of reporting options. It allows project manager to make experiments with various condition through "what if" simulation. Most new micro-computer based Project Management Information Systems (PMIS) are considerably more sophisticated; they use the microcomputer's graphics colour, and other features more extensively.

However, it must be realized that although the use of project management software can help the project manager to plan and control the project, with a wide range of facilities but this is true only if the project manager understands and can apply the principle and techniques of project management. The project manager must be inventive and force the software to accomplish the desired results. Since, the software can not make on-the-job management decision and no piece of software can do all things. But, it releases the project manager from processing large amount of data manually and then allows him/her to have more time and accurate information to concentrate on and to manage project effectively.