

Critical path (CRM) method

Identifying the critical path

There will be at least one path through the network that defines the duration of the project. This is known as the critical path. The critical path is the longest path through the network. Any delay to any activity on this critical path will delay the completion of the project.

The significance of the critical path is two-fold.

- In managing the project, we must pay particular attention to monitoring activities on the critical path so that the effects of any delay or resource unavailability are detected and corrected at the earliest opportunity.
- In planning the project, it is the critical path that we must shorten if we are to reduce the overall duration of the project.

Figure shows the activity span. This is the difference between the earliest start date and the latest finish date and is a measure of the maximum time allowable for the activity.

Activity float:

- Although the total float is shown for each activity, it really 'belongs' to a path through the network. Activities A and C in Figure each have 2 weeks' total float. If, however, activity A uses up its float (that is, it is not completed until week 8) then activity B will have zero float (it will have become critical). In such circumstances it may be misleading and detrimental to the project's success to publicize total float!
- There are a number of other measures of activity float, including the following:
- *Total float*: the difference between an activity's earliest start date and its latest start date is known as the activity's float – it is a measure of how much the start or completion of an activity may be delayed without affecting the end date of the project.

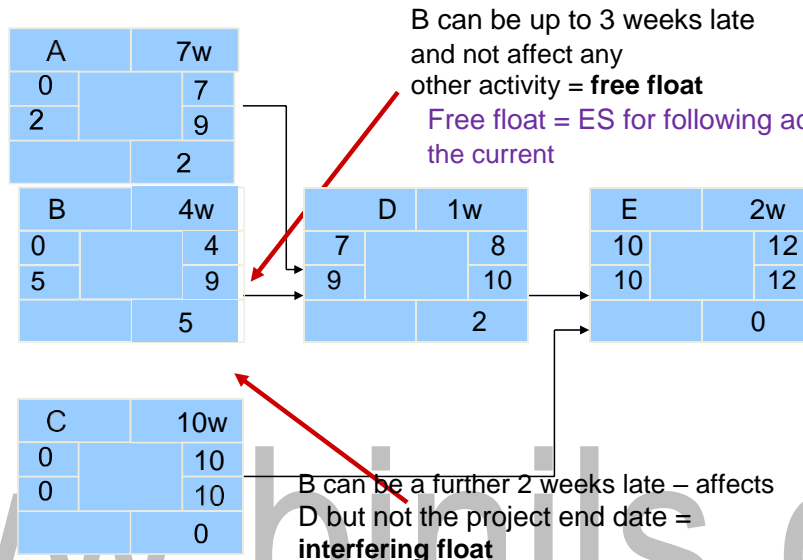
$$\text{Total float} = \text{LF} - \text{ES} - \text{duration (or LS-ES or LF-EF)}$$

- *Free float*: the time by which an activity may be delayed without affecting any subsequent activity. It is calculated as the difference between the earliest completion date for the activity and the earliest start date of the succeeding activity. This might be considered a more satisfactory measure of float for publicizing to the staff involved in undertaking the activities.
- *Interfering float*: the difference between total float and free float. This is quite commonly used, particularly in association with the free float. Once the free float has been used (or if it is zero), the interfering float tells us by how **much** the activity may be delayed without delaying the project end date - even though it will delay the start of subsequent activities.

- Calculate the free float and interfering float for each of the activities shown in the activity network (Figure).

Free and interfering float

$$\text{Total float} = \text{LF} - \text{ES} - \text{duration}$$



Shortening the project duration

- If we wish to shorten the overall duration of a project we would normally consider attempting to reduce activity durations. In many cases this can be done by applying more resources to the task - working overtime or procuring additional staff, for example. The critical path indicates where we must look to save time - if we are trying to bring forward the end date of the project, there is clearly no point in attempting to shorten non-critical activities. Referring to Figure , it can be seen that we could complete the project in week 12 by reducing the duration of activity F by one *week* (to 9 weeks).

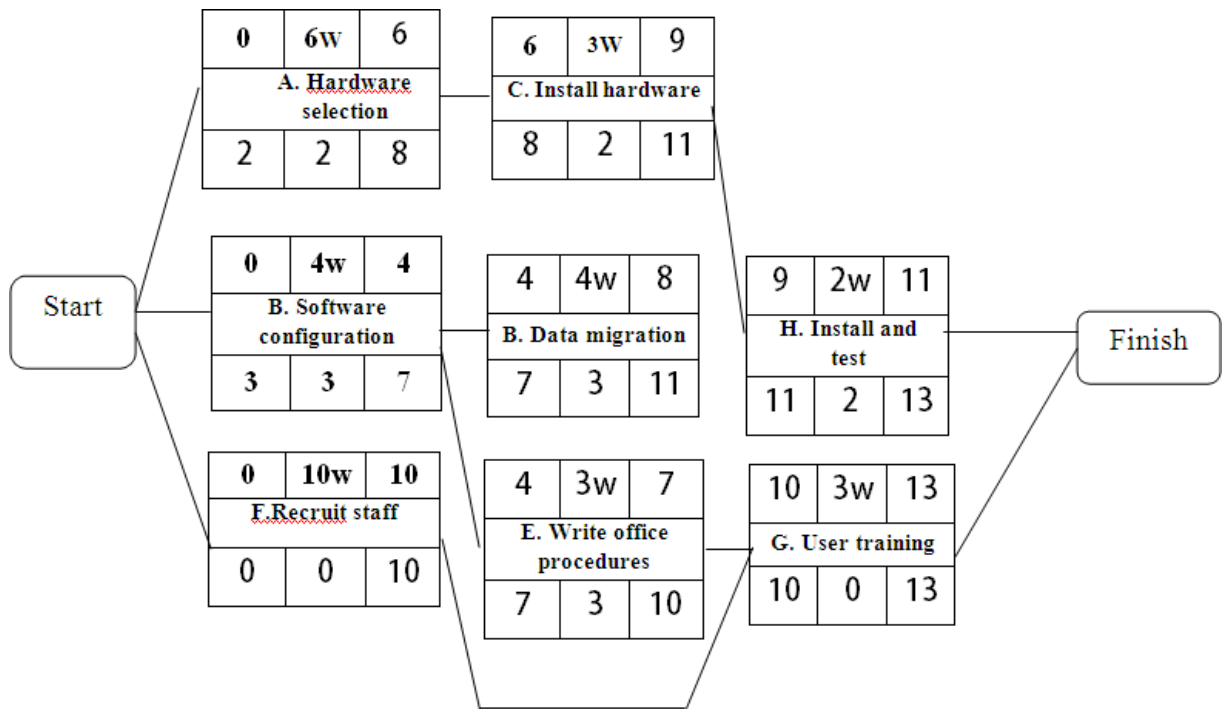


Figure: The Critical path

Exercise

- Referring to Figure , suppose that the duration for activity F is shortened to 8 weeks. Calculate the end date for the project.
- What would the end date for the project be if activity F were shortened to 7 weeks? Why?
- As we reduce activity times along the critical path we must continually check for any new critical path emerging and redirect our attention where necessary.
- There will come a point when we can no longer safely, or cost-effectively, reduce critical activity durations in an attempt to bring forward the project end date. Further savings, if needed, must be sought in a consideration of our work methods and by questioning the logical sequencing of activities. Generally, timesavings are to be found by increasing the amount of parallelism in the network and the removal of bottlenecks (subject always, of course, to resource and quality constraints).

Activity on Arrow Networks

- The project scheduling techniques model the project's activities and their relationships as a network. In the network, time flows from left to right.
- The two best known being **CPM (Critical Path Method)** and **PERT (Program Evaluation**

Review Technique).

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- Both of these techniques used an **activity-on-arrow approach** to visualizing the project as a network where activities are drawn as arrows joining circles, or nodes which represent the possible start and/or completion of an activity or set of activities.
- More recently a variation on these techniques, called **precedence network**, has become popular. This method uses **activity-on-node networks** where activities are represented as nodes and the links between nodes represent precedence (or sequencing) requirements.
- This latter approach avoids some of the problems inherent in the activity-on-arrow representation and provides more scope for easily representing certain situations. It is this method that is adopted in the majority of computer applications currently available. These three methods are very similar and it must be admitted that many people use the same name (particularly CPM) indiscriminately to refer to any or all of the methods.
- In the following sections of this chapter, we will look at the critical path method applied to activity-on-arrow networks

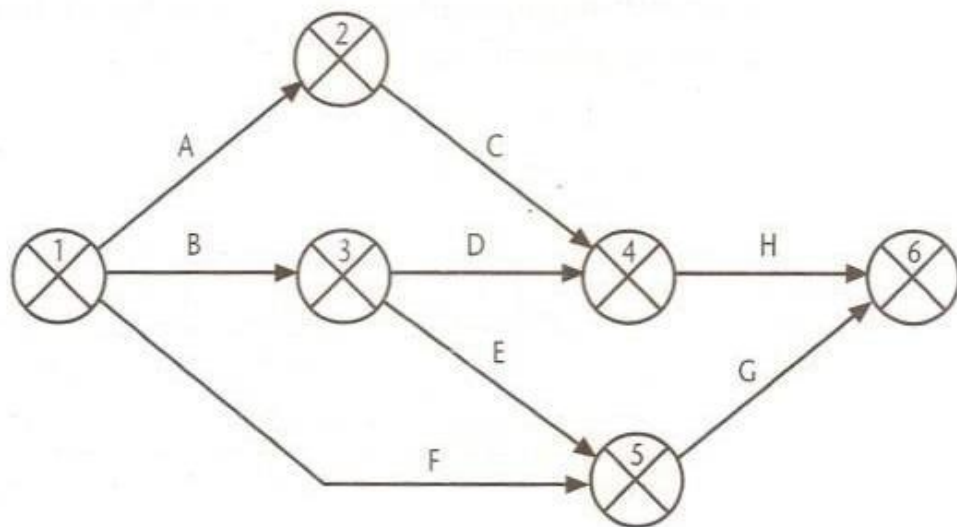


Figure: An activity on-arrow network

Activity-on-arrow network rules and conventions

- A project network may have only one start node
- A project network may have only one end node
- A link has duration
- Nodes have no duration
- Time moves from left to right

- Nodes are numbered sequentially

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- A network may not contain loops

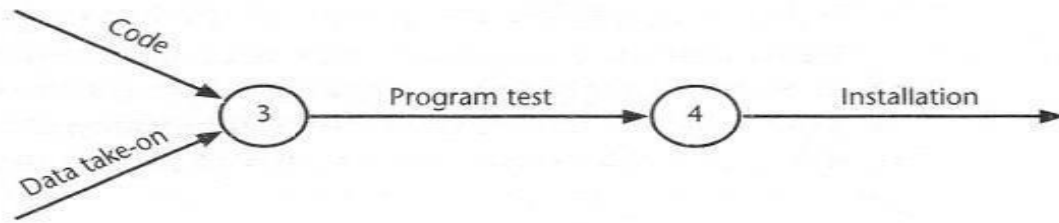


Figure: Fragment of CPM network

A network may not contain loops Figure demonstrates a loop in a network. A loop is an error in that it represents a situation that cannot occur in practice. While loops, in the sense of iteration, may occur in practice, they cannot be directly represented in a project network.

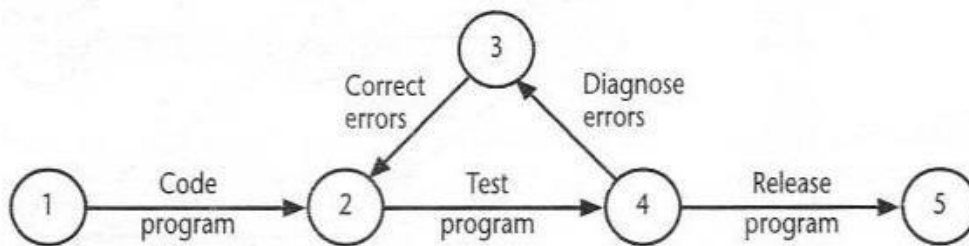


Figure: A loop represents an impossible sequence

A network should not contain dangles. A dangling activity such as 'Write user manual' in Figure should not exist as it is likely to lead to errors in subsequent analysis.

- Redraw the network with a final completion activity — which, at least in this case, is probably a more accurate

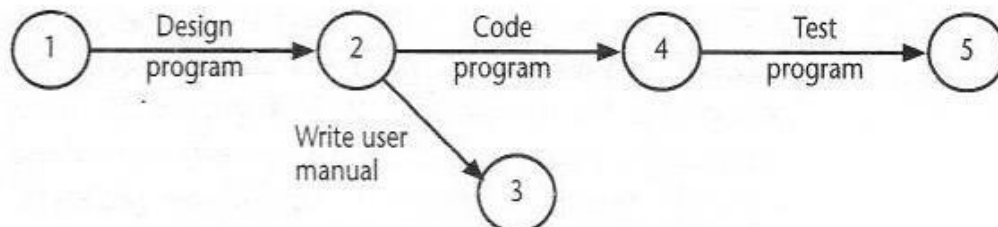


Figure: A dangle

Using dummy activities

When two paths within a network have a common event although they are, in other respects, independent, a logical error such as that illustrated in Figure might occur. Suppose that, in a particular project, it is necessary to specify a certain piece of hardware before placing an order for it and before coding the software. Before coding the software it is also necessary to specify the appropriate data structures, although clearly we do not need to wait for this to be done before the hardware is ordered.

Figure is an attempt to model the situation described above, although it is incorrect in that it requires both hardware specification and data structure design to be completed before either an order may be placed or software coding may commence.

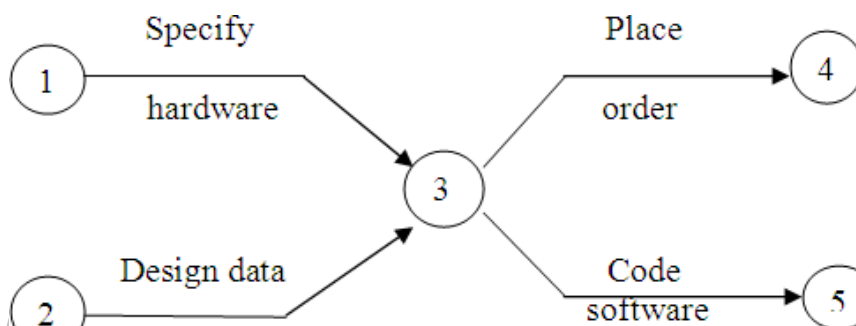


Figure: Two paths with a common node

We can resolve this problem by separating the two (more or less) independent paths and introducing a dummy activity to link the completion of ‘specify hardware’ to the start of the activity ‘code software’. This effectively breaks the link between data structure design and placing the order and is shown in Figure.

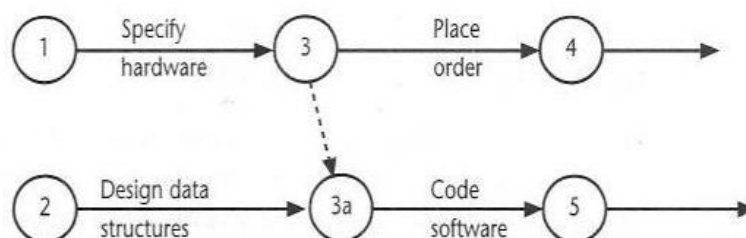


Figure: Two paths linked by a dummy activity

Dummy activities, shown as dotted lines on the network diagram, have a zero duration and use no resources. They are often used to aid in the layout of network drawing as in Figure. The use

of a dummy activities where two activities share the same start and end nodes makes it easier to

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distinguish the activity end-points.

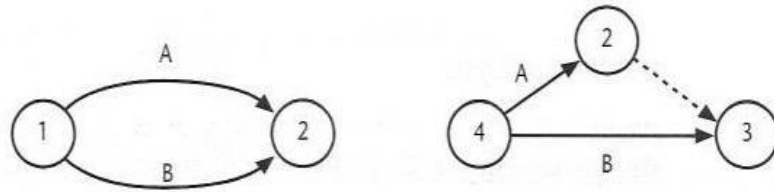
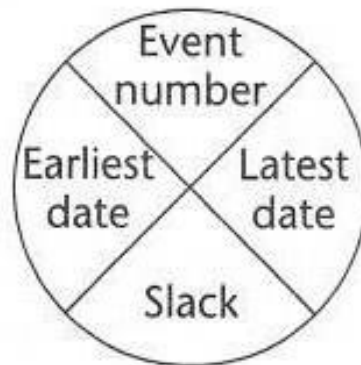


Figure: Another use of a dummy activity

Activity labeling

There are a number of differing conventions that have been adopted for entering information on an activity-on-arrow network. Typically the diagram is used to record information about the events rather than the activities – activity-based information is generally held on a separate activity table.



Forward Pass and backward pass Techniques

Activity-on-node network:

Critical path method uses **activity-on-node networks** where activities are represented as nodes and the links between nodes represent precedence (or sequencing) requirements.

Labeling conventions

- There are a number of differing conventions that have been adopted for entering information on an activity-on-node network. One of the more common conventions for labelling nodes, and the one adopted here, is shown on the left.
- The activity label is usually a code developed to uniquely identify the activity and may incorporate a project code
- The activity description will normally be a brief activity name such as 'Test take-on module'.

Earliest start	Duration	Earliest finish
Activity label, activity description		
Latest start	Float	Latest finish

Adding the time dimension

- Having created the logical network model indicating what needs to be done and the interrelationships between those activities, we are now ready to start thinking about when each activity should be undertaken.
- The critical path approach is concerned with two primary objectives: planning the project in such a way that it is completed as quickly as possible: and identifying those activities where a delay in their execution is likely to affect the overall end date of the project or later activities' start dates.
- The method requires that for each activity we have an estimate of its duration. The network is then analyzed by carrying out a **forward pass**, to calculate the earliest dates at which activities may commence and the project be completed, and a **backward pass**, to calculate the latest start dates for activities and the **critical path**.
- In practice we would use a software application to carry out these calculations for anything but the smallest of projects. It is important, though, that we understand how the calculations are carried out in order to interpret the results correctly and understand the limitations of the method.

- The description and example that follow use the small example project outlined in Table — a project composed of eight activities whose durations have been estimated as shown in the table

Activity		Duration (weeks)	Precedents
A	Hardware selection	6	
B	Software design	4	
C	Install hardware	3	A
D	Code & test software	4	B
E	File take-on	3	B
F	Write user manuals	10	
G	User training	3	E, F
H	Install & test system	2	C, D

Table: An Example project specification with estimated activity durations and precedence requirements

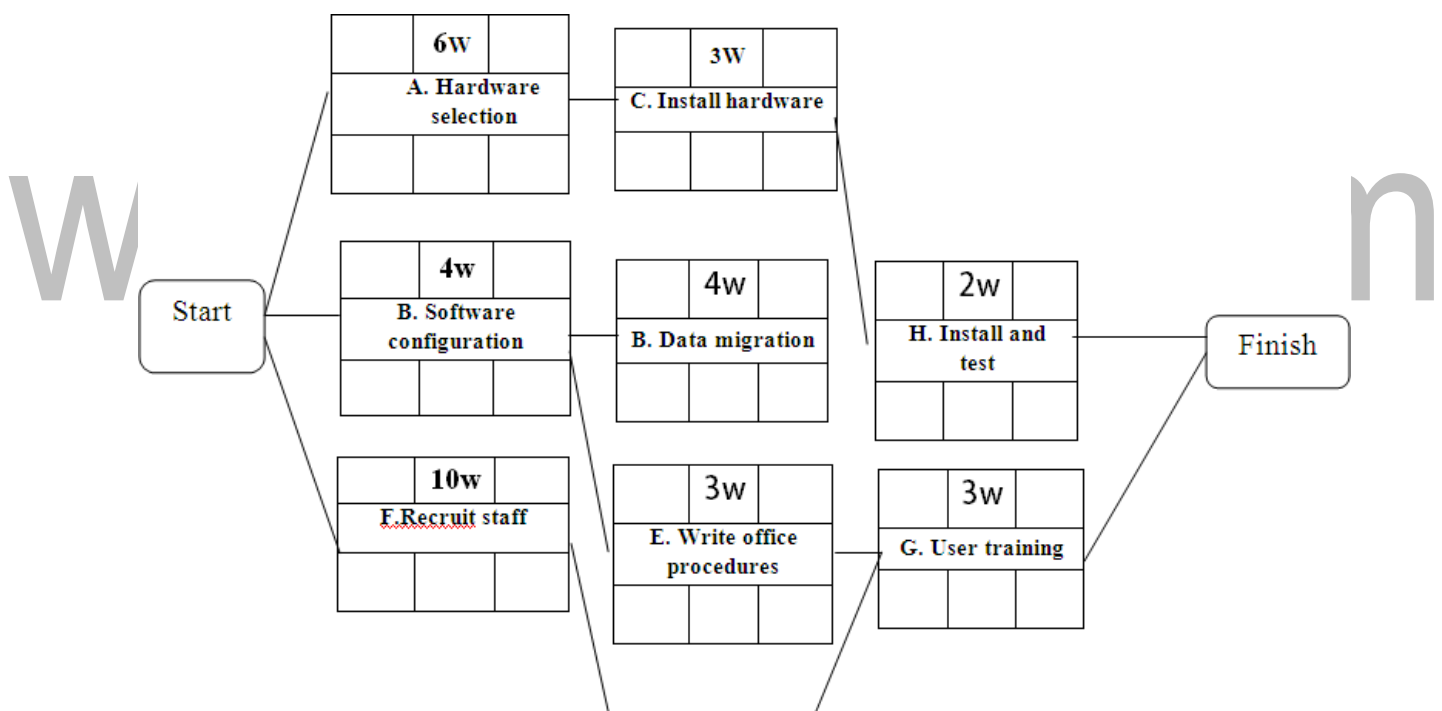


Figure: The precedence network for the example project

The forward pass

- The forward pass is carried out to calculate the earliest dates on which each activity may be started and completed.

- Where an actual start date is known, the calculations may be carried out using actual dates. Alternatively we can use day or week numbers and that is the approach we shall adopt here. By convention, dates indicate the end of a period and the project is therefore shown as starting at the end of week zero (or the beginning of week 1).
- The forward pass and the calculation of earliest start dates is calculated according to the following reasoning.
- Activities A, B and F may start immediately, so the earliest date for their start is zero.
- Activity A will take 6 weeks, so the earliest it can finish is week 6.
- Activity B will take 4 weeks, so the earliest it can finish is week 4.
- Activity F will take 10 weeks, so the earliest it can finish is week 10.
- Activity C can start as soon as A has finished so its earliest start date is week 6. It will take 3 weeks so the earliest it can finish is week 9.

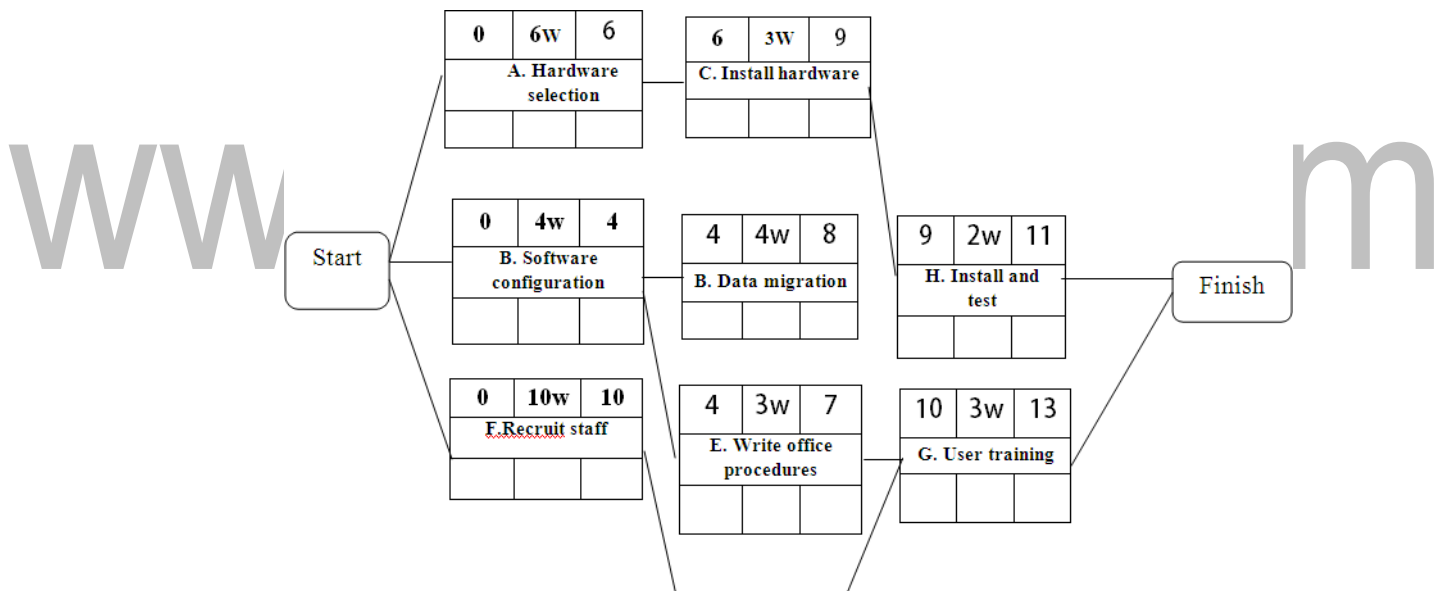


Figure: The network after the forward pass

- Activities D and E can start as soon as B is complete so the earliest they can each start is week 4. Activity D, which will take 4 weeks, can therefore finish by week 8 and activity E, which will take 3 weeks, can therefore finish by week 7.
- Activity G cannot start until both E and F have been completed. It cannot therefore start until week 10 — the later of weeks 7 (for activity E) and 10 (for activity F). It takes 3 weeks and finishes in week 13.
- Similarly, Activity H cannot start until week 9 — the later of the two earliest finished dates for the preceding activities C and a
- The project will be complete when both activities H and G have been completed. Thus the

earliest project completion date will be the later of weeks 11 and 13— that is, week 13. The results of the forward pass are shown in Figure.

The backward pass

- The second stage in the analysis of a critical path network is to carry out a backward pass to calculate the latest date at which each activity may be started and finished without delaying the end date of the project. In calculating the latest dates, we assume that the latest finish date for the project is the same as the earliest finish date — that is, we wish to complete the project as early as possible.
- Figure 6.16 illustrates our network after carrying out the backward pass.
- The latest activity dates are calculated as follows.
- The latest completion date for activities G and 1-1 is assumed to be week 13.
- Activity H must therefore start at week 11 at the latest (13-2) and the latest start date for activity G is week 10 (13-3).
- The latest completion date for activities C and D is the latest date at which activity H must start — that is, week 11. They therefore have latest start dates of week 8 (11- 3) and week 7 (11-4) respectively.
- Activities E and F must be completed by week 10 so their earliest start dates are weeks 7 (10-3) and 0 (10-10) respectively.
- Activity B must be completed by week 7 the latest start date for both activities D and E so its latest start is week 3 (7-4).
- Activity A must be completed by week 8 (the latest start date for activity C) so its latest start is week 2 (8-6).

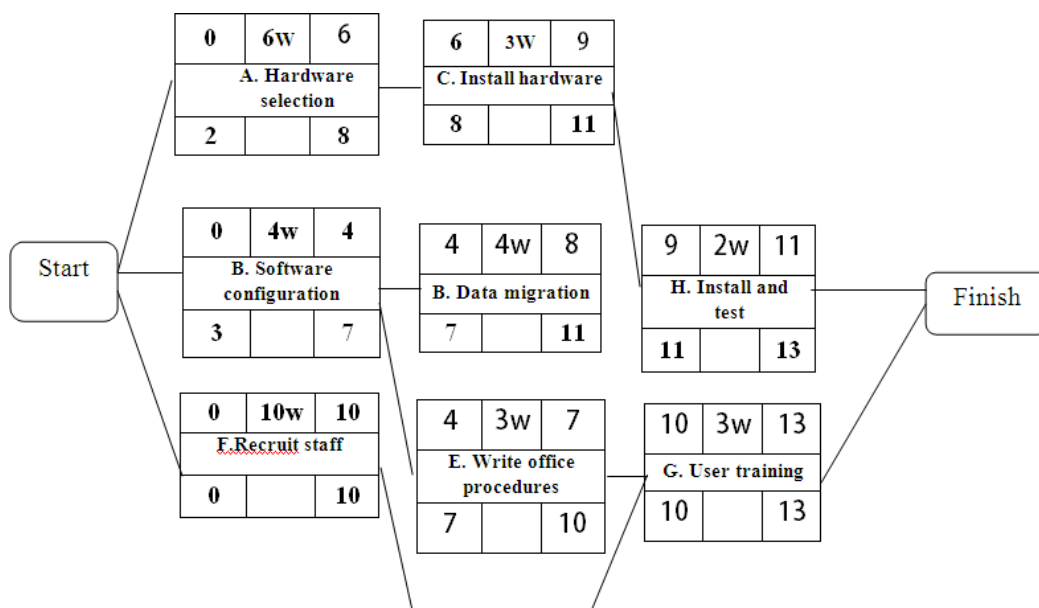


Figure: The network after the backward pass

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The latest start date for the project start is the earliest of the latest start dates for activities A, B and F. This is week zero. This is, of course, not very surprising since **it** tells us that if the project does not start on time it won't finish on time.

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Network Planning Models

Introduction:

- These project scheduling techniques model the project's activities and their relationships as a network. In the network, time flows from left to right.
- The two best known being CPM (Critical Path Method) and PERT (Program Evaluation Review Technique).
- Both of these techniques used an activity-on-arrow approach to visualizing the project as a network where activities are drawn as arrows joining circles, or nodes which represent the possible start and/or completion of an activity or set of activities.
- More recently a variation on these techniques, called precedence network, has become popular. This method uses activity-on-node networks where activities are represented as nodes and the links between nodes represent precedence (or sequencing) requirements.
- This latter approach avoids some of the problems inherent in the activity-on-arrow representation and provides more scope for easily representing certain situations. It is this method that is adopted in the majority of computer applications currently available. These three methods are very similar and it must be admitted that many people use the same name (particularly CPM) indiscriminately to refer to any or all of the methods.
- In the following sections of this chapter, we will look at the critical path method applied to precedence (activity-on-node) networks followed by a brief introduction to activity-on-arrow networks

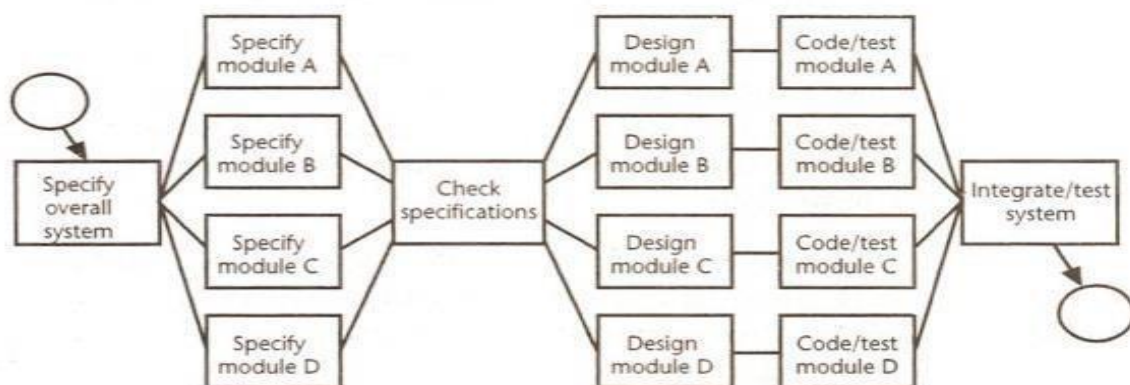


Fig: The IOE maintenance group accounts project activity network fragment with a check point activity added

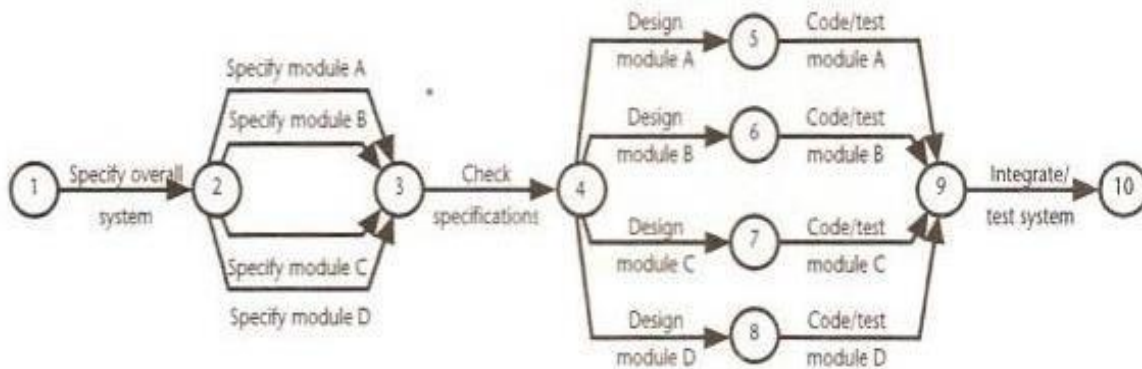


Fig: The IOE maintenance group accounts project activity network fragment represented as a CPM network

Formulating a network model

- The first stage in creating a network model is to represent the activities and their interrelationships as a graph. In activity-on-node we do this by representing activities as links (arrowed lines) in the graph — the nodes (circles) representing the events of activities starting and finishing.

Constructing precedence networks

- A project network should have only one start node
- A project network should have only one end node
- A node has duration
- A node represents an activity and, in general, activities take time to execute.
- Links normally have no duration
- precedents are the immediate preceding activities In Figure, the activity 'Program test' cannot start until both 'Code' and 'Data take-on' have been completed and activity 'Install' cannot start until 'Program test' has finished. 'Code' and 'Data take-on' can therefore be said to be precedents of 'Program test', and 'Program test' is a precedent of 'Install'. Note that we do not speak of 'Code' and 'Data take-on' as precedents of 'Install' - that relationship is implicit in the previous statement. Time moves front left to right

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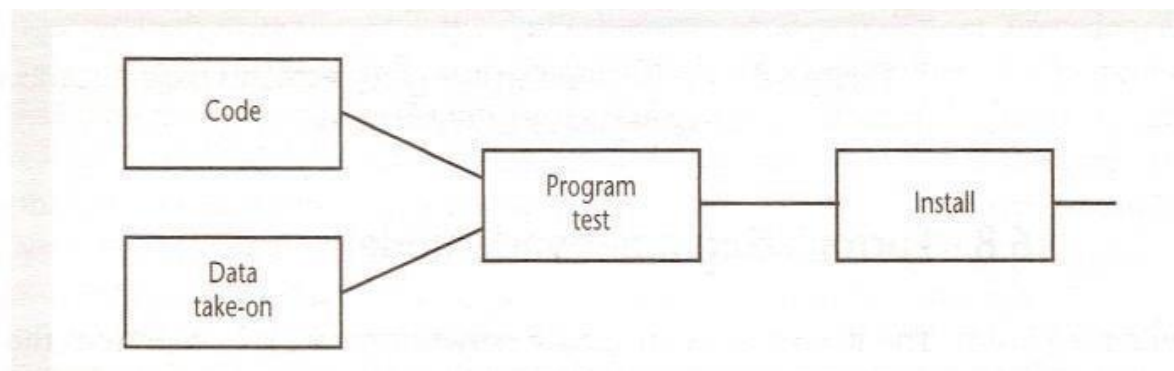


Fig : Fragment of a precedence network

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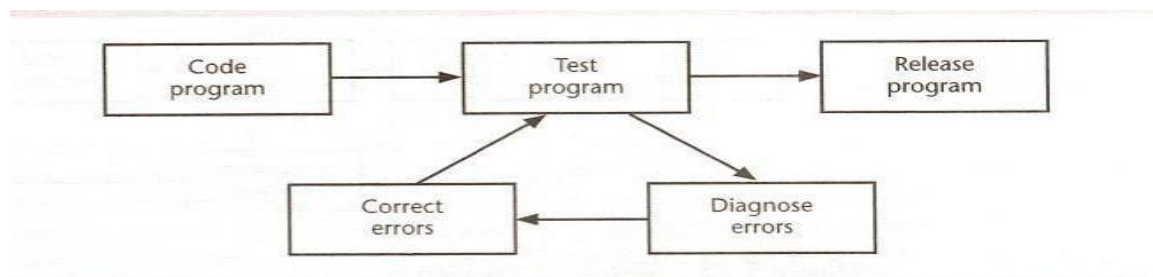


Fig: A Loop representing an impossible sequence

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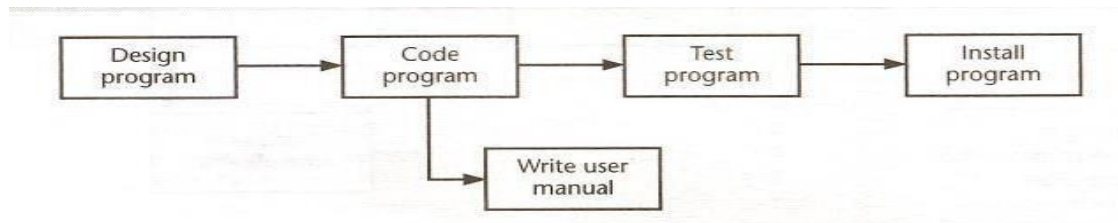


Fig: A Dangle

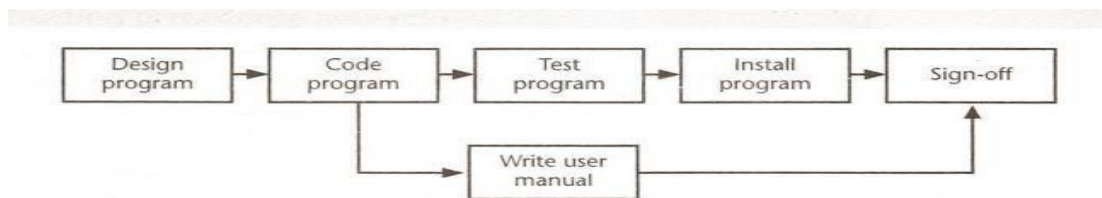


Fig: Resolving the dangle

Representing lagged activities

- We might come across situations where we wished to undertake two activities in parallel so long as there is a lag between the two. We might wish to document amendments to a program as it was being tested - particularly if evaluating a prototype.
- Where activities can occur in parallel with a time lag between them we represent the lag with a duration on the linking arrow as shown in Figure 6.13. This indicates that documenting amendments can start one day after the start of prototype testing and will be completed two days after prototype testing is completed.

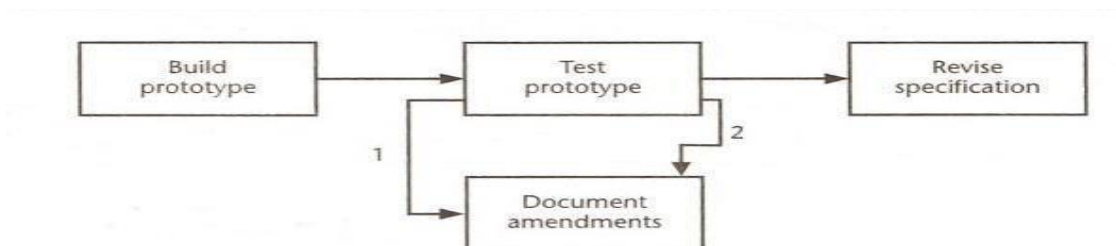


Fig: Indicating lags

Objectives of Activity Planning

What is Planning

- Plans are nothing but planning is everything. Planning is a continuous process of refinement done during development.
- A detailed plan has to include the schedule of the project comprising of the start and the completion time of every activity defined. The actual achievement can be measured using the detailed plan.
- Planning process ensures that necessary resources needed at different stages are precisely available at requirement.
- Planning also produce a cash flow forecasting that indicates when the expenditure and he income takes place in the process.
- First of all, a plan must contain the start and completions of every activity that produces deliverables must be clearly visible in ensuring that the products of each activity are delivered on time.
- Every stage of the development plan must strive to achieve the objectives as the project moves from one to another.
- A plan must be defined with a set of targets that are achieved which can be measured. At the same instance, when target dates are not achievable the plan must be effectively modified to focus on the target.

Elements of Detailed Planned Activity

- Along with factors described with activity planning, the following elements play a very important role in achieving the target.
- The elements of a detailed planned activity are:
 - Feasibility assessment
 - Allocation of resources
 - Estimation of costs
 - Project coordination
 - Personal encouragement

Feasibility assessment

- Feasibility assessment talks about an very early stage describing whether it is feasible for the project to exist within the specified time constraint.
- A detailed plan will help in forecasting of the project as it progresses from one stage to other stages of activities.
- The feasibility factor also lies in the availability of resources that includes specialized staff to carry out the activities.

Allocation of resources

- The best way to allocate resources to the project depends on the availability factor.
- The project plan must analyze the available resources and the timescales for each and every activity.
- Additional usage of resources more than the stipulated timescale will result in slacking the progress of the project.

Estimation of costs

- The project plan must provide solutions to the following questions:
 - What is the total expenditure?
 - How much will the project costs?
 - What are the various estimating factors involved in the development process.
- These can be answered only when a detailed estimation of costs and timing is defined.

Project coordination

- Interaction and communication plays a vital role in handling complex projects.
- Effective team management must be established to carry out the activities in a well-coordinated manner.
- In particular, the availability of staff for a set of integrated project schedules must be carefully allocated with no period of idleness.

Personal encouragement

- Staff involved in the development process must be motivated in an effective way so that they achieve the target without any delay.
- The targets provided to the staff are monitored and personal encouragement must be given to individual staff if achieve the target on time.
- Activity planning helps in completing the project in minimum time with an nominal

cost with the help of project schedules.

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- To shorten the time limit, activities can be carried out in parallel based on the conditions defined for obtaining resources.
- Project scheduling activities includes the extension of timescale provided with constraints that can be relaxed to have effective usage.

Project Schedules

- A stage of a larger project, the project plan must be developed to the level of showing dates when each activity should start and finish and when and how much of each resource will be required. Once the plan has been refined to this level of detail *we* call it a project schedule
 - Creating a project schedule comprises four main stages.

First step

- step in producing the plan is to decide what activities need to be carried out and in what order they are to be done_ From this *we* can construct an ideal activity plan — that is, a plan of when each activity would ideally be undertaken were resources not a constraint

- This activity plan is generated by Steps 4 and 5 of Step Wise

Second step

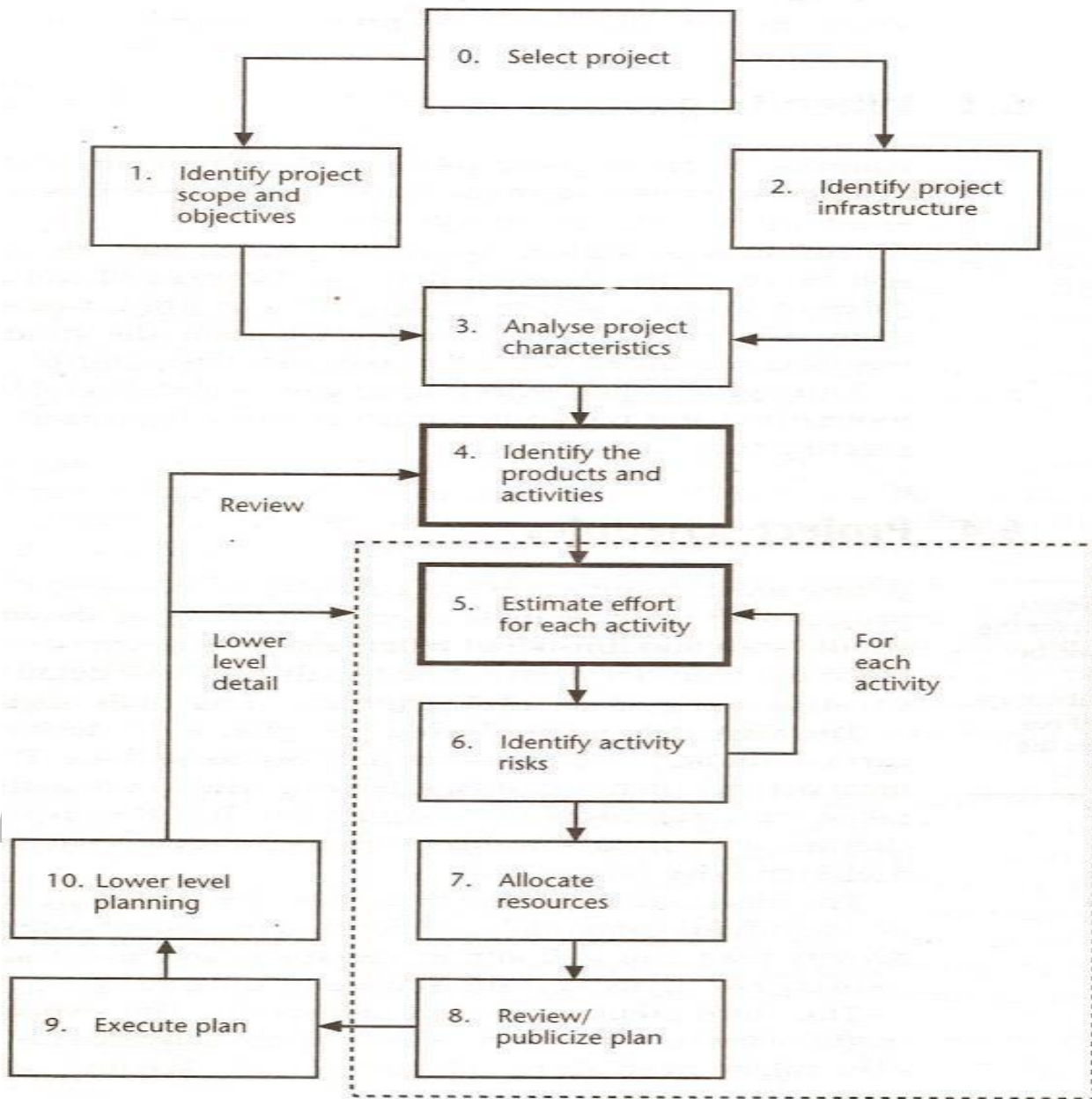
- The ideal activity plan will then be the subject of an activity risk analysis, aimed at identifying potential problems. This might suggest alterations to the ideal activity plan and will almost certainly have implications for resource allocation.

Third step

- This is resource allocation. The expected availability of resources might place constraints on when certain activities can be carried out

Final step

- The final step is schedule production. Once resources have been allocated to each activity, we will be in a position to draw up and publish a project schedule, which indicates planned start and completion dates and resource requirements statement for each activity.



Activity planning is carried out in step 4 and step 5

PERT TECHNIQUE:

- Before any activity begins related to the work of a project, every project requires an advanced, accurate time estimate. Without an accurate estimate, no project can be completed within the budget and the target completion date.
- Developing an estimate is a complex task. If the project is large and has many stakeholders, things can be more complex.
- Therefore, there have been many initiatives to come up with different techniques for estimation phase of the project in order to make the estimation more accurate.
- PERT (Program Evaluation and Review Technique) is one of the successful and proven methods among the many other techniques, such as, CPM, Function Point Counting, Top-Down Estimating, WAVE, etc.
- PERT was initially created by the US Navy in the late 1950s. The pilot project was for developing Ballistic Missiles and there have been thousands of contractors involved.
- After PERT methodology was employed for this project, it actually ended two years ahead of its initial schedule.

The PERT Basics

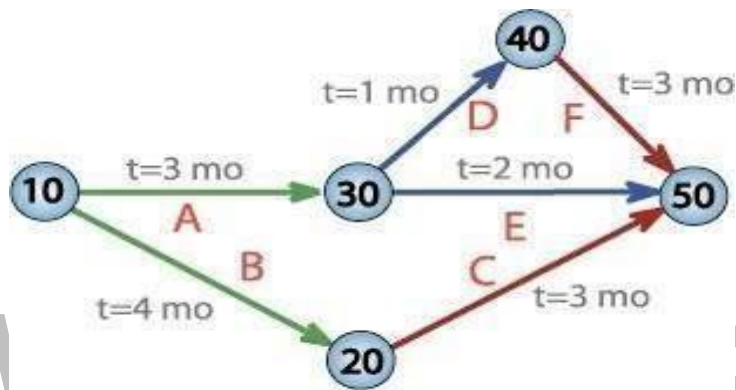
- At the core, PERT is all about management probabilities. Therefore, PERT involves in many simple statistical methods as well.
- Sometimes, people categorize and put PERT and CPM together. Although CPM (Critical Path Method) shares some characteristics with PERT, PERT has a different focus.
- Same as most of other estimation techniques, PERT also breaks down the tasks into detailed activities.
- Then, a Gantt chart will be prepared illustrating the interdependencies among the activities. Then, a *network* of activities and their interdependencies are drawn in an

illustrative manner.

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- In this map, a *node* represents each event. The activities are represented as arrows and they are drawn from one event to another, based on the sequence.
- Next, the Earliest Time (TE) and the Latest Time (TL) are figured for each activity and identify the slack time for each activity.
- When it comes to deriving the estimates, the PERT model takes a statistical route to do that. We will cover more on this in the next two sections.

Following is an example PERT chart:



PERT network chart for a seven-month project with five milestones (10 through 50) and six activities (A through F)

The Three Chances

- There are three estimation times involved in PERT; Optimistic Time Estimate (TOPT), Most Likely Time Estimate (TLIKELY), and Pessimistic Time Estimate (TPESS).
- In PERT, these three estimate times are derived for each activity. This way, a range of time is given for each activity with the most probable value, TLIKELY.

Following are further details on each estimate:

1. TOPT

This is the fastest time an activity can be completed. For this, the assumption is made that all the necessary resources are available and all predecessor activities are completed as planned.

2. TLIKELY

Most of the times, project managers are asked only to submit one estimate. In that case, this is

the estimate that goes to the upper management.

3. TPESS

This is the maximum time required to complete an activity. In this case, it is assumed that many things go wrong related to the activity. A lot of rework and resource unavailability are assumed when this estimation is derived.

The PERT Mathematics

BETA probability distribution is what works behind PERT. The expected completion time (E) is calculated as below:

$$E = (TOPT + 4 \times TLIEKLY + TPESS) / 6$$

At the same time, the possible variance (V) of the estimate is calculated as below:

$$V = (TPESS - TOPT)^2 / 6^2$$

Now, following is the process we follow with the two values:

- For every activity in the critical path, E and V are calculated.
- Then, the total of all Es are taken. This is the overall expected completion time for the project.
- Now, the corresponding V is added to each activity of the critical path. This is the variance for the entire project. This is done only for the activities in the critical path as only the critical path activities can accelerate or delay the project duration.
- Then, standard deviation of the project is calculated. This equals to the square root of the variance (V).
- Now, the normal probability distribution is used for calculating the project completion time with the desired probability.

Monte Carlo simulation

- Having been named after the principality famous for its casinos, the term Monte Carlo Analysis conjures images of an intricate strategy aimed at maximizing one's earnings in a casino game.

- However, Monte Carlo Analysis refers to a technique in project management where a manager computes and calculates the total project cost and the project schedule many times.
- This is done using a set of input values that have been selected after careful deliberation of probability distributions or potential costs or potential durations.

Importance of the Monte Carlo Analysis

- The Monte Carlo Analysis is important in project management as it allows a project manager to calculate a probable total cost of a project as well as to find a range or a potential date of completion for the project.
- Since a Monte Carlo Analysis uses quantified data, this allows project managers to better communicate with senior management, especially when the latter is pushing for impractical project completion dates or unrealistic project costs.
- Also, this type of an analysis allows the project managers to quantify perils and ambiguities in project schedules.

A Simple Example of the Monte Carlo Analysis

- A project manager creates three estimates for the duration of the project: one being the most likely duration, one the worst case scenario and the other being the best case scenario. For each estimate, the project manager assigns the probability of occurrence.

The project is one that involves three tasks:

- The first task is likely to take three days (70% probability), but it can also be completed in two days or even four days. The probability of it taking two days to complete is 10% and the probability of it taking four days to finish is 20%.
- The second task has a 60% probability of taking six days to finish, a 20% probability each of being completed in five days or eight days.
- The final task has an 80% probability of being completed in four days, 5% probability of

being completed in three days and a 15% probability of being completed in five days.

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Using the Monte Carlo Analysis, a series of simulations are done on the project probabilities. The simulation is to run for a thousand odd times, and for each simulation, an end date is noted.

- Once the Monte Carlo Analysis is completed, there would be no single project completion date. Instead the project manager has a probability curve depicting the likely dates of completion and the probability of attaining each.
 - Using this probability curve, the project manager informs the senior management of the expected date of completion. The project manager would choose the date with a 90% chance of attaining it.
 - Therefore, it could be said that using the Monte Carlo Analysis, the project has a 90% chance of being completed in X number of days.
 - Similarly, a project manager can adjudge the estimated budget for a project using probabilities to simulate different end results and in turn use the findings in a probability curve.

How is the Monte Carlo Analysis Carried Out?

- The above example was one that contained a mere three tasks. In reality, such projects contain hundreds if not thousands of tasks.
- Using the Monte Carlo Analysis, a project manager is able to derive a probability curve to show the ambiguity surrounding the duration and the costs surrounding these hundreds or thousands of tasks.
- Conducting simulations involving hundreds or thousands of tasks is a tedious job to be done manually.
- Today there is project management scheduling software that can conduct thousands of simulations and offer the project manager different end results in a probability curve.

The Different Types of Probability Distributions/Curves

- A Monte Carlo Analysis shows the risk analysis involved in a project through a

probability distribution that is a model of possible values.

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➤ Some of the commonly used probability distributions or curves for Monte Carlo Analysis include:

- **The Normal or Bell Curve** - In this type of probability curve, the values in the middle are the likeliest to occur.
- **The Lognormal Curve** - Here values are skewed. A Monte Carlo Analysis gives this type of probability distribution for project management in the real estate industry or oil industry.
- **The Uniform Curve** - All instances have an equal chance of occurring. This type of probability distribution is common with manufacturing costs and future sales revenues for a new product.
- **The Triangular Curve** - The project manager enters the minimum, maximum or most likely values. The probability curve, a triangular one, will display values around the most likely option.

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Resource Allocation

- **Resource allocation** is the assignment of available resources to various uses. In the context of an entire economy, resources can be allocated by various means, such as markets or central planning.
 - In project management, **resource allocation** or resource management is the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time
 - In strategic planning, resource allocation is a plan for using available resources, for example human resources, especially in the near term, to achieve goals for the future. It is the process of allocating scarce resources among the various projects or business unit
 - Resource allocation may be decided by using computer programs applied to a specific domain to automatically and dynamically distribute resources to applicants.
 - This is especially common in electronic devices dedicated to routing and communication. For example, channel allocation in wireless communication may be decided by a base transceiver station using an appropriate algorithm.
 - One class of resource whereby applicants bid for the best resource(s) according to their balance of "money", as in an online auction business model (see also auction theory). A study by Emmanuel Yartebai Annan shows that this is highly important in the resource allocation sector.

Creation of critical patterns

- The job pattern of an IT company engaged in software development can be seen split in two parts:
 - Software Creation
 - Software Project Management
- A project is well-defined task, which is a collection of several operations done in order to achieve a goal (for example, software development and delivery). A Project can be

characterized as:

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- Every project may has a unique and distinct goal.
- Project is not routine activity or day-to-day operations.
- Project comes with a start time and end time.
- Project ends when its goal is achieved hence it is a temporary phase in the lifetime of an organization.
- Project needs adequate resources in terms of time, manpower, finance, material and knowledge-bank.

Software Project

- A Software Project is the complete procedure of software development from requirement gathering to testing and maintenance, carried out according to the execution methodologies, in a specified period of time to achieve intended software product.

Need of software project management

- Software is said to be an intangible product. Software development is a kind of all new stream in world business and there's very little experience in building software products. Most software products are tailor made to fit client's requirements.
- The most important is that the underlying technology changes and advances so frequently and rapidly that experience of one product may not be applied to the other one. All such business and environmental constraints bring risk in software development hence it is essential to manage software projects efficiently.



- The image above shows triple constraints for software projects. It is an essential part of software organization to deliver quality product, keeping the cost within client's budget

constrain and deliver the project as per scheduled. There are several factors, both internal and external, which may impact this triple constrain triangle. Any of three factor can severely impact the other two.

- Therefore, software project management is essential to incorporate user requirements along with budget and time constraints.

Software Project Manager

- A software project manager is a person who undertakes the responsibility of executing the software project. Software project manager is thoroughly aware of all the phases of SDLC that the software would go through. Project manager may never directly involve in producing the end product but he controls and manages the activities involved in production.
 - A project manager closely monitors the development process, prepares and executes various plans, arranges necessary and adequate resources, maintains communication among all team members in order to address issues of cost, budget, resources, time, quality and customer satisfaction.
- Let us see few responsibilities that a project manager shoulders -Managing People
- Act as project leader
 - Liaison with stakeholders
 - Managing human resources
 - Setting up reporting hierarchy etc.

Managing Project

- Defining and setting up project scope
- Managing project management activities
- Monitoring progress and performance
- Risk analysis at every phase
- Take necessary step to avoid or come out of problems
- Act as project spokesperson

SoftwareManagement Activities

- Software project management comprises of a number of activities, which contains planning of project, deciding scope of software product, estimation of cost in various terms, scheduling of tasks and events, and resource management. Project management activities may include:
- Project Planning
- Scope Management
- Project Estimation

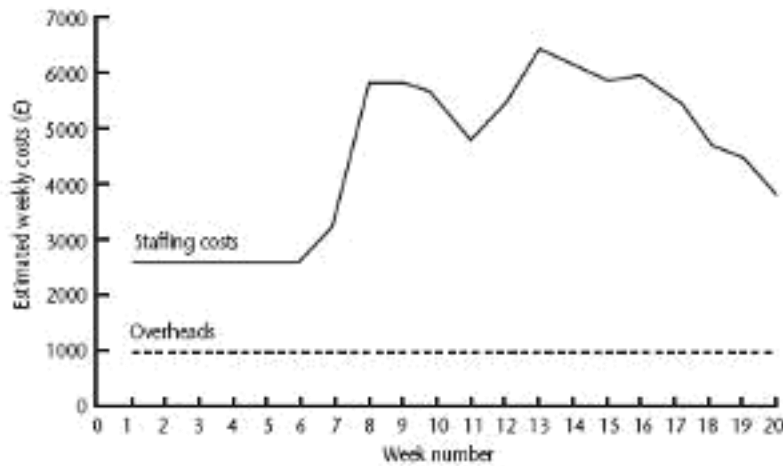
Cost Schedules

Calculating cost is straightforward where organization has standard cost figures for staff and other resources. Staff costs includes not just salary, but also social security contributions by the employer, holiday pay etc. Timesheets are often used to record actual hours spent on each project by an individual. One issue can be how time when a staff member is allocated and available to the project, but is not actually working on the project, is dealt with. Overheads e.g. space rental, service charges etc. Some overheads might be directly attributable to the project, in other cases a percentage of departmental overheads may be allocated to project costs. Usage charges are some charges can be on a 'pay as you go' basis e.g. telephone charges, postage, car mileage –at the planning stage an estimate of these may have to be made.

In general, costs are categorized as follows.

- Staff Costs
- Overheads
- Usage Charges

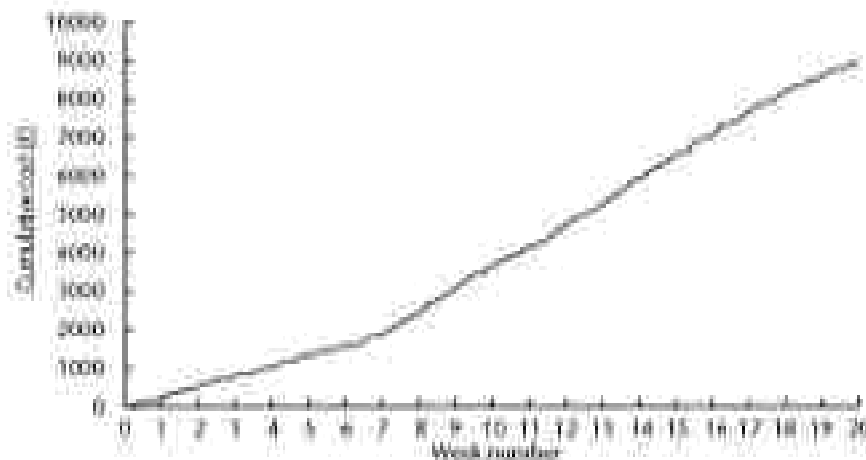
Cost profile



This shows how much is going to be spent in each week. This could be important where an organization allocates project budgets by financial year or quarter and the project straddles more than one of these financial periods

Accumulative costs

The project manager will also be concerned about planned accumulative costs. This chart can be compared to the actual accumulative costs when controlling the project to assess whether the project is likely to meet its cost targets.



Risk Management and category of risks

Every project involves risk. Risk is “an uncertain event or condition that, if it occurs has a positive or negative effect on a project objectives”, include transferring the risk to another party, avoiding the risk, reducing the negative effect of the risk, and accepting some or all of the consequences of a particular risk.

Some definitions of risk

- ‘the chance of exposure to the adverse consequences of future events’

PRINCE2

- Project plans have to be based on *assumptions*
- *Risk* is the possibility that an assumption is wrong
- When the risk happens it becomes a *problem* or an *issue*

Risk Occurs:

- When the project exceed its original specification
- Deviations from achieving it objectives and so on.

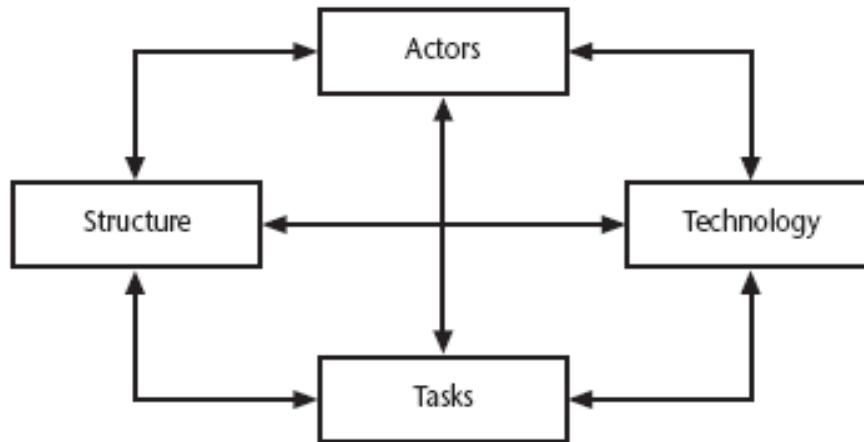
There are two types of risks.

1. **Project risk** – which prevent the project from being completed successfully. Project risk are those could prevent achievement of objectives given to the project manager & project team.

2. **Business risk** – delivered products are not profitable. Economic downturn or import of cheaper alternative products.

- Risk evaluation is meant to decide whether to proceed with the project or not, and whether the project is meeting its objectives.
- Uncertain event or condition that if it occurs has positive or negative condition on project objectives.
- Key elements of Risk follows:-
 - **It relates to the future**-risk involves speculating about future events.
 - **Involves cause & effects**

Categories of risk:



This is based on Lytinen's socio technical model of risk

- **Actors** relate to all those involved in the project including both developers, users and managers
 - Includes various department specialists, user groups, managers with different responsibilities.
 - If developer builds software components & leave before testing, team member taking over that component find lack of familiarity with software make correction of faults difficult.
 - e.g. a risk could be that high staff turnover leads to information of importance to the project being lost
- **Technology** – both that used to implement the project and that embedded in the project deliverables – risk could be that the technologies selected are not in fact appropriate.
- **Structure** – this includes management procedures, risk here is that a group who need to carry out a particular project task are not informed of this need because they are not part of the project communication network
- **Tasks** – the work to be carried out. A typical risk is that the amount of effort needed to carry out the task is underestimated.

A risk could be well belong to more than one of the four areas – for example, estimates being wrong could be influenced by problems with actors (e.g. lack of experience with a technical domain) or the structure (over optimism of managers keen to win work).

Some other categories of risks:

- **Schedule Risk**
 - Wrong time estimation
 - Resources are not tracked properly. All resources like staff, systems, skills of individuals etc.
 - Unexpected project scope expansions
- **Budget Risk**
 - Wrong budget estimation
 - Cost overruns
 - Project scope expansion
- **Operational Risks**
 - No proper subject training
 - No resource planning
 - No communication in team.
- **Technical risks**
 - Product is complex to implement.
 - Difficult project modules integration.
 - Continuous changing requirements
- **Programmatic Risks**
 - Market development
 - Changing customer product strategy and priority
 - Government rule changes

ISPL situational factors: the target domain

1. **Information system** - the characteristics of the information system - these are independent of the technologies that might be used
2. **Computer system** - the characteristics of the part of the information system that have been computerized

ISPL situational factors: project domain

- | | |
|------------|---|
| Project | • the types of task to be undertaken |
| Structure | • the communication systems, management structures, workflows etc |
| Actors | • the people involved in the project |
| Technology | • the methods, techniques and tools to be used |

Managing Risk

The proactive management of risks throughout the software development lifecycle is important for project success. In this chapter, we will explain the following:

- the risk management practice, which involves risk identification, analysis, prioritization, planning, mitigation, monitoring, and communication
- software development risks that seem to reoccur in educational and industrial projects
- a risk-driven process for selecting a software development model

A framework for dealing with risk

The planning for risk includes these steps:

- Risk identification – what risks might there be?
- Risk analysis and prioritization – which are the most serious risks?
- Risk planning – what are we going to do about them?
- Risk monitoring – what is the current state of the risk?

Risk identification

Approaches to identifying risks include:

- Use of checklists – usually based on the experience of past projects
- Brainstorming – getting knowledgeable stakeholders together to pool concerns
- Causal mapping – identifying possible chains of cause and effect

Checklists

- ✓ They are simply lists of the risks have been found to occur regularly in software development projects
- ✓ Creators of checklists also suggest potential counter measures for each risk.
- ✓ If manager identifies risk ,he can use counter measures to cope with them.

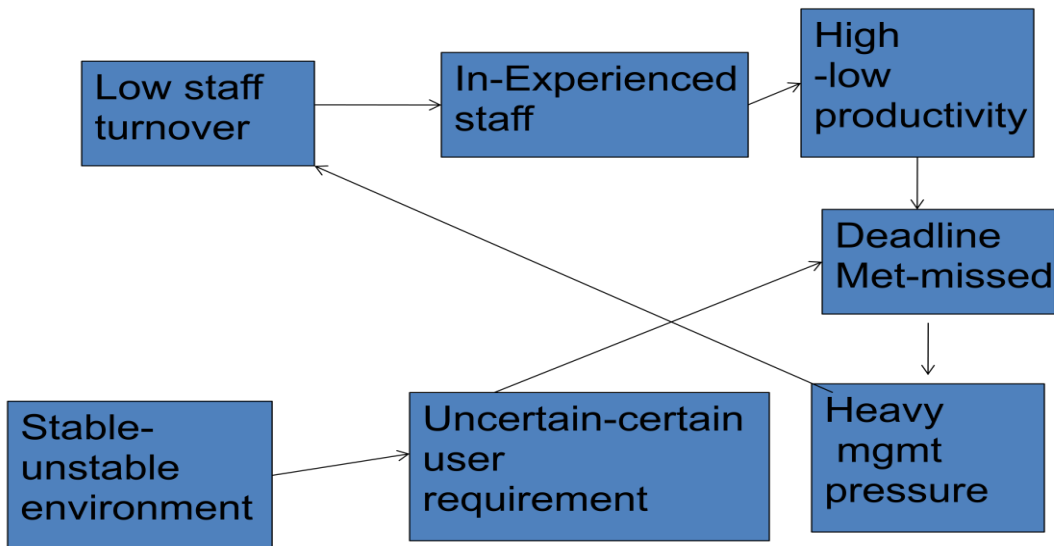
Brain storming

- ✓ Representative of main stakeholders can be brought together ,and a plan is drafted.
- ✓ It is used to identify the possible solutions to the problem.
- ✓ All stakeholders have a meeting and risk in the projects are discussed.

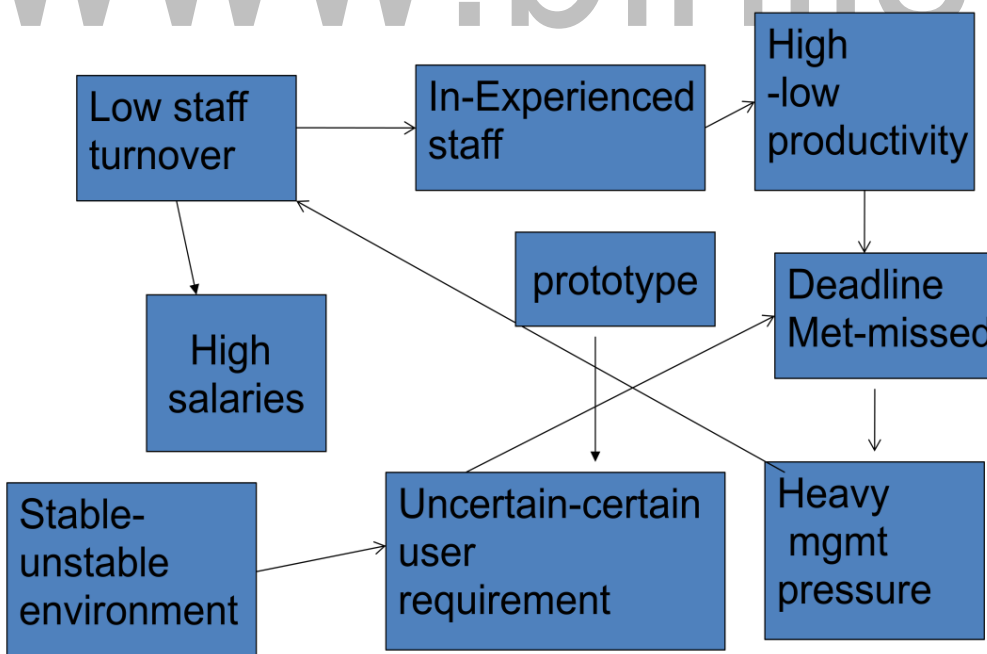
Casual mapping

- ✓ One way of identifying possible threats to the success of a project & measures that might eliminate & reduce them is the use of casual mapping.
- ✓ Casual maps & diagrams represent chains of causes & effects that will influence outcomes in particular area

✓ Example: Casual map of problem area



Casual map of problem area with solution



Risk Analysis

Risk exposure (RE) = (potential damage) x (probability of occurrence)

Ideally

Potential damage: a money value e.g. a flood would cause £0.5 millions of damage **Probability** 0.00 (absolutely no chance) to 1.00 (absolutely certain) e.g. 0.01 (one in hundred chance)

If there were 100 people chipping in £5,000 each, there would be enough for the 1 in 100 chance of the flooding. If there were 2 floods then the system collapses! Exercise

in the textbook is strongly recommended to explore these issues. In practice, with project risks, these quantitative approaches are usually impractical and more qualitative approaches are used instead. See the next overhead.

$$RE = £0.5m \times 0.01 = £5,000$$

Crudely analogous to the amount needed for an insurance premium

	<i>Hazard</i>	<i>Likelihood</i>	<i>Impact</i>	<i>Risk exposure</i>
R1	Changes to requirements specification during coding	1	8	8
R2	Specification takes longer than expected	3	7	21
R3	Staff sickness affecting critical path activities	5	7	35
R4	Staff sickness affecting non-critical activities	10	3	30
R5	Module coding takes longer than expected	4	5	20
R6	Module testing demonstrates errors or deficiencies in design	1	10	10

Table: Part of Amanda risk exposure assessment

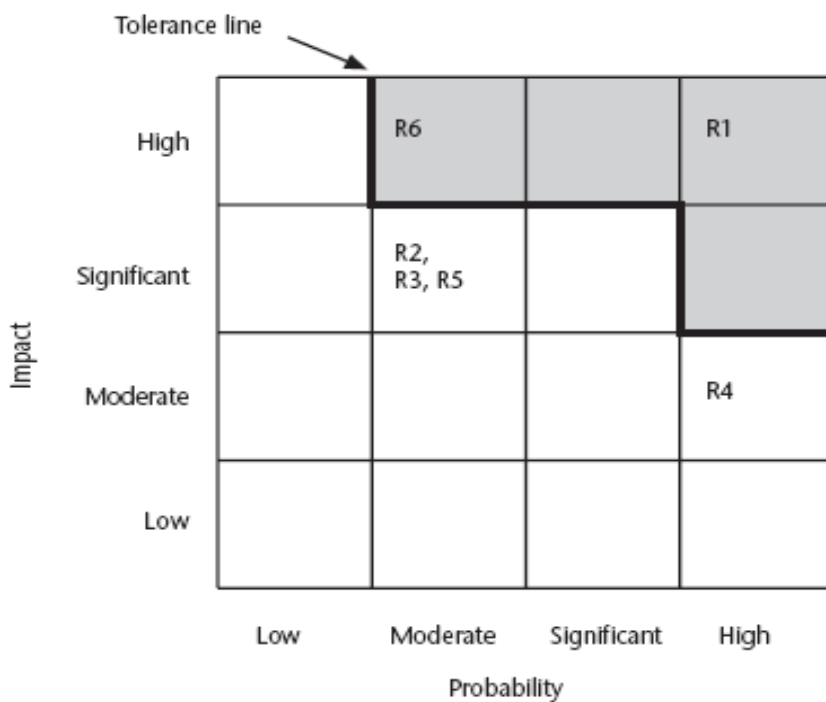
Table: Risk probability: qualitative descriptors

Probability level	Range
High	Greater than 50% chance of happening
Significant	30-50% chance of happening
Moderate	10-29% chance of happening
Low	Less than 10% chance of happening

Table: Qualitative descriptors of impact on cost and associated range values

Impact level	Range
High	Greater than 30% above budgeted expenditure
Significant	20 to 29% above budgeted expenditure
Moderate	10 to 19% above budgeted expenditure
Low	Within 10% of budgeted expenditure.

Probability impact matrix



- R1, R2 etc refer to particular risks (See Table 7.4 in the textbook). They are located on the grid according to the likelihood and impact ratings that have been allocated to them. A zone around the top right hand corner of the grid can be designated and risks falling within that zone are treated as requiring urgent action.

Risk planning:

Risks can be dealt with by:

- **Risk acceptance** – the cost of avoiding the risk may be greater than the actual cost of the damage that might be inflicted
- **Risk avoidance** – avoid the environment in which the risk occurs e.g. buying an OTS application would avoid a lot of the risks associated with software development e.g. poor estimates of effort.
- **Risk reduction** – the risk is accepted but actions are taken to reduce its likelihood e.g. prototypes ought to reduce the risk of incorrect requirements
- **Risk transfer** – the risk is transferred to another person or organization. The risk of incorrect development estimates can be transferred by negotiating a fixed price contract with an outside software supplier.
- **Risk mitigation** – tries to reduce the impact if the risk does occur e.g. taking backups to allow rapid recovery in the case of data corruption

Risk acceptance

- This is do nothing option.
- We would decide that damage inflicted by some risk would be less than cost of action.

Risk avoidance

- Some activities are so prone to accidents that it is best to avoid them
- If u are worried about crocodiles then don't go into the water
- When Manager will decide to avoid the risk he will buy an off the shelf components.

Risk reduction

Risk reduction leverage = $(RE_{\text{before}} - RE_{\text{after}}) / (\text{cost of risk reduction})$

RE_{before} is risk exposure before risk reduction e.g. 1% chance of a fire causing £200k damage

RE_{after} is risk exposure after risk reduction e.g. fire alarm costing £500 reduces probability of fire damage to 0.5%

- If you think in terms of the analogy to insurance. An insurance company might reduce the fire insurance premium from £2k to £1k on condition that a fire alarm is installed. The insured would save £1k a year by investing £500 so it would be worth doing.

$$RRL = (1\% \text{ of } £200k) - (0.5\% \text{ of } £200k) / £500 = 2$$

$RRL > 1.00$ therefore worth doing

Risk mitigation

- Risk mitigation is action taken to ensure that impact of risk is lessened when it occurs.
- It tries to reduce the impact if the risk does occur e.g. taking backups to allow rapid recovery in the case of data corruption

Risk transfer

- Risk is transferred to another person or organization
- With software projects example would be where a software development task is outsourced to an outside agency for a fixed fee.

Evaluating risk to schedule

- We use PERT technique
 - Use to evaluate the effects of uncertainty
 - PERT require three estimates
 - ✓ Most likely time
 - ✓ Optimistic time
 - ✓ Pessimistic time
 - Most likely time --The time we would expect the task to take under normal circumstances, denoted by: -m
 - Optimistic time—shortest time in which we could expect to complete the activity, denoted by a.
 - Pessimistic time—worst possible, denoted by b
- $$t_e = (a + 4m + b) / 6$$
- Calculate standard deviation for each project events $s = (b - a) / 6$
 - Calculate z value for each event that has target date $z = (T - t_e) / s$
- where
- t_e expected date
- T target date

Sequencing and Scheduling Activities

- Project and its activities must be clearly defined to achieve the target. An activity plan will contain the following factors:
 - A project is basically, composed of number of interrelated activities.
 - The initiation of a project happens only if atleast one activity is ready to start.
 - An activity is clearly defined with its start and end point that produce good deliverables.
 - Activity requiring resources must be analyzed well in advance and made available during the execution.
 - Some activities would depend on other activities for them to complete.
 - A project can attain its completion only when all activities have been completed.

Approaches to Identify Activities

- The various approaches used in identifying activities are:
 - Activity-based approach
 - Product-based approach
 - Hybrid approach

Activity-based approach

- In the activity-based approach, all the activities are listed and created for the project.
- This is achieved by a brainstorming session where the entire project team analysis the various activities needed at different stages with the help of similar projects.
- This approach usually generates the list of activities using a work breakdown structure (WBS).
- WBS helps in identifying the lowest level of effort i.e. the task required to complete a project by breaking down into lower sets of tasks.

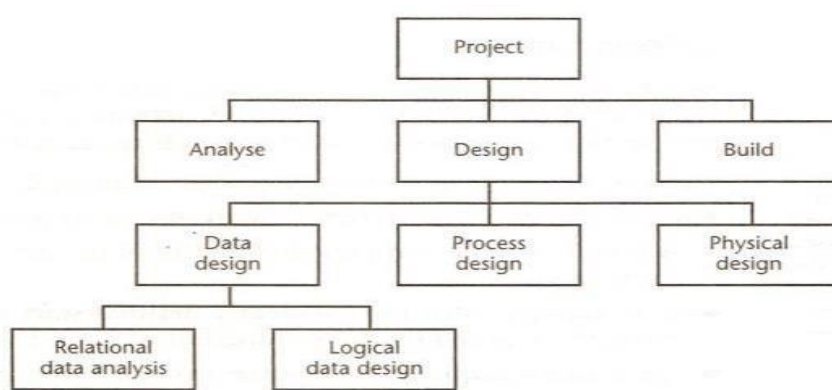


Figure - Activity-based approach Work Breakdown Structure

- Task defined at lower level includes everything that is required to complete the task at the higher level.
- The work breakdown structure provides an in-depth knowledge about the lowest level of activity that has to be completed.
- WBS is a refined structure that clearly defines the milestones that has to be achieved in accomplishing a specific task.
- The ordering of sequence of activities can also be done in this approach by defining those activities that have to be completed for others to start.
- In a purely activity-based approach, activities are identified and defined in five levels:
 - **Level 1** : Project – goals, objectives defined
 - **Level 2**: Deliverables – software, manuals, training
 - **Level 3** : Components – work items, modules, tests
 - **Level 4** : Work-packages – major work items, related tasks
 - **Level 5** : Tasks – responsibility of an individual in accomplishing it

Product-based approach

- The product-based approach produces a product breakdown structure along with a product flow diagram.
- The approach accepts the products as inputs which is transformed into an ordered list of activities.
- Product Flow Diagram do not leave out any activity from its ordered list and adopts a methodology which clearly specifies what are the products required and what are the activities required to produce the product.

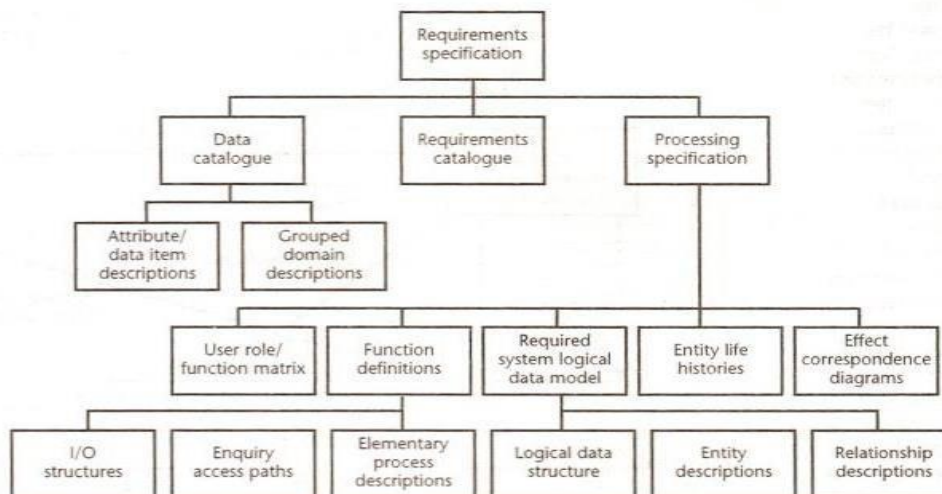


Figure - SSADM Product Breakdown Structure

- Using Structured Systems Analysis and Design Method (SSADM), a generic activity network can be derived for a project-specific product breakdown structure.
- The development of a PFD indicates the sequence of activities of the activity network.

Hybrid approach

- WBS deals with list of final deliverables whereas PBS deals in producing the products using the product flow diagram.
- Hybrid approach combines both the activity-based and product-based approach to structure both activities and products.
- Structuring of product-based or activity-based approach depend on the nature of the project type.

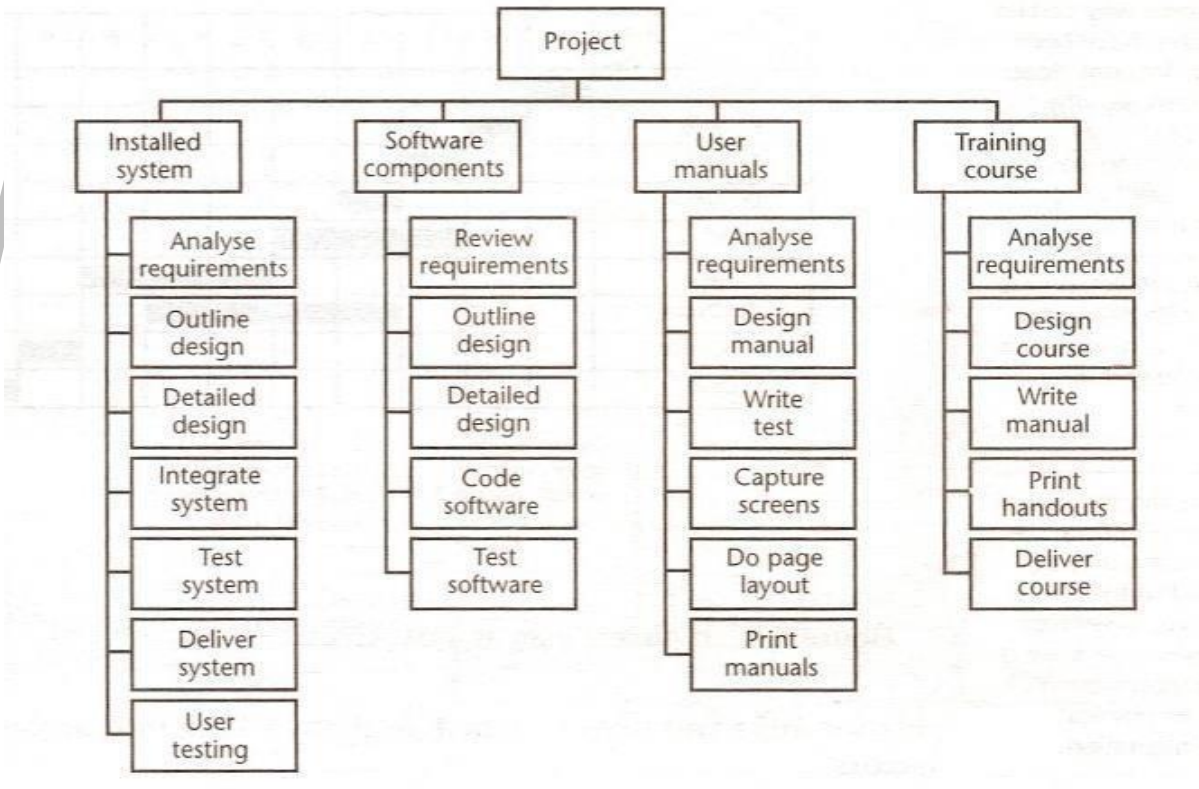


Figure - Hybrid Approach combining Activities and Products

Sequencing and scheduling activities

- Scheduling is required for every activity that is planned along with the resources and can be represented using a bar chart.
- The chart describes the nature of the development process and the resources available for completing the specified activities

Weeks	1	2	3	4	5	6	7	8	9	10	11	12
Person												
Requirements	■											
Design Module1		■										
Design Module2			■									
Design Module 3				■								
Code Module1			■	■	■							
Code Module2				■	■	■	■	■				
Code Module 3				■	■	■	■	■	■			
Integration									■			
System Acceptance										■	■	■

Figure - Bar chart representing Scheduling

- The chart defines two factors: sequencing of tasks and the schedule of the task. Scheduling includes the staff availability and the activities allocated to them.
- Combining sequencing – scheduling approach is suitable only for smaller projects and needs to be separated for complex projects as individual process.
- In case of larger projects, the logical relationship between the activities are grouped together and then scheduled for resources.