NIILM University

Project Scheduling Techniques

Subject: PROJECT SCHEDULING TECHNIQUES **Credits: 4**

SYLLABUS

Resource Scheduling

Introduction, Project Stages, Project Constraints, Resource Constraints, Resource Aggregation, Resource Leveling, Time-Constrained Network, Computerized Resource Scheduling.

Resource Allocation Method

Introduction, Methods, Resource Allocation Methods, Securing Project Rescheduling.

Splitting and Multitasking

Multi-Tasking, Multi-tasking and project performance, Is Multi-tasking really so prevalent? Purpose of Multitasking, Stop Multitasking, Exposure of Multi tasking.

Multi Project Resources Scheduling

Introduction, Multiple Projects, Methods, Resource allocation syndrome.

Critical Chain Scheduling

Introduction, Critical Chain Schedules, Resource Behaviors and Risk Mitigation, Project Control with Buffer Management, Buffer Management and Risk Mitigation, Project development role.

Critical Chain Scheduling Methods

Introduction, Concept, Planning with CCM, Introduce Buffers, Monitoring the project, Estimating and Scheduling, Multi-project Environment.

Application of Critical chain scheduling

Introduction, Problems and Challenges, Challenges, Benefits, Projects, The critical chain - special case.

Suggested Readings:

Construction Project Scheduling and Control, Saleh Mubarak, John Wiley and Sons

Project Scheduling: a research handbook, Erik L. Demeulemeester and Willy S. Herroelen, Kluwer Academic Publishers

Project Scheduling Techniques

CHAPTER 1
Resource Scheduling

Learning Objectives

- Describe the types of project constraints.
- Understand the nature of resource constraints.
- Explain the steps and issues involved in scheduling resources in a project environment.
- Explain the benefits of resource scheduling.

1.1 Introduction

Can you envision starting a long car trip to an unfamiliar destination without a map or navigation system? You're pretty sure you have to make some turns here and there, but you have no idea when or where, or how long it will take to get there. You may arrive eventually, but you run the risk of getting lost, and feeling frustrated, along the way. Essentially, driving without any idea of how you're going to get there is the same as working on a project without a schedule. No matter the size or scope of your project, the schedule is a key part of project management. The schedule tells you when each activity should be done, what has already been completed, and the sequence in which things need to be finished.

Luckily, drivers have fairly accurate tools they can use. Scheduling, on the other hand, is not an exact process. It's part estimation, part prediction, and part 'educated guessing.' Because of the uncertainty involved, the schedule is reviewed regularly, and it is often revised while the project is in progress. It continues to develop as the project moves forward, changes arise, risks come and go, and new risks are identified. The schedule essentially transforms the project from a vision to a time-based plan.

1.1.1 Schedules also help you do the following:

- They provide a basis for you to monitor and control project activities.
- They help you determine how best to allocate resources so you can achieve the project goal.
- They help you assess how time delays will impact the project.
- You can figure out where excess resources are available to allocate to other projects.

- They provide a basis to help you track project progress.
- With that in mind, what's the best way of building an accurate and effective schedule for your next project?
- Project managers have a variety of tools to develop a project schedule – from the relatively simple process of action planning for small projects, to use of Gantt Charts and Network Analysis for large projects. Here, we outline the key tools you will need for schedule development.

1.1.2 Schedule Inputs

You need several types of inputs to create a project schedule:

- Personal and project calendars – Understanding working days, shifts, and resource availability is critical to completing a project schedule.
- Description of project scope – From this, you can determine key start and end dates, major assumptions behind the plan, and key constraints and restrictions. You can also include stakeholder expectations, which will often determine project milestones.
- Project risks – You need to understand these to make sure there's enough extra time to deal with identified risks – and with unidentified risks (risks are identified with thorough Risk Analysis).
- Lists of activities and resource requirements – Again, it's important to determine if there are other constraints to consider when developing the schedule. Understanding the resource capabilities and experience you have available – as well as company holidays and staff vacations – will affect the schedule.
- A project manager should be aware of deadlines and resource availability issues that may make the schedule less flexible.

1.1.3 Scheduling Tools

Here are some tools and techniques for combining these inputs to develop the schedule:

- Schedule Network Analysis – This is a graphic representation of the project's activities, the time it takes to complete them, and the sequence in which they must be done. Project management software is typically used to create these analyses – Gantt charts and PERT Charts are common formats.

- Critical Path Analysis – This is the process of looking at all of the activities that must be completed, and calculating the 'best line' – or critical path – to take so that you'll complete the project in the minimum amount of time. The method calculates the earliest and latest possible start and finish times for project activities, and it estimates the dependencies among them to create a schedule of critical activities and dates. Learn more about Critical Path Analysis.
- Schedule Compression – This tool helps shorten the total duration of a project by decreasing the time allotted for certain activities. It's done so that you can meet time constraints, and still keep the original scope of the project. You can use two methods here:
- Crashing – This is where you assign more resources to an activity, thus decreasing the time it takes to complete it. This is based on the assumption that the time you save will offset the added resource costs.
- Fast-Tracking – This involves rearranging activities to allow more parallel work. This means that things you would normally do one after another are now done at the same time. However, do bear in mind that this approach increases the risk that you'll miss things, or fail to address changes.

1.2 Project Stages:

One of the biggest reasons that projects over-run is that the 'final' polishing and error-correction takes very much longer than anticipated. In this way, projects can seem to be '80% complete' for 80% of the time! What's worse, these projects can seem to be on schedule until, all of a sudden, they over-run radically.

A good way of avoiding this is to schedule projects in distinct stages, where final quality, finished components are delivered at the end of each stage. This way, quality problems can be identified early on, and rectified before they seriously threaten the project schedule.

1.2.1 Project Review

Once you have outlined the basic schedule, you need to review it to make sure that the timing for each activity is aligned with the necessary resources. Here are tools commonly used to do this:

- 'What if' scenario analysis – This method compares and measures the effects of different scenarios on a project. You use simulations to determine the effects of various adverse, or harmful, assumptions – such as resources not being available on time, or delays in other areas of the project. You can then measure and plan for the risks posed in these scenarios.
- Resource leveling – Here, you rearrange the sequence of activities to address the possibility of unavailable resources, and to make sure that excessive demand is not put on resources at any point in time. If resources are available only in limited quantities, then you change the timing of activities so that the most critical activities have enough resources.
- Critical chain method – This also addresses resource availability. You plan activities using their latest possible start and finish dates. This adds extra time between activities, which you can then use to manage work disruptions.
- Risk multipliers – Risk is inevitable, so you need to prepare for its impact. Adding extra time to high-risk activities is one strategy. Another is to add a time multiplier to certain tasks or certain resources to offset overly optimistic time estimation.

After the initial schedule has been reviewed, and adjustments made, it's a good idea to have other members of the team review it as well. Include people who will be doing the work – their insights and assumptions are likely to be particularly accurate and relevant.

1.2.2 Key Points

Scheduling aims to predict the future, and it has to consider many uncertainties and assumptions. As a result, many people believe it's more of an art than a science. But whether you're planning a team retreat, or leading a multimillion-dollar IT project, the schedule is a critical part of your efforts. It identifies and organizes project tasks into a sequence of events that create the project management plan. A variety of inputs and tools are used in the scheduling process, all of which are designed to help you understand your resources, your constraints, and your risks. The end result is a plan that links events in the best way to complete the project efficiently.

1.3 Project Constraints

The primary impact of project constraints is the likelihood of delaying the completion of the project. There are three types of project constraints: technological, resource and physical. The technological constraints relate to the sequence in which individual project activities must be completed. For example, in constructing a house, pouring the foundation must occur before building the frame. Resource constraints relate to the lack of adequate resources which may force parallel activities to be performed in sequence. The consequence of such a change in network relationships is delay in the completion date of the project. Physical constraints are caused by contractual or environmental conditions. For example, due to space limitations an activity such as painting a wall may have to be performed by only one person.

In general, from a scheduling perspective, projects can be classified as either time constrained or resource constrained. A project is classified as time constrained in situations where the critical path is delayed and the addition of resources can bring the project back on schedule and the project completed by the required date. However, the additional resource usage should be no more than what is absolutely necessary. The primary focus, for purposes of scheduling, in time constrained projects is resource utilization. On the other hand, a project is resource constrained if the level of resource availability cannot be exceeded. In those situations where resources are inadequate, project delay is acceptable, but the delay should be minimal. The focus of scheduling in these situations is to prioritize and allocate resources in such a manner that there is minimal project delay. However, it is also important to ensure that the resource limit is not exceeded and the technical relationships in the project network are not altered.

1.4 Resource Constraints

1.4.1 Definition

The first step in resource modeling is to decide exactly what resources are considered important enough to be modeled. While most resource modeling is concerned with people or workers (such as welders or computer programmers), it may also include other resources such as machines (such as a computer of a particular specification), or space on a project where space is restricted and where this restriction limits the amount of other resources which can be deployed at any one time. Often resources are specified in terms of the number of units of resource required, e.g., 5 welders or 3 computer programmers. Alternatively, resources may be specified in terms of the hours or days that a specific resource is required, e.g., 40 welder hours or 24 computer programmer days. Resources may be considered as consumable, such as materials that may be used once and once only, or non-consumable, such as people, which may be used again and again. The way in which consumable resources are used is not critical as long as they are used efficiently. However, the way in which non-consumable resources are used can have a significant impact on the project. For example, there is a significant difference between requiring 16 units of a non-consumable resource for one week, thus requiring 16 units to be made available at that time, and requiring 1 non-consumable unit for 16 weeks, thus only requiring 1 unit which can be reused 16 times.

Resource modeling is therefore mainly concerned with non-consumable resources with an important caveat. It should never be assumed that the quantity of resources deployed and the task duration are inversely related. Thus one should never automatically assume that the work that can be done by one man in 16 weeks can actually be done by 16 men in one week. Furthermore, there are many situations in which tasks may have to be carried out in a serial fashion, while in other situations; only one or two persons can be usefully employed due to a limited number of workers. Understanding the nature of the job and the size of the work team needed to do the job is an essential aspect of resource modeling. Resource definition may also include the creation of resource profiles which show how many units of each resource are available for use in the project at any given time. In multi-project situations, this is not an easy matter, as resources may be required to work on several projects simultaneously and there determination of the resources required for one project must also consider the use of the same resources for other projects.

1.4.2 Constraints

The most important resources that project managers have to plan and manage on day-to-day basis are people, machines, materials, and working capital. Obviously, if these resources are available in abundance then the project could be accelerated to achieve shorter project duration. On the other hand, if these resources are severely limited, then the result more likely will be a delay in the project completion time. Depending on the type of resources, the costs of providing an abundance of such resources to accelerate project completion time can be very high. However, if resources are readily available and excess premiums are not incurred to use them on the project, then project cost should be low, as some project costs are resource related while others are likely to be time dependent. In general, projects with a shorter duration are less expensive. The longer the duration of the project, the higher will be overall project cost due to the increase in fixed costs such as overheads. The reality is that as long as the work on a project is ongoing it will continue to draw resources into its orbit. Whatever the parameters of the project, it is unlikely that the relationship between cost and duration is linear. For any particular project, the decision to place the project on the curve between the point of least duration with its associated higher resource requirements and a point of increased duration with its associated lower resource requirements depends on the particular parameters of the project.

When a project plan is first devised it is likely that the plan will identify peaks of resource requirements. However, given the finite nature of resource availability, it may be impractical to meet such peak resource needs. Ideally, there should be an even demand for resources over the entire project duration, with a smooth increase at the beginning of a project and a smooth decrease at the end. Given the limited nature of resources, thoughtful consideration should be given to the project resource requirements; the project plan should be refined when necessary so that it is practical. The process of refining the plan to effectively manage and schedule resources (sometimes referred to as resource modeling) comprises four major stages: resource definition, resource allocation, resource aggregation, and resource leveling (which includes resource smoothing).

1.4.3 Allocation

Resource allocation, also called resource loading, is concerned with assigning the required number of those resources identified in the previous step to each activity identified in the plan. More than one type of resource may be attributed to a specific activity. For example, fixing the plates on a ship's hull may require 10 fitters, 20 welders, 15 laborers and a certain type of welding machine. From a practical standpoint, resource allocation does not have to follow a constant pattern; some activities may initially require fewer resources but may require more of the same resources during the later stages of the project. At this stage, the impact of any resource allocation decision is not known and we cannot yet answer questions such as:

- Is lack of resources on this particular activity having an adverse effect on the duration of the whole project? Such an activity is more likely to be on the critical path.
- By excessive use of resources are we completing this activity more quickly than necessary in terms of the overall project duration? Such an activity is not likely to be on the critical path.

1.5 Resource Aggregation

Resource aggregation, or resource loading, is simply the summation, on a period-by-period basis, of the resources required to complete all activities based on the resource allocation carried out in the previous stage. The results are usually shown graphically as a histogram. Such aggregation may be done on an hourly, daily, or weekly basis, depending on the time unit used to allocate resources. When a bar chart is used as the planning tool, the resource aggregation is fairly simple and straightforward. For a given bar chart, there is a unique resource unit aggregation chart which can be drawn underneath the bar chart. However, a separate graph will be required for each resource unit. An example is shown in Figure 1.1 below, where, for a particular resource, the required resource units for each time period are annotated on the bar chart. The total number of resource units for each time period can then be summed and a resource aggregation or load chart can be produced.

Week / Activity	1	2	3	4	5	6	7	8	9
A	10	10							
B		8	8	6					
C				2	6				
D				2	6	10	10	8	
E								6	6
Total resource units requirement	10	18	8	10	12	10	10	14	6

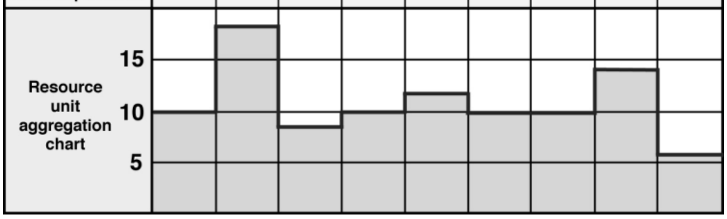


Figure 1.1 Resource Unit Aggregation Chart

However, when a network is used for planning, the resource aggregation procedure is not so simple or straightforward. As the network is not drawn to a time-scale, there is not a direct link between the network and the demand for resources. Therefore, a schedule must be prepared which tabulates activities in terms of time. However, this highlights another difficulty, namely that those activities which are not on the critical path do not have fixed starting and finishing times but are constrained by the earliest and latest starting and finishing times. However, this seeming difficulty offers the planner considerable scope for adjusting the demand for resources. This will be discussed, but the limits, within which resources can be adjusted, without extending the overall project duration, are the resource requirements between the earliest starting times and the latest starting times. This is illustrated in Figure 1.2, which shows the differing resource requirements that arise when both earliest and latest start times are considered and also highlights the resource requirements for those activities which are on the critical path.

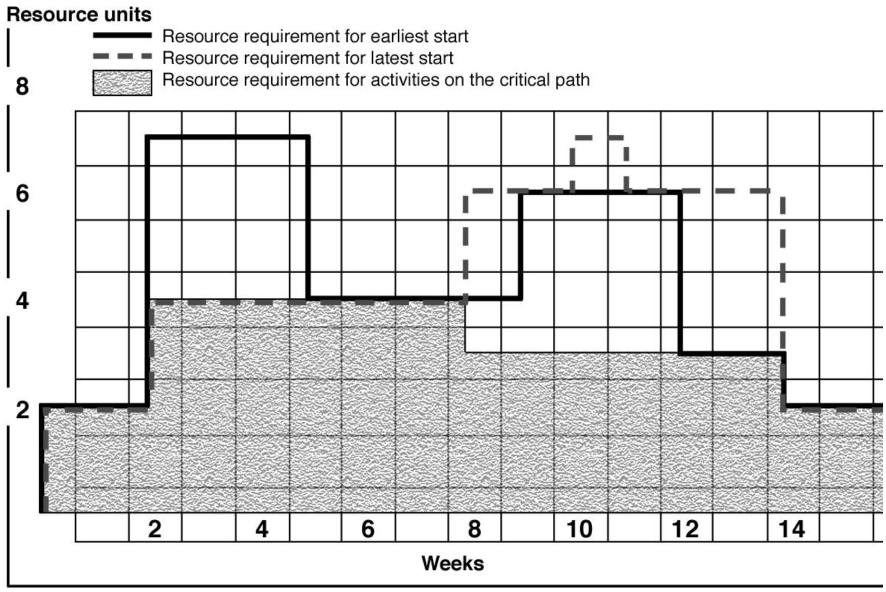


Figure 1.2 Resource Unit Aggregation Chart Showing Resource Requirements

1.6 Resource Leveling

Having established the resource requirements through resource allocation and aggregation, we will now examine the next phase of the planning and resource management process--resource leveling. We will now compare those requirements with resource availability by developing resource profiles. Disregarding factors such as economic considerations, if sufficient resources are available so that supply always exceeds demand then, we should have no problem. However, the most likely scenario is that, at some point, demand will exceed supply. Such a scenario is illustrated in Figure 1.3.

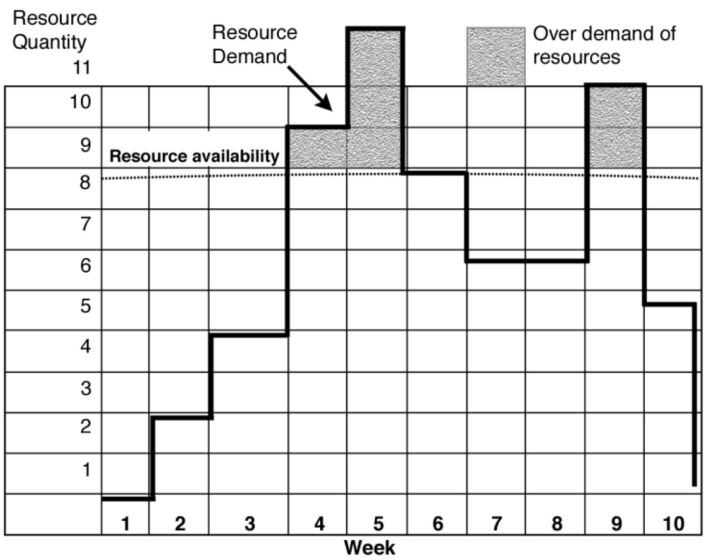


Figure 1.3 Resource Demand Compared to Resource Availability

Resource leveling is the process that ensures resource demand does not exceed resource availability. The ideal scenario would be a build up of resource usage at the beginning of the project and a reduction at the end of the project. However, the approach to resource leveling will also depend on whether resources are dedicated to a particular project or shared across several projects and whether there is a need to keep all resources fully utilized.

We will begin by analyzing the issues involved in resource leveling for a situation where a bar chart has been used as the primary planning technique for a simple project. The reason for this is that resource leveling must be considered within a time framework and bar charts are drawn to a time scale while networks are not. Examine Figure 1.1, where the time-scale for the activities comprising the project are shown in a bar chart, which also shows resource requirements for one particular resource unit. An examination of the bar chart and its associated resource chart in Figure 1.1 shows that improvements can be made to the level of resource requirements by:

- Delaying or bringing forward the start of certain activities
- Extending the duration of certain activities and so reducing the demand for resources over the duration of the activity or by a combination of both of these adjustments

However, there are problems with using the simple bar chart as a tool for resource leveling. For example, we do not have any information about the interdependency of tasks. Therefore, if we delay a task by starting later than originally planned or by extending the duration of the task, we cannot evaluate the exact impact this will have on the overall project. Referring to Figure 8.1 again, if we assume that the maximum amount of resource availability is 14 units, then we have a problem in week 2 because 18 units of resources are required in that week. In order to reduce the resource demand in week 2, we may have to extend Activity A into week 3 and spread the resource demand over three weeks, or delay the commencement of Activity B. However, the exact impact of these changes on the overall project duration cannot be easily determined.

Another issue is that the critical path(s) cannot be easily determined, although we may be able to deduce which activities are critical by inspection. Clearly, if we do not wish to extend the overall duration of the project we must avoid extending or delaying activities which are on the critical path. Finally, the availability of slack or float is not clear. Knowing this is important because it is this attribute that can be utilized to adjust our resource requirements.

Resource leveling can be accomplished more easily if resource requirements to complete an activity are expressed in terms of hours or days required. The definition of resource requirements using such units of measure can help us determine if an activity should be completed in a short time through the use of many resources or over a longer period of time through the use of fewer resources. In practice, however, there is a limit to the number of resources that can be deployed and, therefore, a limit to the amount by which any activity duration can be shortened.

We will now examine situations where networks are used as the primary planning method. Generally, there are two approaches to leveling and smoothing the resources required:

- **Time-limited resource considerations**
  In this case emphasis will be placed on completing the project within a specified time. This time will usually have been determined by network analysis. Adjustments in the timing of any activity, and the resources required at a given time, must be undertaken within the float (slack) available. Obviously there can be no adjustment of activities which are on the critical path.
- **Resource-limited resource considerations**
  In this case the project must be completed with the resources available even if this means extending the project duration. If the total resource demand exceeds the resource availability at any time then some of the activities must be delayed until there is sufficient resource availability.

1.6.1 Resource Smoothing

Resource smoothing is part of the resource leveling process. In itself, resource smoothing is the process that, not withstanding any constraints imposed during the leveling process, attempts to determine a resource requirement that is "smooth" and where peaks and troughs are eliminated. For example, even if 7 units of a given resource are available at any one time, utilizing 5 of these units each week is preferable to 4 one week, 7 the next, 2 the next and so on. Even if there is no limit to the amount of any one resource available, it is still desirable that resource usage is as smooth as possible. Given that the resource requirements of those activities on the critical path are fixed, some order or priority needs to be established for selecting which activity and which particular resource associated with this activity should be given priority in the smoothing process. In determining which activity should be given priority, a subjective judgment should be made about the type of resource (or resources) associated with each activity; priority should be given to the activities whose resources are considered to be most important. Beyond this consideration, activities should be ranked in order of total work content and total float or slack available for that activity. A useful device for prioritizing is to consider the ratio of total work content/total float remaining and give priority to activities with the highest value of this ratio.

Solving the resource scheduling problem for optimal solutions is extremely complex, particularly for large project networks with many different resource types. However, several heuristics are available to solve such problems. These heuristics allocate resources to activities to minimize project delay based on certain priority rules. The two most commonly used heuristics are the **serial** and the **parallel** methods. In the serial method of resource allocation, activities are sorted into a list and resources are allocated to each of these activities one at a time until resources are allocated to all activities. In the parallel method, however, resources are allocated on a period by period basis rather than each activity. In this method only those activities whose preceding activities have been completed will be considered. If two or more activities compete for the same resources, then allocation of resources is based on certain prescribed priority rules. Compared to the serial method, the parallel method has been the most widely used heuristic. The following priority rules, in the order presented, have been found to be the most effective in minimizing project delay.

- Minimum slack
- Smallest duration
- Lowest activity identification number

Regardless of the scheduling heuristic used, the primary impact of resource constrained scheduling is the loss of flexibility due to the reduction in slack. Furthermore, the reduction in slack also increases the number of critical or near-critical activities.

1.7 Time-Constrained Network

This example has several parts.

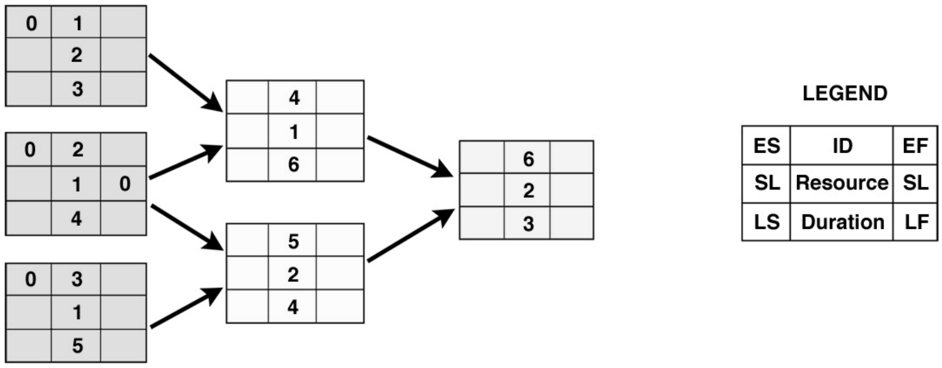


Figure 1.4 Time-Constrained Network Example

First, compute the early, late, and slack times for the activities in the network in Figure 1.4, assuming a time-constrained network. Which activities are critical? What is the time constrained project duration?

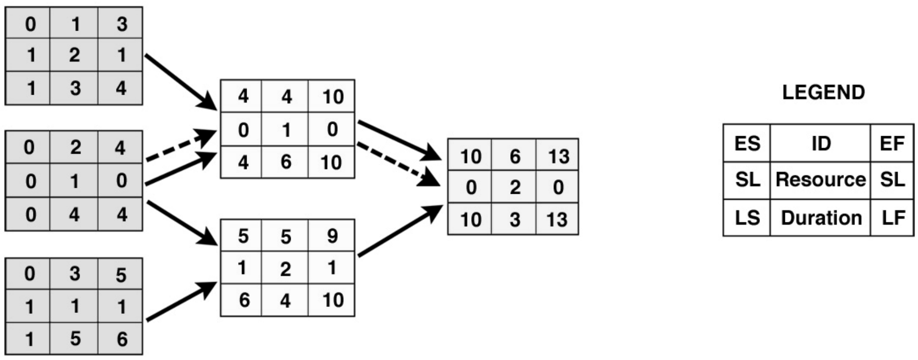


Figure 1.5 Time-Constrained Network Example Showing Early, Late, and Slack Times

Now, assume you are a computer using software that schedules projects by the parallel method and the following heuristics. Schedule only one period at a time!

- Minimum slack
- Smallest duration
- Lowest activity identification number

ID	RES	DUR	ES	LF	SL	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2	3	0	4	1	2	2	2													
2	1	4	0	4	0	1	1	1	1												
3	1	5	0,1,2,3	6	1,0, -1.-2	X	X	X	1	1	1	1	1								
4	1	6	4	10	0					1	1	1	1	1	1						
5	2	4	5,6,7,8	10	1,0, -1,-2						X	X	X	2	2	2	2				
6	2	3	10,11,12	13	0,1, -2											X	X	2	2	2	
Resources Scheduled					3	3	3	2	2	2	2	2	3	3	2	2	2	2	2	2	
Resources Available					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	

Figure 1.6 Scheduled Resource Load Chart with ES and Slack Updates

We see that the parallel method schedules resources to various activities through leveling and smoothing. This is accomplished in the above problem by delaying and reducing the slack on activities 3, 5 and 6. Using the load profiles presented above, graphical resource aggregation charts, similar to the ones presented earlier in this lesson, can be developed.

Next, keep a log of each activity change and the update you make each period--e.g., period 0-1, 1-2, 2-3, etc. The log should include any changes or updates in ES and slack times each period, activities scheduled and activities delayed. The log is shown in Table 1.1 below.

Table 1.1 Log of the Parallel Method of Scheduling

PERIOD	**ACTIVITY**	**CHANGES**
0-1	2	Schedule activity 2 first by the minimum slack rule
	1	Schedule activity 1
	3	Delay activity 3 ES to period 1. Reduce slack to 0.
	5	Delay activity 5 ES to period 6. Reduce slack to 0.
1-2	3	Delay activity 3 ES to period 2. Reduce slack to -1.
	5	Delay activity 5 ES to period 7. Reduce slack to -1.
	6	Delay activity 6 ES to period 11. Reduce slack to -1.

2-3	3	Delay activity 3 ES to period 3. Reduce slack to -2.
	5	Delay activity 5 ES to period 8. Reduce slack to -2.
	6	Delay activity 6 ES to period 12. Reduce slack to -2.
3-4	3	Schedule activity 3
4-5	4	Schedule activity 4
5-6	---	No changes
6-7	---	No changes
7-8	---	No changes
8-9	5	Schedule activity 5
9-10	---	No changes
10-11	---	No changes
11-12	---	No changes
12-13	6	Schedule activity 6

We see that the parallel method schedules resources to various activities through leveling and smoothing. The log presented above shows how this was accomplished in the above problem by delaying and reducing the slack on activities 3, 5, and 6.

Now, list the order in which you scheduled the activities of the project. Which activities of the schedule are now critical? The order is (2, 1, 3, 4, 5, 6) and the critical activities are 2, 3, 5, and 6 as these are the activities with the least or negative slack. Finally, recompute the slack for each activity given the new schedule. What is the slack for activity 1? 4? 5? For this, see the answer to the second question. The slack for 1 = (0), 4 = (2), and 5 = (0).

1.8 Computerized Resource Scheduling

The resource scheduling examples that we solved above used the manual approach. For large networks, however, this is not a feasible approach. Fortunately, all the better quality computer packages for project management, besides network analysis, also feature the ability to schedule activities taking into account resource constraints. Thus for most people engaged in project management today, a computerized approach is preferred. While a full description of the way in which current packages perform resource scheduling is beyond the scope of this topic, these packages commonly use the serial scheduling and parallel scheduling algorithms. The basic features of both these algorithms were described earlier in this lesson, even though the computer packages use more sophisticated versions of these algorithms. Given the nature of the resource constraints, each method may produce a feasible schedule; however, the schedules need not necessarily be the same. Furthermore, if the same problem is solved by two different project management packages, different schedules may be generated.

Review Questions

1. Why is it important of Resource modeling?
2. What is resource levelling?
3. What is parallel method schedules resources?
4. Give some **resource scheduling examples**?

Discussion Questions

Discuss the tools required in Project reviewing?

Application Exercises

1. Explain the different types of project constraints?
2. What are scheduling tools? Explain with examples?
3. Explain the primary impact of project constraints?

CHAPTER 2

Resource allocation method

Learning Objectives

- To understand about Resource allocation.
- Understand the **resource allocation report**.
- Explain the methods of allocation of resources.
- To gain the idea of Resource leveling.

2.1 Introduction

Resource allocation is the process of determining the best way to use available assets or resources in the completion of a given project. Companies attempt to allocate resources in a manner that helps to minimize costs while maximizing profits, typically by using strategic planning methods to structure the operation, establish operational guidelines, and implement policies and procedures that move the business toward the achievement of its goals. The actual process will vary, depending on the type of project undertaken and the collection of tangible and intangible assets on hand.

As it relates to project management in general, resource allocation involves the scheduling and use of materials, equipment, and labor in order to achieve the identified goal. This means that the allocation process will require determining how to arrange the plant floor to its best advantage, so that raw materials can move through the manufacturing process with the greatest degree of efficiency. At the same time, designing tasks so that employees can achieve the highest levels of production is also important. With the proper allocation and use of resources, it is possible to limit the waste of raw materials, generate high production rates per hour, and, in general, allow a company to produce more finished goods during a typical production day.

While the focus of this process is often on assigning or allocating tangible resources to different tasks necessary to the success of the project, this type of management strategy also takes into consideration intangible assets that may be present. For example, a new business that is attempting to make the best use of available resources may note that a particular employee has inherent talents that would benefit the company over the long term. Here, the company may choose to assist that employee in developing his or her talents, ultimately earning a return on the resources devoted toward that development. Many companies use this model to develop employees for promotion to supervisory and management positions in later years, effectively providing the business with a consistent supply of full-qualified leaders for the next generation.

Resource allocation often focuses on what is happening today, but the process can also be used to prepare for future scenarios. For example, a business may put together a contingency plan that allows for the redistribution of resources in the event that one or more of its product lines experiences a significant decrease in sales. Companies that operate multiple locations often design contingency plans that help to redistribute or reallocate resources in the event one of those locations is rendered inoperable by some type of disaster. This type of allocation preparedness allows the business to continue providing goods and services to customers with a minimum of interruption, which in turn helps to minimize losses and keep profits as high as possible under the new circumstances.

2.1.1 Report

Imagine that you use your Quick Base application to manage projects and their related tasks. You've assigned fourteen tasks to Penny and they're all due on Friday. She'd never say it, but she can't possibly finish on time. Meanwhile, Fred's yapping to his buddies on the phone without a thing to do. If only there were a way to measure how much work you've put on each person's shoulders.

There is! It's Quick Base's Resource Allocation tool. This nifty feature can show you if you've over or under-committed a staff member, and let you make changes in a snap. The Resource Allocation report shows you what percentage of your resources' time is filled. At a glance you can see that Fred has assignments that fill only 20% of his week, while Penny's assignments add up to 250% of her 40 hour work week. If she can find another 60 hours, no problem. If not, you may want to transfer some of her tasks to Fred and others.

To access and configure the resource allocation report:

If you've converted your Microsoft Project plan into a Quick Base application using Quick Base's Synchronization tool, or created an application from Quick Base's Project Management app templates, your application Dashboard features a number of links.

If your application didn't start life as a Microsoft Project application or one of the templates mentioned above, you can still use this feature—as long as the table you want it to focus on includes the following fields:

- **Resource Name** - You need to have a field that includes a name of a resource. This is usually a user type field called **Resource Name** or **Assigned To**. **Note:** The resource allocation tool works only with regular user fields; it does not support the use of list-user fields.
- **Start** - This must be a date field.
- **Finish** - This also must be a date field.

If the table in question meets all these requirements, you can use the resource tool. But, you'll need to do some setup:

1. Sign into Quick Base.
2. Access the setup screen.

   Quick Base displays the Resource Allocation configuration screen.
3. Select the table from the dropdown which contains the task or assignment records you're tracking. After you do so, Quick Base displays additional fields.

   Tip: If your application contains an Assignments table that links Resources to Tasks, select the Assignments table.
4. Choose a resource field. Select the User field that specifies who's tasked with an item. Depending on your application, this field is probably named something like **Assigned To** or **Resource Name**.
5. Choose a start date field.

   To measure allocation, Quick Base needs to know which field you use to measure the duration of a job. Within the **Start Date** dropdown, select the name of the field which you use to specify the date a task begins.
6. Choose a finish date field.

   Round out the picture by telling Quick Base which field users enter a Finish or completion date. Select the field from the **Finish Date** dropdown.
7. Tell Quick Base how you measure staff contributions.

   In order to measure resource allocation, Quick Base needs to know how you assign work to each person. Within the **In the projects resources are assigned to tasks** section, select one of these three options:

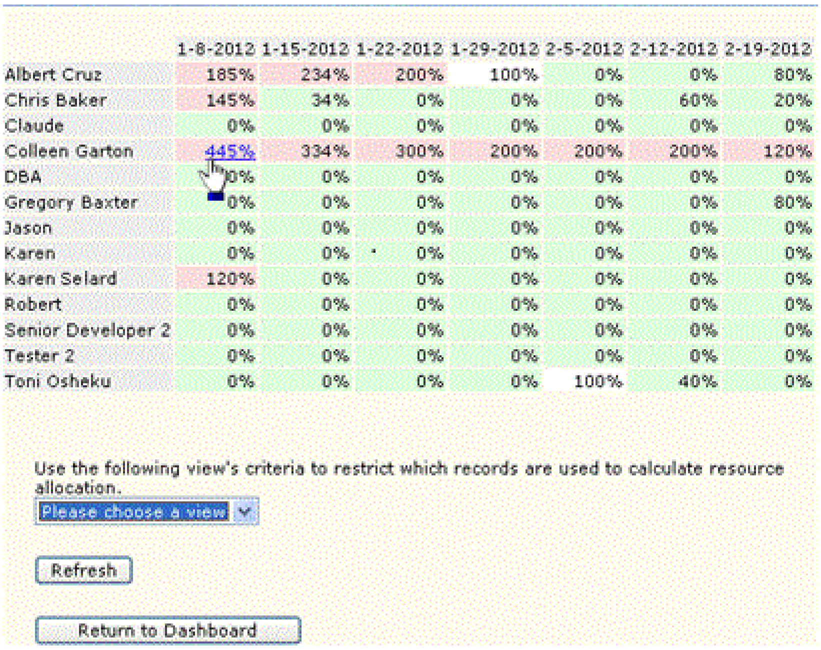
- **always at 100%.** Choose this radio button if your resources work full-time on the tasks you assign to them. With this setting, Quick Base counts each day in a task's duration as a 100% commitment. To get a better idea of how this works, consult the examples that follow discussion of your options.
- **by some % of the resource's time.** Select this option if any of your resources only complete a portion of a particular task. Quick Base will ask you to choose the field you use to measure percent effort. So, if you haven't already, you'll need to create a numeric percentage type field in your Tasks or Assignments table. The idea is, when you assign a task, you can indicate what percentage will be completed by the person you've assigned it to. Then the Allocation report adds this to its calculations. Read on to get some examples of how those calculations work.
- **by a specific amount of work (like days or hours).** If you track staff effort in increments of time, like days or hours, select this option. When you do, Quick Base asks you to choose the field you use to measure effort in time. so, if you haven't already, you'll need to create a numeric type field in your Tasks or Assignments table. When you create or assign a task, you'll use this field to type the number of hours or days an assigned staffer will work on that particular item. To get your Resource Allocation report to take this number into consideration, click the **Please choose a time loading field** dropdown and select this numeric field. Finally, beneath that dropdown, tell QuickBase if that field measures time in days or in hours by clicking the appropriate radio button. If you choose Hours, Quick Base lets you specify how many hours you and your colleagues work each day. Why? The program needs to know how long your workdays are.

8. Click **Display Resource Allocation**.
9. Save the report.

You've created a unique report whose details are stored in the URL you see in your browser's address bar. If this is a report you want to return to again and again, you'll need to create a shortcut to this URL. To do so, you can bookmark the page in your browser. If you want to share this report with your users, go one better and create a hyperlink to the report on your application's Dashboard page. Add a new hyperlink that opens the report you created or replace the destination of **Report on Resource Allocation** link that comes with many project management app templates. Quick Base displays the Resource Allocation table. If you decide you want to change any settings you just made, click your browser's back button to return to the configuration screen.

2.1.2 Reading the Resource Allocation Report

When you've set all your preferences and clicked Display, the report you designed appears. Each row is a resource and each column represents a week indicated by the date of the Sunday that kicks off each week. The percentages you see represent each person's allotted work for the week. But what does that percentage number really mean? QuickBase calculates that number based on the choices you made when you created the allocation report. Each figure represents the percentage of a week's work that a given resource is scheduled to be working on specific jobs.



	1-8-2012	1-15-2012	1-22-2012	1-29-2012	2-5-2012	2-12-2012	2-19-2012
Albert Cruz	185%	234%	200%	100%	0%	0%	80%
Chris Baker	145%	34%	0%	0%	0%	60%	20%
Claude	0%	0%	0%	0%	0%	0%	0%
Colleen Garton	445%	334%	300%	200%	200%	200%	120%
DBA	0%	0%	0%	0%	0%	0%	0%
Gregory Baxter	0%	0%	0%	0%	0%	0%	80%
Jason	0%	0%	0%	0%	0%	0%	0%
Karen	0%	0%	0%	0%	0%	0%	0%
Karen Selard	120%	0%	0%	0%	0%	0%	0%
Robert	0%	0%	0%	0%	0%	0%	0%
Senior Developer 2	0%	0%	0%	0%	0%	0%	0%
Tester 2	0%	0%	0%	0%	0%	0%	0%
Toni Osheku	0%	0%	0%	0%	100%	40%	0%

Use the following view's criteria to restrict which records are used to calculate resource allocation.

Please choose a view

Refresh

Return to Dashboard

.

When the Resource Allocation Report first displays, it includes information for ALL task or assignment records. If you want to see a specific subset (like only tasks belonging to a certain project or those scheduled to start after a particular date) you can specify that by selecting a report from the dropdown beneath the table.

2.1.2.1 Reallocating resources

The numbers in the report shown above are out of whack. How can you reallocate these resources? To do so, click on any value and Quick Base shows a list of the underlying task or assignment records. Even out the workload by editing them. Assign several to a different person, for instance. This report is just that: a report. It doesn't perform load balancing. You must do that manually.

2.2 Methods

2.2.1 Assignment Method

An assignment method is an approach to the allocation of resources, from personnel to equipment that will result in the most optimal distribution and utilization of those resources. Assignment methods are used not just in the business world, but also in organizational structures and a variety of other applications. There are many different ways to approach resource problems, and periodic reevaluations may reveal new ways to handle them, especially in changing work environments where needs and resources may change quickly.

Businesses use an assignment method to make budgeting decisions, deciding where to invest funds and how to distribute monies to different departments and projects. They may consider past performance, ongoing projects, and things in development when they decide how to allocate the assets. The goal is to make money available while discouraging waste in a department, to keep the department functional and lean. Companies may also want to retain funds for emergencies, investments, and other needs that could arise during their operations.

Equipment and facilities can also be allocated with an assignment method. Businesses have a finite number of physical resources like computers and warehouses, and need to use them effectively. It might devote new computers and resources like more bandwidth and storage to a department working on a big project, for instance, so the project's needs won't outstrip its available resources. Conversely, a small department might need much less, and would find new computers or equipment like tablets redundant for its operations.

People can also be treated as resources and sent to various departments and regions under an assignment method. This can commonly be seen with a sales force, where a company wants personnel in the right markets at the right times. It can recall salespeople to move them to different districts, beefing up representation where necessary and cutting back in communities where these personnel are not as necessary.

The same assignment method approach is used for things like assigning Internet protocol (IP) addresses, registration numbers for aircraft, liquor licenses, and a wide variety of other unique identifiers and privileges. The assignment method can help an agency decide how many to offer, and how to distribute the offer to make it fair and reasonable. In a county with a small population, for example, few drivers' license numbers are needed by the department of motor vehicles, while in an urban county with a big population; a huge number might need to be allocated.

An assignment of trade is a term that is used to describe a situation in which one of the parties involved in a forward trade decides to assign that trade to a party that was not part of the original deal. The use of this particular approach is more common with deals that involve mortgage-backed securities that are part of a deal in a to be announced (TBA) market, and is usually employed when there is a desire to avoid either the delivery of the securities involved or to get around making a delivery of those securities. This type of strategy can also be employed as a means of eventually trading all the relevant assets involved with a loan to that outside party, who in turn makes a covenant to orchestrate a delivery into the original to be announced trade.

The underlying purpose of an assignment of trade is usually to control how and when trading activity on the assets associated on a loan will be delivered in a TBA market. This is sometimes necessary to ensure that the maximum amount of return is generated from the deal, while also preventing the rise of any additional risk to the parties involved in the original deal. By involving a third party in the arrangement, it is easier to manipulate the delivery of one or more of the securities backing the mortgage loan, both in terms of either receiving or issuing that delivery. Under the best of circumstances, the strategy helps to forgo a loss that would have occurred otherwise while still providing the latest party in the arrangement to receive some sort of benefit from the deal.

The strategy of an assignment of trade goes beyond simply selling one of the underlying securities to a third party. Typically, the deal will include a covenant by current holders to sell entire loans to that third party, who in turn is also agreeing to purchase those whole loans. An originator of a mortgage loan can use this process to effectively reduce risk associated with holding the loan, while the buyer has the chance to use the transaction to generate a steady stream of income from the ownership of those mortgage-backed securities associated with the acquired loans.

Like any type of investment strategy, an assignment of trade does carry some degree of risk. Default on the mortgage loans associated with the securities can mean losses to whomever currently holds those assets. This means that if the assignment of trade is complete when the default on the mortgages involved occurs, it is the third party who ultimately bears the loss. At the same time, if those mortgage-backed securities are associated with loans that have floating or variable rates of interest, there is also the opportunity for that investor to enjoy a greater return than originally projected.

2.2.2 Resource Leveling

Resource leveling is a type of allocation process that seeks to match the demand for specific resources with the availability of those same resources. The idea is to make sure that when and as those resources are needed as part of the day to day process of doing business, they are on hand and ready for use. Managing this balance between demand and availability typically requires accurately projecting future needs and taking steps to acquire the resources in a manner that benefits the production process.

One way to understand the concept of resource leveling is to consider a manufacturing plant that requires certain raw materials in order to produce a line of goods. In order to keep costs within reason, the business will project the influx of orders from customers and the number of finished units required to fill those orders in a timely manner. That information is used to determine the volume of raw materials needed to create those units within the time frame allotted. Orders are placed so that the raw materials arrive just ahead of when they are needed to keep the production flowing without any interruption.

It is important to note that resource leveling is not just about knowing what is needed to keep a production line going, but when to have those resources delivered and available. In many nations, taxes are assessed on the inventories of raw materials that are kept on hand. By structuring the delivery of those materials so they do not languish in a warehouse for weeks on end before entering the production process, companies enjoy less of a tax burden, a move that helps to enhance the overall profitability of the operation.

At the same time, resource leveling requires accounting for any shifts in demand that would also affect the arrival of resources at the plant site. For example, if a large customer should cancel an order, the business would in turn revise the delivery schedule for various lots of raw materials so that only the resources needed to fill other orders are received. In the event that a new customer places a large order and requests delivery as soon as possible, there may be a need to work with suppliers to increase the frequency of materials deliveries in order to keep up with the increased demand. From this perspective, resource leveling should be viewed as an ongoing process and not a single event that is considered complete at any given point in time.

The allocation of resources is an economic theory concerned with the discovery of how nations, companies or individuals distribute economic resources or inputs in the economic marketplace. Traditional business inputs are land, labor and capital. Entrepreneurship or enterprise may also be included in this group since entrepreneurs or enterprises are usually responsible for the allocation of resources. The economic concept of private resource allocation is an important area of study in the free market system and the economic theory known as "the invisible hand."

Many economists believe that "the invisible hand" theory is the driving force for allocating resources in the free market economic system. Under this theory, the allocation of resources is created through the self interest, competition and supply and demand of individuals and companies in the economic marketplace. Individuals and companies distribute resources through self regulation by using only the inputs they need and selling or giving away their leftover economic resources or inputs. Through this allocation of resources, the economic market place grows and expands as more individuals and companies have access to resources.

Each economic resource or input has an important place in the economic marketplace. Historically, land includes natural resources, such as timber, wildlife, soil and rock. In modern terms, this economic resource includes buildings, equipment or other major assets owned by individuals and companies needed to produce consumer goods or services. Labor is the manpower companies use to transform raw economic resources into finished goods or services. Capital usually represents the money acquired or made from the sale of consumer goods and services produced by the other two economic resources. Economics is concerned with how these resources are allocated to determine the best use for a nation’s natural economic resources and the labor of its citizens.

An allocation of resources analysis also looks at the costs involved with acquiring economic resources or inputs and how efficiently these resources are transformed into valuable goods or services. This analysis may also attempt to determine the competitive advantage nations or companies have when using their economic resources or inputs to create goods or services. Rather than using inefficient production processes or methods to develop goods, nations or companies may be better off selling their economic resources to other nations or companies and earn higher amounts of capital resources. Using the competitive advantage method for the allocation of resources can be a beneficial way to improve the quality of life of individuals living in the nation or working for private companies.

2.3 Resource Allocation Methods

Resource allocation methods determine what method or policy the Database Resource Manager uses when allocating a particular resource to a resource consumer group or resource plan. Oracle provides the following methods shown in Table 2.1 for allocating resources to a resource consumer group or resource plan:

Table 2-1 Methods for Allocating Resources

Method	**Resource**	**Resource Recipient**
Round-robin method	CPU allocation to sessions	Resource consumer groups
Emphasis method	CPU allocation to consumer groups	Resource plans
Absolute method	Parallel degree limit	Resource plans

2.3.1 CPU Allocation for Resource Plans: Emphasis Method

The emphasis CPU allocation method determines how much emphasis is given to sessions in different consumer groups in a resource plan. CPU usage is assigned using levels from 1 to 8, with level 1 having the highest priority. Percentages specify how to allocate CPU to each consumer group at each level.

The following rules apply for the emphasis resource allocation method:

- Sessions in resource consumer groups with non-zero percentages at higher-priority levels always get the first opportunity to run.
- CPU resources are distributed at a given level based on the specified percentages. The percentage of CPU specified for a resource consumer group is a maximum for how much that consumer group can use at a given level. If any CPU resources are left after all resource consumer groups at a given level have been given an opportunity to run, the remaining CPU resources fall through to the next level. If a consumer group does

not consume its allotted resources, then the resources are passed to the next level, not given to the other consumer groups at the same level.

- The sum of percentages at any given level must be less than or equal to 100.
- Any unused CPU time gets recycled. In other words, if no consumer groups are immediately interested in a specific period of CPU time (due to percentages), the consumer groups get another opportunity to use the CPU time, starting at level one.
- Any levels that have no plan directives explicitly specified have a default of 0% for all subplans/consumer groups.

The emphasis resource allocation method offers the following advantages:

- Setting percentages enables you to bring CPUs online and offline and to add and remove servers without having to change CPU percentages.
- The amount of CPU resources specified is not proportional to the number of servers, so there is a fine level of control even with a small number of servers.
- Setting percentages avoids the starvation problem associated with priorities. Users do not run at priorities; instead, they run based on the percentages specified for their resource consumer group. In addition, percentages can be used to simulate a priority scheme.

2.3,1,1 Parallel Degree Limit for Resource Plans: Absolute Method

The parallel degree limit allows the administrator to specify a limit on the degree of parallelism of any operation. This parameter is only allowed in directives that refer to resource consumer groups. Currently, the only resource allocation method for a limit on the degree of parallelism is the absolute method. Absolute refers to the fact that a number (rather than a percentage or fraction, for example) specifies how many processes may be assigned to an operation.

2.3.2 Parallelizing by Block Range

Oracle parallelizes a query dynamically at execution time. Dynamic parallelism divides the table or index into ranges of database blocks (rowid range) and executes the operation in parallel on different ranges. If the distribution or location of data changes, Oracle automatically adapts to optimize the parallelization for each execution of the query portion of a SQL statement.

Parallel scans by block range break the table or index into pieces delimited by high and low rowid values. The table or index can be nonpartitioned or partitioned. For partitioned tables and indexes, no rowid range can span a partition although one partition can contain multiple rowid ranges. Oracle sends the partition numbers with the rowid ranges to avoid partition map lookup. Compile and run-time predicates on partitioning columns restrict the rowid ranges to relevant partitions, eliminating unnecessary partition scans (partition pruning).

This means that a parallel query which accesses a partitioned table by a table scan performs the same or less overall work as the same query on a non-partitioned table. The query on the partitioned table executes with equivalent parallelism, although the total number of disks accessed might be reduced by the partition pruning. Oracle can parallelize the following operations on tables and indexes by block range (rowid range):

- Queries using table scans (including queries in DML and DDL statements)
- Move partition
- Split partition
- Rebuild index partition
- Create index (non-partitioned index)
- Create table ... as select (non-partitioned table)

2.3.3 Parallelizing by Partition

Partitions are a logical static division of tables and indexes which can be used to break some long-running operations into smaller operations executed in parallel on individual partitions. The granule of parallelism is a partition; there is no parallelism within a partition except for:

- Queries, which can be parallelized by block range as described above
- Composite partitioning, in which the granule of parallelism is a sub-partition

Operations on partitioned tables and indexes are performed in parallel by assigning different parallel execution servers to different partitions of the table or index. Compile and run-time predicates restrict the partitions when the operation references partitioning columns. The operation executes serially when compile or run-time predicates restrict the operation to a single partition.

The parallel operation may use fewer parallel execution servers than the number of accessed partitions (because of resource limits, hints, or table attributes), but each partition is accessed by a single parallel execution server. A parallel execution server, however, can access multiple partitions.

Operations on partitioned tables and indexes are performed in parallel only when more than one partition is accessed. Oracle can parallelize the following operations on partitioned tables and indexes by partition:

- CREATE INDEX
- CREATE TABLE ... AS SELECT
- UPDATE
- DELETE
- INSERT ... SELECT
- ALTER INDEX ... REBUILD
- Queries using a range scan on a partitioned index

2.4 Securing Project Rescheduling

2.4.1 Project silos

The company project managers keep their own project plans on their local drive, and a shared resource pool isn’t used. In this case, Karen Smith needs a DBA for three weeks beginning the December 9. Joe Green needs a DBA 25 percent of the time for his three-month project beginning November 15. Both project managers want to use Frank Kelly. Karen drops by Frank’s desk and asks what he’s working on. He tells her that he’s doing normal fire fighting and supporting the CRM project in his "spare time". Karen knows that the CRM project is scheduled to finish in November. Because this is the third time they’ve pushed out the date, Karen decides that the November end date should hold firm. Karen also believes that since her project is critically important, even if the CRM project slips it shouldn’t be too difficult to pull enough strings to get Frank out of fire fighting for the three weeks she needs him. Satisfied that she has a reasonable staffing solution, Karen sends an e-mail to Frank’s manager letting him know that she’s planning to use Frank in December and she’s confirmed that his schedule is clear.

At the same time, Joe is going through a similar process. He too knows that the CRM project should be completed in November. But even if the CRM project isn't completed, Joe needs only about eight to 10 hours a week of Frank’s time. Joe is confident that Frank can fit in some time somewhere. As a good PM, he also drops a note to Frank’s boss saying that he’ll need Frank for a couple of hours a week starting November 15.

Frank’s boss receives both notes and sadly shakes his head muttering, “these people.” He knows that the CRM project is running late and that a couple of production systems are being persnickety (requiring a great deal of Frank’s time). But in the past he’s found that both Karen and Joe overestimate the amount of support they need. Frank's boss also doesn't want to join the fight, so he sends an e-mail to the PMs that reads: "Sure, things are a little dicey, but we’ll work it out somehow."

It may appear that he is, but in reality he isn’t. Joe and Karen only think they have a commitment from Frank or from his boss. Because there isn’t any common resource scheduling pool, the PMs have no method in place for identifying the problem. When things really do start to go wrong in late November and December, the impact can quickly escalate to the point where multiple projects are put at risk.

2.4.2 Failure of resource pools

When organizations begin to realize the folly of this situation, many of them take the logical step of implementing a software tool designed to give them a view of their resource pool. If we replay the same scenario in a shop that uses a tool to track shared resources, the picture becomes clearer. Frank’s boss can now see that Frank is scheduled at 200 percent for a three-week period (100 percent with Karen, 75 percent on normal maintenance, and 25 percent for Joe). Ignoring the fact that the CRM project will probably slip again, adding another 25 percent to Frank’s workload, it should be obvious that the situation is fairly critical. So in our second scenario does the situation get resolved? My experience shows that in many cases the situation doesn't get resolved but plays out much like the first scenario: No one has the mechanism for resolving the conflicts. Organizations have come to believe that over allocation of resources is standard operating procedure.

2.4.3 Prioritized projects

Now let’s play out the scenario for a third time in an organization that has embraced some level of workforce planning by looking at their projects at the portfolio level. In this case the visibility of the problem moves up a level, and management has accepted the role of decision maker and tiebreaker.

When Karen’s project was in the initial proposal stage, her requirement for a DBA for three weeks in the December timeframe showed up right away as a problem. With five projects scheduled to complete in December and with the holidays, Karen would be able to see from the start that she has two options: Bring in some outside help by hiring a contractor or delay the project start date by a month to move her project outside the congested period. At this point senior management decides that there’s no real reason to delay the project, and they accept Karen’s recommendation that the three weeks' worth of work is perfect for a contractor. When Joe’s project was approved, there were no obvious conflicts in resources. Joe needed a DBA 25 percent of the time, and Frank has 25 percent left open on top of his maintenance and enhancement work.

In this scenario the problem comes to the surface when the CRM project slips for the fourth time. The project steering committee recommends to the portfolio management team that the project be extended yet again, and the impact of this decision can be evaluated against the other requirements in the organization. Reallocating DBAs isn’t really the job of the portfolio management committee, but what the committee can do is to see which projects would be affected if Joe’s project were given priority. In our example, the decision is made to transfer 25 percent of Frank’s troubleshooting work to a new DBA who has completed a number of training courses and to free up Frank for more project work like Joe’s. The other work the new DBA is scheduled to do is then postponed.

2.4.4 Building a culture of decision making

There are a few assumptions that are implicit in scenario number three. The first is that the organization has chosen to *manage* its portfolio of projects. This means that there is a commitment to review and allocate resources against a host of conflicting demands. It also means that the ostrich mentality has been rejected. This strategy takes guts and backbone to implement and agreement from the entire executive staff that the CIO and the CIO's organization have been fully empowered to facilitate these discussions.

Another assumption buried in this scenario is the commitment by the organization to train and align its current resources with future demands. Most organizations go through a very difficult time when their resources have one set of skills and all their future projects require another set of skills. When money was no problem, contractors could always fill the gap. In today's tight economic environment, however, it is actually much more cost effective to determine what skills will be needed in the future and who should be trained in those skills. Unfortunately, this strategy also requires a commitment on management's part to objectively assess its staff and their skills and then train, transfer, or terminate employees as needed.

The final assumption buried in this scenario is that all project managers and all support managers have the discipline to document their resource requirements and that they have the skills and knowledge to make sure that these resource requirements are realistic based on either previous projects or their own experience. In order to ensure that this is true, a company needs to reinforce this behavior in its project teams and offer support through a Center of Excellence or engage a PMO to help where their own experience or knowledge is insufficient.

2.4.5 Creating change from the bottom up

In the last couple of years, every project-centered organization I've talked to has placed the issue of resource management at the top of their list of serious problems. Projects spin out of control because too few people are trying to handle too many projects without a clear way to make the pieces of the project puzzle fit. Some of the new tools on the market seem to offer a quick fix, but, as one of our scenarios illustrates, even with a resource management tool it's still possible for a project to fail if the organization isn't willing to admit that people can be over allocated only in theory rather than in fact.

Resource over allocation can be solved at the organizational level only by establishing clear project priorities and a clear process for mediating the inevitable conflict in priorities. So if the problem can be fully solved only at the organizational level, is there anything a nimble project manager can do to help the situation?

You should consider recruiting other project managers into a Community of Practice (CoP). Specific recommendations on how to set up a CoP can be found in the article "With a little help from my friends: Exploring communities of practice in project management". The key is to get a group of PMs together and to establish a planning committee that would work to keep PMs from stepping all over one another. Simply making the decision to avoid letting the situation reach the crisis point and to open up the communication channels will begin to reduce the probability that resources are mythically over allocated.

Another tool we can use to reduce resource conflicts is risk management. As a general practice, I begin every project by identifying my critical resources and developing a contingency plan for replacement or substitution of those resources in the event of an emergency. In the example above, Frank was clearly a resource everyone counted on. While most organizations are only lucky enough to have one Frank, it is possible to identify consultants and upgrade the skills of other personnel to remove an overreliance on one person. By establishing nothing more than the most minimal practice of risk management, resource problems can be brought to light early in the project life cycle rather than later when the solutions are more limited and more expensive.

In the final analysis, resource over allocation is a failure of prioritization, a failure of planning, and a failure to accept that reality always imposes constraints. The nimble project manager understands that things will always change and that even in the best of systems there will be times when multiple projects are competing for the same resource. The only way to really solve this problem is by eliminating unnecessary conflicts in the initial planning stages through prioritization and project timing and by establishing the discipline to make conscious decisions about which projects slip and which stay on track when Murphy’s Law comes into play.

Review Questions

5. Why is it important of Resource modeling?
6. What is Resource leveling?
7. What are Resource allocation methods?
8. What are Prioritized projects?

Discussion Questions

Imagine that you use your Quick Base application to manage projects and their related tasks. You've assigned fourteen tasks to Penny and they're all due on Friday. She'd never say it, but she can't possibly finish on time. Meanwhile, Fred's yapping to his buddies on the phone without a thing to do. If only there were a way to measure how much work you've put on each person's shoulders?

Application Exercises

4. How to measure the resource allocation?
5. What are the different methods of allocation of resources?
6. Explain what do you mean by Securing Project Rescheduling?

CHAPTER 3
Splitting and Multitasking

Learning Objectives

- To understand about Multi-Tasking.
- Understand about project performance.
- Explain the methods of Preparing Project Plan.
- To gain the idea of multitasking aspects.

3.1 Multi-Tasking

In most project environments multi-tasking is a way of life. This seemingly harmless activity, often celebrated as a desirable skill, is one of the biggest culprits in late projects, long project durations, and low project output. At the same time it is one of the least understood factors in managing projects.

For companies where projects are of strategic importance, the stakes are very high. Whether it is delivering their product or service, bringing new products to market, or expanding/ upgrading their operations with new facilities, systems, or capabilities, the financial impact of being able to reduce project durations and costs, increase the volume of completed projects, or simply deliver more projects on-time is enormous. So understanding how this often overlooked practice of multi-tasking is of critical importance to most companies.

3.1.1 Multitasking and the Myth of Productivity

Many people have studied multitasking over the last decade, and most of them have come to the same conclusion: Multitasking doesn't make us more productive! Several studies have found that multitasking can actually result in us wasting around 20-40 percent of our time, depending on what we're trying to do.

The simple reason that multitasking doesn't work is because we can't actually focus on more than one task at a time. But we think we can – so we multitask to try and get more done.

Imagine trying to talk to someone and write an email at the same time. Both of these tasks involve communication. You can't speak to someone and write a really clear and focused email at the same time. The tasks are too conflicting – your mind gets overloaded as you try to switch between the two tasks.

Now think about listening to someone as you try to write an email. These two tasks are a bit easier to do together because they involve different skills. But your attention to the person will fade in and out as you're writing. You simply can't fully focus on both things at once.

The biggest problem with multitasking is that it can lower the quality of our work – we try to do two things or more things at once, and the result is that we do everything less well than if we focused properly on each task in turn.

When we switch tasks, our minds must reorient to cope with the new information. If we do this rapidly, like when we're multitasking, we simply can't devote our full concentration and focus to every switch. So the quality of our work suffers. The more complex or technical the tasks we're switching between, the bigger the drop in quality is likely to be. For instance, it would be almost impossible to write a good-quality presentation while having an emotionally charged conversation with a co-worker!

Another major downside to multitasking is the effect it has on our stress levels. Dealing with multiple things at once makes us feel overwhelmed, drained and frazzled. On the other hand, think of how satisfied you feel when you devote your full attention to one task. You're able to focus, and you'll probably finish it feeling as if you've not only completed something, but done it well. This is called being in flow, and it's a skill that can be developed with some practice.

3.2 Multi-tasking and project performance

Multi-tasking is the act of stopping a task before it is completed and shifting to something else; in software development the term “thrashing” is often used to describe this practice. When a task is stopped and started there is the immediate effect of a loss of efficiency. Each time a person has to re-start a task, time is required to become re-familiarized with the work and get re-set in where he was in the process. It is very much like the physical set-ups done on a machine in production. Each time you tear down a machine to do another task, you have to set it up to run the part again.

While the loss in efficiency is not insignificant, especially in "knowledge work," it is far from the most important reason multi-tasking is so damaging. What happens when a task is interrupted mid-stream is that its completion is delayed. Most people in project management will readily agree that it is not important when a task finishes, it is important when the project finishes. The diagram below shows three tasks a given resource must do, related to three different projects, and when they are expected to finish: Task A after 10 days, B after 20, and C after 30.

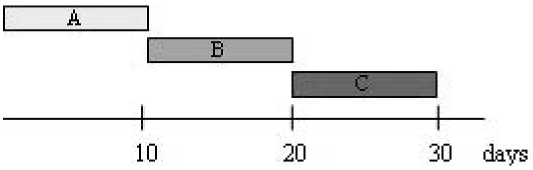


Fig 3.1

But if the resource has to stop and start the task even just once in the process, the actual completion times of the tasks quickly extends, as shown below. Task A now finishes only after 20 days instead of 10, task B at 25 days rather than at 20 days, and task C may still finish on-time at 30 days, without considering the impact of the loss in efficiency.

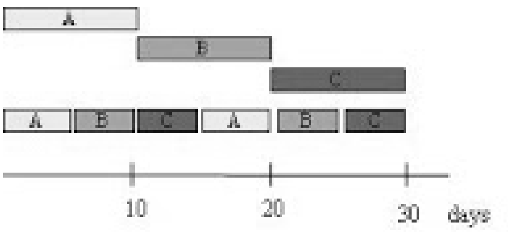


Fig 3.2

The delays on tasks A and B immediately translates into are delays on the downstream tasks in those projects, who now can only start at Day 20 and 25 respectively. The impact on project A is illustrated below. Even in a very small project like this one with just four tasks, and with only one instance of multi-tasking, the project is delivered almost 30% late. It's not hard to see how the more likely scenario of having several or many instances of multi-tasking during a project can cause the delays to accumulate considerably and lengthen project durations considerably.

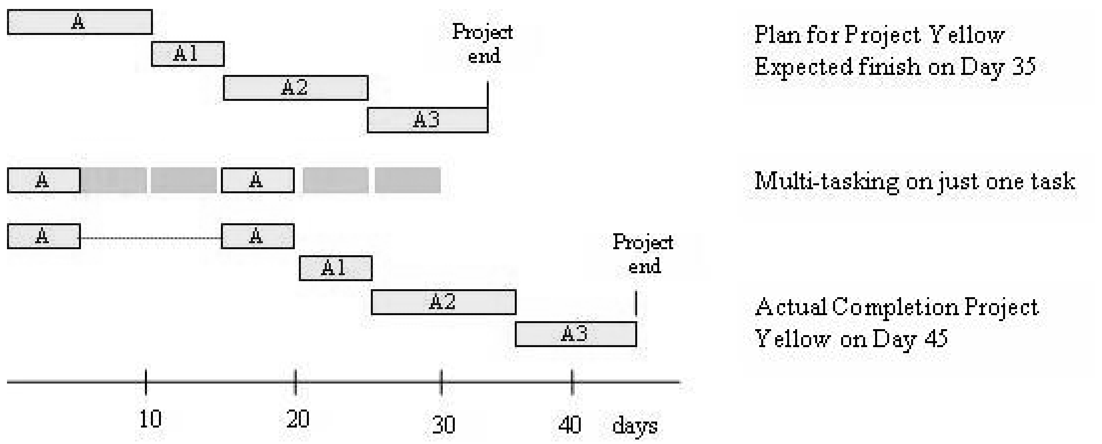


Fig 3.3

In many companies the impact of multi-tasking is obscured by the fact that in spite of its prevalence most projects still finish on time. While this reliability is nice, it masks the even more significant opportunity to cut project durations substantially. If projects are being delivered on or close to schedule, and multi-tasking is occurring, it can only mean that the task estimates used in the plan are significantly inflated. In other words, we are planning for the lost time due to multi-tasking, as this is the only way that the time losses could be recovered. In such cases, reducing the multi-tasking offers enormous potential to cut the planned project durations substantially, without eroding delivery performance. These companies are in a great position to reap the benefits of delivering more projects faster.

For years we have put the project managers, executives, and teams through a simple project simulation game using beads, first with multi-tasking, and then a second time, blocking it. The results are nearly always that the time to complete each of the two projects is cut in half, enabling them to double the output, and cut individual durations in half, simply by eliminating multi-tasking. And the same happens when companies drive out the multi-tasking in their own projects.

3.3 Is Multi-tasking really so prevalent?

Given the substantial negative impact on durations and project volume, it makes sense to explore just how common multi-tasking is. Since multi-tasking is difficult to see or measure precisely, we need to look at some other things to answer this question. The first issue is to understand the opportunity to multi-task. The way to see if your organization has the “opportunity” to do bad multi-tasking is ask how many jobs/ tasks an individual has on their desk at any given point in time. If there is more than one task that could be worked on a person’s desk then there is the opportunity for multi-tasking. When we ask managers how many tasks are on any given persons desk at one time, the not surprising answer is usually more than five.

The next way to check is to ask people how often they get interrupted or asked to work on something else that is “hot”, “urgent”, or “important”. In most companies one need not even ask this as “constantly shifting priorities” is usually one of people’s biggest complaints in projects. Every meeting that shifts or alters the priorities of projects, or adds new important things for someone to do, is a source of multi-tasking. How often does it happen in your organization?

Another way to look at it is to recognize that in most organizations where multiple projects are being done simultaneously, the resources who do the work on a project have to serve multiple, different project managers. For these project managers what is most important tends to be their projects. As a result they typically create pressure on resources to do their work first, institutionalizing multi-tasking. And when the multi-tasking starts to creep in, it initiates a negative spiral that only increases the pressure to multi-task. If one resource starts the multi-tasking, it delays the completion of their tasks, putting some projects behind. This increases the pressure on project managers and executives to adjust priorities to compensate, which in turn creates more, bad multi-tasking. It’s not hard to see how this spiral quickly becomes the reality we see in many organizations where managers at all levels are quickly pulled into managing work priorities across the organization on a daily basis.

On top of it, many resources who work on projects also support daily operational functions like QA/ QC, production, engineering, customer service. This support role means that they are frequently presented with unexpected, usually urgent things to do which readily drive more multi-tasking. The result is that in the majority of companies there is the opportunity and the pressure to create a significant amount of bad multi-tasking.

3.4 Purpose of Multitasking

Our experience with hundreds of companies is that there are three central reasons organizations find themselves in the trap of multi-tasking:

- Lack of understanding of the impact of multi-tasking
- Incorrect assumptions
- The desire to do a good job

The simple fact is that most people and organizations do not understand how damaging multi-tasking is. Our clients, who see the impact illustrated in the bead exercise, mentioned earlier, are stunned and amazed that eliminating the practice results in a doubling of output and a halving of the project durations, with no other improvements. Once people do start to understand how damaging the practice is they become much more conscious of it, and start to change their behavior and the behavior of their organization.

But understanding is not enough. The drivers of multi-tasking are built into the processes, measurements, and systems most companies manage their projects. We strive hard to keep people busy all of the time, to maximize the output of all of our resources and be efficient. Performance measures on project managers and executives motivate them to focus on delivering individual projects, without understanding of the impact of their actions on the rest of the pipeline. Conventional scheduling and pipelining tools pay no attention to these factors and routinely overload resources making multi-tasking nearly inevitable.

The second reason is 'incorrect assumptions.' Chief among these is the belief that "the earlier you start a project, the earlier it will finish." While this is probably a valid statement in a single project environment where resources do not need to work on multiple projects, starting new projects earlier only increases the work in process in a multi-project environment and with it the likelihood of multi-tasking. People will get out of a building during a fire alarm much faster if they don't all rush at the door at once. Though it seems counter-intuitive, projects will finish earlier and we will get more of them done, if we start them later.

Again here the obstacle for companies in applying these principles is that these erroneous assumptions are built into the processes, measures, and systems we use to manage projects. The pressure from upper management and sales to add more projects or start them earlier can make it virtually impossible for managers below to cope with the pressure to multi-task. Conventional software, nearly all of which is based on Critical Path methodology, fails to provide managers with a way to accurately evaluate task priorities across projects. Critical Path can identify which tasks have priority over others within a given project, but it breaks down when considering tasks on different projects. How many times does it happen that someone works on an urgent task, only to learn later that it ended up sitting a downstream step waiting on something else, or because the priorities shifted again?

The final reason for the pervasiveness of multi-tasking is that people want to do a good job. People multi-task in response to a perceived need of the organization: an urgent job, a hot task, a breakdown, a customer complaint, etc. Shifting to work urgent, pressing jobs gives people a chance to be heroes, to save the day, or put out the fire. In fact if you have multi-tasking in your organization, it is an almost sure sign that you have people who care about and are working hard to do a good job for the organization. It is essential to help people to realize the impact of multi-tasking, so they shift their belief of what it means "to do a good job." But this must be backed by the needed process, measurement, and system changes or their efforts will be overwhelmed by these other forces.

In order to maintain a competitive edge, project managers, particularly technology project managers, must be able to cope with multiple projects with no less an expectation of perfection than if their workload consisted just of a single project. The excuse of being "too busy" to be a great project manager simply doesn't work. It can't. This is why, more than ever before, project management is not for everyone.

But multitasking can be done - can be learned - and typically becomes better with experience. If you are drowning in your project workload and are about to have a complete meltdown, take a deep breath, step back a moment and take time to reflect on the following techniques:

3.4.1 Preparing Project Plan

It is difficult to think clearly when you are bombarded with one crisis after another. The truth is, however, there is no better time to step back and remember the fundamentals of project management than now. The two most important fundamentals are planning and communication.

First and foremost, recall your project plan. If you don't have one, it's probably one of the reasons you are having a nervous breakdown to begin with. Although the temptation is great to dive right into the project and keep it moving during extremely busy times, you can't take shortcuts in planning. If you don't take the time to plan diligently, you won't be able to follow your plan (or communicate expectations and progress). You also won't be able to influence it in the future. Careless planning leads to careless execution. Instead, frontload your project at the beginning by taking the time to create a complete project plans. Your time invested will quickly yield returns by turning into a tool which will do most of your hard work for you moving forward.

3.4.2 Time Management (Prioritize Productively)

When it rains it pours, and for many project managers who are overloaded with work and seem to be constantly fighting one crisis after the other, it just doesn't seem to stop. If it happens to you, step back and reorganize your project schedules by way of priority in a way that is traceable and transparent. You should be able to break your project into small parts with clearly identifiable project milestones.

3.4.3 Prepare to Change (and to Keep Changing)

Setting priorities and developing a plan is just the beginning (especially if priorities are shifting as one crisis follows another). Constantly changing priorities can become a burden and put project resources under immense physiological strain. As the project leader, be aware of how much gear-switching your resources can tolerate before they start tuning out and becoming less productive. Ride momentum on changes that result in traction-gain and prepare to fix bottlenecks and make alterations if your tweaks don't kick in and produce results quickly.

3.4.4 Reducing Bad Multi-tasking

The impact on project performance from reducing multi-tasking is profound. Without so many interruptions and delays on individual tasks the work flows much more quickly and smoothly. Without adding resources or working people any harder, more projects get completed, faster. And without the constant pressure to re-prioritize work, and with more projects tracking on-time, the organizational climate improves dramatically. With these improvements follow the business results companies in project environments are universally seeking. The typical results we have seen companies achieve are:

On-time completions to 95+%
Project durations cut by 1/3 or more
Project output 25%-100%

3.5 Stop Multitasking

If we want to improve the quality of our work, lower our stress levels, and become more efficient, then we need get out of the multitasking habit. Below are some suggestions to help you cut back on multitasking:

- Plan your day in blocks. Set specific times for returning calls, answering emails, and doing research.
- **Manage your interruptions**. Keeps a log showing that interrupts you the most, and how urgent the requests are. Once you've compiled a week's worth of interruptions, politely but **assertively** approach your colleagues with a view to managing and reducing their interruptions.
- Learn how to **improve your concentration** so you can focus properly on one task at a time. Doing this may feel awkward at first if you frequently multitask. But you'll be surprised at how much you get done just by concentrating on one thing at a time.
- Every time you go to check your email or take a call when you're actually supposed to be doing something else, take a deep breath and resist the urge. Focus your attention back to what you're supposed to be doing.
- If you get an audible or visual alert when emails come in, turn it off. This can help you avoid the temptation to check your inbox whenever you get new mail.
- Whenever you find yourself multitasking, stop. Take five minutes to sit quietly at your desk with your eyes closed. Even short breaks like this can refocus your mind, lower your stress levels, and improve your concentration. Plus it can give your brain a welcome break during a hectic day.
- There will be times when something urgent comes up and you can't avoid interruptions. But instead of trying to multitask through these, stop and make a note of where you left your current task. Record any thoughts you had about how to move forward. Then deal with the immediate problem, before going back to what you were doing. This way you'll be able to handle both tasks well, and you'll leave yourself with some clues to help you restart the original task more quickly.
- If you find your mind wandering when you should be focusing on something else, you need to guide your thoughts back to what you are doing by putting yourself in the moment. For example, you might be sitting in an important team meeting, but thinking about a speech you'll be giving soon. Tell yourself, "I am in this meeting, and need to focus on what I'm learning here." Often, acknowledging the moment can help keep you focused.

3.6 Exposure of Multi tasking

In some companies the impact of multi-tasking is obscured because even though multi-tasking may be wide spread most projects still finish on time. While this reliability is nice, it masks the even more significant opportunity to substantially cut project durations. If projects are being delivered on or close to schedule, and multi-tasking is occurring, it means that the task estimates are significantly inflated. In other words, we are planning for the lost time due to multi-tasking, as this is the only way that the time losses from multi-tasking could be recovered. In such cases, reducing the multi-tasking provides the opportunity to reduce planned project durations without eroding delivery performance. These companies are in a great position to reap the benefits of delivering more projects faster.

For years we have put project managers, executives, and project teams through a simple project simulation game using beads. When a group of beads are moved, it represents the completion of a task. Two different projects are simulated, first with multi-tasking and then without multi-tasking. The results typically show that the time required to complete the two projects is halved when multi-tasking is eliminated, which enables a doubling of the output. Our experience is that results are repeated hen companies drive out the multi-tasking in their own projects.

Review Questions

9. Why is Multitasking and the Myth of Productivity?
10. Explain Multi-tasking and project performance?
11. Should multitasking be required? Explain?
12. What are the steps involved in Preparing Project Plan?

Discussion Questions

Explain in detail the purpose of Multitasking? State this with example?

Application Exercises

7. How to measure the resource allocation?
8. Why multitasking is sometimes not required?
9. Explain what is exposure of Multi tasking?

CHAPTER 4

Multi project resources scheduling

Learning Objectives

- To explain about Projects.
- To analyse about multiple Projects.
- To recognise the methods used in Project Scheduling.
- To explain the rules based on time constraints.
- To identify Resource allocation syndrome.

4.1 Introduction

Projects are limited in quality by three factors:

- resources,
- time,
- scope.

By optimizing both human and financial resources under a fixed duration, a project manager can maintain or increase the scope and quality of a project. More often, with a fixed scope and duration, effective project management seeks to maintain quality by optimizing resources. Frequently, the availability of resources assigned to a project is limited and not sufficient to accomplish all the required activities, without compromising quality.

In a survey of 176 private and public companies in Canada in 1997, 61 percent of respondents reported project failures. Of the failed projects, more than three-quarters exceeded schedules by 30 percent or more, and more than half exceeded their budgets by a substantial margin. The primary cause of project failure was poor project planning, and projects failed more often because of scheduling overruns than budget overruns. In these situations, project managers who do not optimize resources will reduce the quality of the project or cause delays in activity completion. In a survey of 365 American companies in 1995, only 16 percent of projects were completed on time, on budget, and within specifications. On average, completed projects were 74 percent of the content of the original scope.

Since this annual survey began in 1995, there have been some improvements in project performance such as decreasing failures by 15 percent in 2004. Cost overruns have been reduced for challenged projects from 180 percent to 43 percent. Still CHAOS estimates that United States project waste accounts for $38 billion in lost dollar value and $17 billion in cost overruns.

The benefits to working in an environment with multiple projects include increased learning opportunities and a rich work environment. However, a large number of projects have scarce time resources and inadequate routines, and project overload leads to a lack of recuperation and missed deadlines.

Considering restricted per-period availabilities of multiple resource types, a project must be finished as early as possible without wasting resources that project managers could use more efficiently elsewhere. Compounding the problem, companies manage various projects simultaneously, sharing a pool of renewable resources.

4.2 Multiple Projects

Managing multiple projects has been termed the resource-constrained multiple-project scheduling problem (RCMPSP).5 Managing this RCMPSP can be accomplished by exact procedures, metaheuristics, or simple priority rules. For real-world problems with a large number of jobs, optimizing a resource and cost schedule using exact procedures such as dynamic programming, or metaheuristic techniques such as search algorithms are computationally difficult, time-consuming, expensive, and unnecessary.6 Instead construction companies, urban maintenance schedules, auditors, and software design companies have used simple heuristic (rules-of-thumb) priority rules to establish priorities for resources.

The advantage of using priority rules for managing resources is that the rules are straightforward, which makes them easy to implement. They are also the most commonly used methods in experimental literature to simulate ideal scheduling of scarce resources for multiple projects. Also, most commercial scheduling software programs rely on these priority rules.

To implement simple priority rules, a framework of a scheduling scheme must be present. This framework includes using parallel, bidirectional, dynamic, and global planning. With the appropriate scheduling scheme, priority rule setting is as effective as exact procedures and met heuristics in managing resources.

Healthcare research is unique. If the projects are simply repetitive in nature, managers can use the Projects in Controlled Environments (PRINCE) model for routine research supervision. However, healthcare research projects are not repetitive. In contrast, software engineering projects have a client that has set detailed specifications for the project, and there are ongoing communications and managed expectations. Healthcare research, especially academic health services research, has a broad scope and the details cannot be defined at the start of the project, making planning an ongoing process. In addition, the topic is usually a one-time subject for academic researchers who have received a grant that may be used to hire new staff and form new collaborations. With a new team, considerable effort must be put into early planning and early learning resulting in early schedule slippage, which is the greatest early warning sign for project failures.

When early schedule slippage occurs, there is no chance of project overruns because the grant value has been specified. Projects then are compromised in quality by poor planning and have little advantage for catching up. There is also limited streamlining with non-repetitive tasks that require judgment. Continual judgment demands cause further delays. With multiple projects flexibility in planning has been shown to be desirable, but flexibility in execution is undesirable. Thus, healthcare research requires ongoing planning and execution of nonrepetitive activities or decisions, since delays in planning contribute significantly to project failure.

The purpose of this paper is to investigate the effectiveness of management of multiple projects in healthcare research. This was achieved by first reviewing and summarizing the literature to identify best practices for managing multiple projects, second by using best evidence to create a survey, and third by using the survey to identify current practices for project management of faculty, directors, and research managers. Finally, team members compared actual management priority setting practices versus best practice. Further, we present recommendations for setting priorities in the management of multiple projects in healthcare research when resources are constrained.

4.3 Methods

The electronic databases searched included International Abstracts in Operational Research, EconLit, ABI/INFORM Global, ProQuest Nursing & Allied Health, Business Source Complete (Limited to Project Management and Academic Journals), Management & Organization Studies: A SAGE Full-Text Collection, and OVID (Medline, Embase, CINAHL). Literature was searched for managing multiple projects in healthcare research, assignment of priority rules when managing projects in healthcare research, implementation of simple priority rules in manufacturing/operations setting. Key words used includes:

- project planning,
- multiple projects,
- priority rules,
- RCMPSP.

The most common priority rules and the situations in which they performed best were identified.

4.3.1 Survey

Despite the abundance of priority rules, no previous instrument to assess priority rules was available. The survey was developed and pretested on a group similar to the target population. Comments lead to revisions of the survey instrument.

The finalized survey was sent by e-mail to a small convenient sample of healthcare researchers, including department heads, managers, directors, and faculty and experienced project managers within an urban academic institution. From the nature of the institution, all were involved in clinical and health services research. This group was selected because they were senior staff and faculty who had success in project management, and in most cases had no formal training in project management such as the citation Project Management Professional (PMP) designation, or had an MBA or equivalent advanced degree in management.

The survey instrument was divided into three parts. In part, respondents were asked how often they used each of most common priority rules. They were allowed to classify their response as:

- “Always,”

- “Very Often,”
- “Sometimes,”
- “Rarely,”
- “Never,”
- “Not Applicable.”

In next part, we asked the respondents to rank the three most common priority rules, from first to second to third choice. Further, we asked for details on how many projects they currently manage, the average project duration, the shortest and longest project, and the number of staff they have in each project. The choice of top three priority rules were compared to project characteristics.

A total of 278 references were found that dealt with multiple projects. No direct evidence of the use of setting priorities was found regarding managing multiple projects in healthcare research, nor on the implementation of simple priority rules in manufacturing/operations setting. The literature located on priority rules or RCMPSP provides surveys on types and number of resource constraints, and the activity and project characteristics. These surveys provide inputs for the more substantial published literature that provides evidence on optimal priority rules in computer simulations. Several papers reported on managing projects in healthcare research and several articles discussed project management in healthcare research.

4.3.2 Common Priority Rules

A review of the literature identified seven priority rules that had robust superiority in achieving due date and efficient resource management. The following is a description of these seven most effective priority rules described in the research literature that were included in the survey instrument. The first priority rule identified First Come First Served (FCFS), where the first eligible activity is assigned the highest priority. This procedure is representative of scheduling heuristics found in many dynamic scheduling environments. In FCFS, activities are not screened by work content or due date. The project manager gives priority to the earliest arrived activity. In particular, the project manager will not begin a new activity until the current activity is completed. This could be called the simple checklist method. A manager adds items to a list of activities to perform, and then assigns items at the top of the list regardless of activity characteristics.

Best Practice Recommendations Based on the Literature

Priority Rule	Definition	Conditions
First Come First Served **(FCFS)**	Assign the first eligible activity the highest priority, regardless of other factors.	With simple tasks and when new projects arrive randomly (dynamic)[43], [44]
Shortest Activity for Shortest Project **(SASP)**	Assign activities that are feasible in a short period of time with preference for short projects.	Many simple tasks with few constraints, or when there are many short projects[45], [46]

Table: 4.1

Similar to FCFS is the Shortest Activity for the Shortest Project (SASP), which gives precedence based on the minimum of the sum of project duration and activity time. Here the length of the project is considered as well as the length of the activity. SASP could be answering daily e-mail, while activities that have a longer duration are set aside until the person completes the little things. This could be called the modified checklist method. A manager adds items to a list of activities to perform, and then assigns items that are feasible in a short period of time with preference for short projects.

An opposite of SASP is Maximum Total Work content (MAXTWK). This simple priority rule looks at the activities that require the most resources and the manager assigns these the highest priority. The manager assumes that the little tasks that take small amounts of resources and time will be completed in parallel with the larger tasks.

Similar to MAXTWK is the Resource Scheduling Method (RSM). Under this priority rule, the manager assigns resources to activities that would increase the project duration if resources were inadequate. The process has two steps. In the first step, the project manager determines the timeline of the project and then identifies the sequence of critical activities. In the second step, the project manager reviews the ability to perform activities subject to the resource constraints, and then adjusts the schedule of activities subject to these resource constraints. The goal is to minimize project duration. By using the two-step approach, this method assigns priorities to activities that are time sensitive subject to resources. This method is most effective in construction-industry projects.

One priority rule that looks at activities in the overall project flow is Most Total Successors (MTS). MTS assigns priority to the activities with the largest number of successor activities that require completion before another activity can begin. For two similar projects, the priority is given to the project with the most number of activities remaining. This rule ignores the time constraint of a due date and resource constraints, and is most efficient when two similar competing projects begin at the same time and have the same due date.

A number of rules are based strictly on time constraints. These include Latest Start Time (LST), Latest Finish Time (LFT), and Minimum Slack (MINSLK). MINSLK is equivalent to the Min LST rule and was not included in the survey instrument. The LST is the latest an activity can start and not extend the overall project duration. In contrast, the Earliest Start Time (EST) is the earliest possible time (usually in days into the project) that an activity can be started. Slack is the difference in the EST and LST. Difference between EST and Early Finish Time (EFT) is the duration of the activity. Similarly, the difference between LST and Late Finish Time (LFT) is also the activity duration.

Activity boxes and time-based priority rules

Figure 1A. Activity A

0	A	5
2		2
2	5	7

Figure 1B. Activity B

0	B	3
3		3
3	3	6

Figure 1C. Key

EST	ID	EFT
SLACK		SLACK
LST	Duration	LFT

Fig 4.1

Limitations of this research include the small sample size of the survey, and the limited scope of the study, as it was conducted at one urban research center. There is also an obvious selection bias. The respondents were all at the senior level, suggesting they must have had success in project management to reach that level. In addition, some respondents provided feedback on how to improve the survey. Other key information could be collected, such as the dynamic nature of the projects whether these projects started at similar times, making some rules more applicable, as well as staff experience and budget details. Finally, the survey could gather project failure information such as whether projects were compromised in scope or if budgets or timelines were met.

The setting of priorities must also be considered with other best practice principles for project management to have efficient use of research resources. Other examples of best project management practice are limiting tasks to 5 to 10 days, having a project with fewer than 10 members, assigning responsibility for awareness to contingencies, building appropriate slack and financial buffers, managing expectations, and encouraging informal and formal communications. In the future, individuals who are designated as project management professionals (PMP) from the Project Management Institute may become more common. This designation will establish the project manager as a professional who understands and can implement the best practice principles.

4.4 Resource allocation syndrome

4.4.1 Introduction

In many organisations, employee workloads consist of a mix of project and operational assignments. Due to endemic shortfalls in staffing, such folks particularly those who have key skills and knowledge that generally have little or no spare capacity to take on more work. However, soon comes along another “important” project in urgent need of staffing and the rest, as they say, is tragedy: folks who are up to their necks in work are assigned to work on the new project. This phenomenon is a manifestation of the resource allocation syndrome, discussed by Mats Engwall and Anna Jerbrant entitled,

4.4.2 Background

Scheduling and resource allocation is a critical part of project planning in multi-project environments. Those who work in such settings know (often from bitter experience) that, despite the best laid plans, it is easy to be over-allocated to multiple projects. Engwall and Jerbrant's work delves into the factors behind resource over-allocation via a comparative case study involving two very different environments: the contracts department of a railway signaling equipment firm and an R&D division of a telecoms company.

Specifically, the work addresses the following questions:

- Are there any (resource allocation) issues that are common to multi-project / portfolio environments?
- What are the mechanisms behind these issues?
- As they point out, there are several articles and papers that deal with the issue of resource allocation on concurrent projects. However, there are relatively few that tackle the question of why problems arise.

4.4.3 Methodology

As mentioned, the aim was the surface factors that are common to multi-project environments. To this end, they gathered qualitative data from a variety of sources at both sites which included:

- interviews,
- studies of project
- technical documentation,
- company procedures
- direct observation of work practices.

The first study was carried out at the contract division of a mid-sized railway signalling equipment firm. The division was well-established and had a long history of successful projects in this domain. As might be expected given the history of the organisation, there was a mature project management methodology in place. The organisation had a matrix management structure with 200 employees who were involved in executing various projects around the world. The work was managed by 20 project managers. Most of the projects were executed for external clients. Further, most projects involved little innovation: they were based on proven technologies that project teams were familiar with. However, although the projects were based on known technologies, they were complex and of a relatively long duration (1 to 5 years).

The second study was done in the R&D division of a telecom operator. The division, which had just been established, had 50 employees who worked within a matrix structure that was organised into five specialist departments. Since the division was new, the project management procedures used were quite unsophisticated. Projects were run by 7 project managers, and often involved employees from multiple departments. Most of the projects run by the division were for internal customers – other divisions of the company. Also in contrast to the first study, most projects involved a high degree of innovation as they were aimed at developing cutting-edge technologies that would attract new subscribers. However, even though the projects involved new technologies, they were of relatively short duration (0.5 to 2 years).

4.4.4 Results

As might be expected from a study of this nature, there were differences and similarities between the two organisations that were studied. The differences were mainly in the client base (external for the contract division, internal for the other), project complexity (complex vs. simple) and organisational maturity.

Despite the differences, however, both organisations suffered from similar problems. Firstly, both organisations had portfolios with extensive project interdependencies. As a consequence, priority setting and resource reallocation was a major management issue. Another issue was that of internal competition between projects – for financial and human resources. In fact, the latter was one of the most significant challenges faced by both organisations. Finally, in both organisations, problems were dealt with in an ad-hoc way, often resulting in solutions that caused more issues down the line.

From the common problems identified, it was clear that:

- In both organizations, the primary management issue revolved around resources. The portfolio management was overwhelmed issues concerning prioritization of projects and, distribution of personnel from one project to another, and the search for slack resources. However, there were no resources available. Furthermore, when resources were redistributed it often produced negative effects on other projects of the portfolio. This forced the management to continuous fire fighting, resulting in reactive behavior and short-term problem solving. However, the primary lever for portfolio management to affect an ongoing project in trouble was resource re-allocation.

- There are a couple of points to note here. Firstly, resource re-allocation did not work. Secondly, despite major differences in between the two organisations, both suffered from similar resource allocation issues. This suggests that this resource allocation syndrome is a common problem in multi-project environments.

4.4.5 Understanding the syndrome

Based on data gathered, it was identified that a number of factors that affect resource allocation are:

- Failure in scheduling: this attributes the resource allocation syndrome to improper scheduling rather than problems of coordination and transition. The fact of the matter is that it is impossible for people to shift seamlessly from one project to another. There is at the very least the overhead of context switching. Further, projects rarely run on schedule, and delays caused by this are difficult to take into account before they occur.
- Over commitment of resources: This is another common problem in multi-project environments: there are always more projects than can be handled by available personnel. This problem arises because there is always pressure to win new business or respond to unexpected changes in the business environment.

- Effect of accounting methods: project organisations often bill based on hours spent by personnel on projects. In contrast, time spent on internal activities such as meetings are viewed as costs. In such situations there is an in-built incentive for management to keep as many people as possible working on projects. A side-effect of this is the lack of availability of resources for new projects.

- Opportunistic management behaviour: In many matrix organisations, the allocation of resources is based on project priority. In such cases there is an incentive for project sponsors and senior managers to get a high priority assigned by any means possible. On the other hand, those who already have resources assigned to their projects would want to protect them from being poached to work on other projects.

The factors were identified based on observations and from comments made by interviewees in both organisations. Resource allocation focuses on the first two points noted above: scheduling and over-commitment. The problem is thus seen as a pure project management issue one that deals with assigning of available resources to meet demand in the most efficient way. In reality, however, the latter two points play a bigger role. As the author's state:

Instead of more scheduling, progress reports, or more time spent on review meetings, the whole system of managerial procedures has to be reconceptualized from its roots. As current findings indicate: the resource allocation syndrome of multi-project management which is not an issue in itself is rather an expression of many other, more profound, organizational problems of the multi-project setting.

The syndrome is thus a symptom of flawed organisational procedures. Consequently, dealing with it is beyond the scope of project management. The key takeaway from the paper is that the resource allocation issues are a consequence of flawed organisational procedures rather than poor project management practices. Project and portfolio managers responsible for resource allocation are only too aware of this. However, they are powerless to do anything about it because, as Engwall and Jerbrant suggest, addressing the root cause of this syndrome is a task for executive management.

Review Questions

13. What are multiple Projects?
14. What do you mean by PRINCE?
15. What are the factors that affect resource allocation?
16. What are some responsibilities of Project and Portfolio managers?

Discussion Questions

Discuss the basic of syndrome? Explain the use of syndrome with examples?

Application Exercises

10. Explain the Common Priority Rules? State examples?
11. State the different rules that are based strictly on time constraints?
12. What is Resource allocation syndrome?

CHAPTER 5

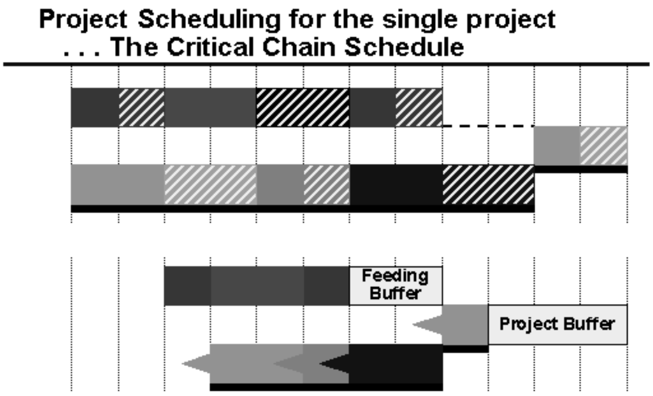
Critical Chain Scheduling

Learning Objectives

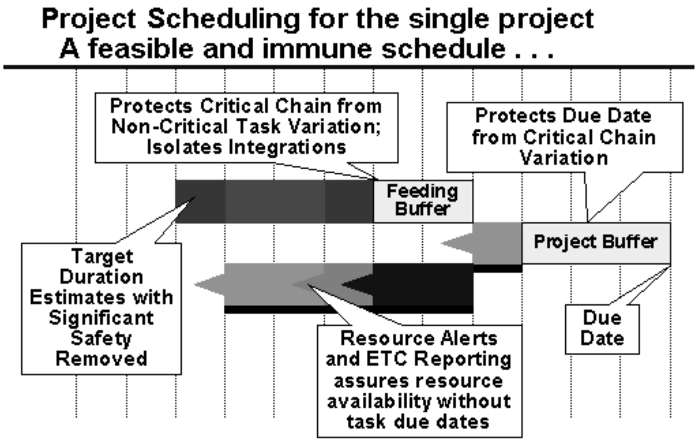
- To explain about Critical Chain scheduling.
- To analyse the development aspect of project Scheduling.
- To recognise **Risk Assessment/Acceptance**.
- To explain about Product development projects.
- To identify Critical Chain approach.

5.1 Introduction

A Critical Chain schedule takes advantage of the 2-point estimate process to translate the dependency network into a reliable project promise. Reliability comes first from feasibility assured by explicitly including resource dependencies as well as handoff dependencies in the determination of the critical chain/path of the project.



Secondarily, the two estimates developed in the planning process are used to aggregate and concentrate safety where it will do the most good to protect the project's promises and its intended value. The body of the schedule the network of tasks and resources used to identify the critical chain that makes use of the smaller of the two estimates. The difference between the "safe" estimate and that "aggressive but achievable" estimate for critical chain tasks is used to develop the primary characteristic of the critical chain schedule that the buffers. A project buffer, which protects the final project due date from the variability in performance on those tasks is built from the estimates associated with the critical chain tasks. Feeding buffers, which are related to chains of tasks that feed into or merge with the critical chain, are similarly sized and placed to isolate the critical chain from the integration effects of those chains, essentially helping to keep the critical.



5.1.1 Critical Chain Schedules and Risk Assessment/Acceptance

Once developed, assessment of the full schedule, including the contribution of the buffers to project lead-time, provides a clear view into the identified potential of schedule risk for the project. In non-Critical Chain environments, when contingency is included, it is often hidden, either in management reserve, or in internal and external commitments. The common practice of keeping these components off the table hides their true impact and implications. The open and explicit communication of buffers that allows a clear assessment of what could happen “in the best of all possible worlds,” versus what might happen if individual concerns accumulate to affect project performance.

The ultimate risk of a project is not delivering the promised value in the required time frame. If the schedule results in a lead-time that does not support business needs of the project, the critical chain schedule provides two primary sources for reduction which are the critical chain and the project buffer. Assumptions that have been made on key critical activities can be revisited to assess whether additional actions or activities can be added to the project to reduce variability and the size of the project buffer, or whether task handoffs can be restructured to allow more parallel activity and reduce the length of the critical chain. At some point, limits on corrective action are reached, resulting in a buffered schedule that reflects the accepted risk of the project’s lead-time and schedule promise.

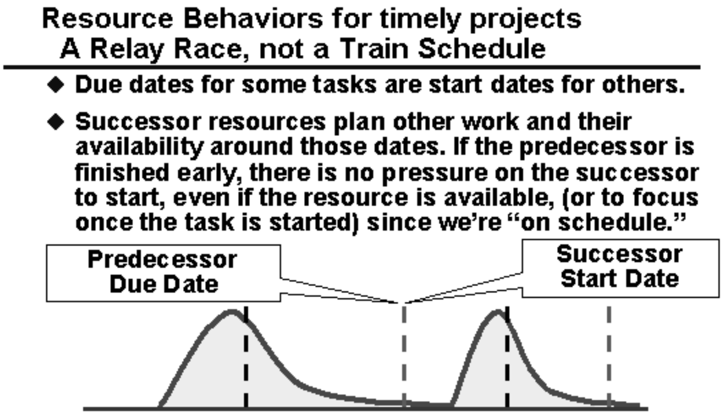
5.1.2 Critical Chain Schedules and Integration Risk Avoidance/Mitigation

While a lot of emphasis is placed on the project buffer and its protection from critical chain variability, feeding buffers are just as important. They serve to protect project promises from a universal source of risk found in every project that involves parallel activity. Integration risk, i.e., the statistical nature of merging parallel paths, is the primary source of changing critical paths in traditionally managed projects. If a set of parallel paths of activity each have a relatively safe 85% probability of completion by certain point in time, it takes only 4 such paths to turn the chance of an on-time start for the task they integrate into to 52% which is not much more than that of a flip of a coin. When one considers that projects are typically made up of integrations of integrations or integrations, there is little wonder that critical paths change during the life of a projects, and that there is difficulty bringing projects in on time without relying on heroics or hoop-jumping.

A common tool for assessing this characteristic of risk in traditional critical path project schedules is Monte Carlo simulation, which provides a view of the impact of these integrations on the probability of promised project completion. The critical chain schedule takes these integrations into account up front by explicitly building feeding buffers to deal with the variability in feeding chains (rather than relying on random amounts of slack or float). While Monte Carlo simulations advise on the probability of keeping promises, buffered critical chain schedules are designed to avoid integration risk and keep that probability high.

5.1.3 Process

Most projects are managed by carefully watching the calendar, comparing where we are today against some baseline schedule. That schedule typically consists of a series of start and due dates for consecutive tasks, with due dates of predecessors matching start dates of successors. Like a train schedule, if a task arrives at its completion on or before its due date, that portion of the project is considered to be “on track.” Successor resources plan other work and their availability around those dates. If the predecessor is finished early, the successor resource may not be available to pick up the handoff. Even if the resource is available, there is commonly little or no urgency for the successor to start, since we’re “ahead of schedule,” and that resource will typically tend to other priorities.



The problem with this common practice is that while it is important for trains to arrive at and depart from their stations at appointed times, project value is more often tied to the absolute speed from beginning to end. The sooner the entire project is completed; the sooner project benefits can be accrued. A more appropriate metaphor to guide projects is a relay race, in which resources are encouraged to pick up the input handoff as soon as it is available, "run with it" in a full, focused, sustainable level of effort, and hand off the output as soon as it is complete.

This behavior is exacerbated in environments where schedules are built upon estimates that are considered commitments by the resources, and therefore contain a substantial amount of localized safety in each task to protect that commitment. If a project is deemed "on track," and a resource realizes that there is chance of completing the work well within the "safe" estimate, the desired sense of urgency is again diminished. As a result, resources are momentarily comfortable sharing their time among several tasks or issues, extending out the time that they would otherwise be able to hand off their output to the next leg of the relay race.

Milestone schedules, like training schedules, become, at best, self-fulfilling prophecies, at least in terms of expectations of speed. They may still take longer due to being derailed by Murphy's Law because they have wasted what might have been early finishes which are now not available to offset tasks that take longer than anticipated.

5.2 Critical Chain Schedules, Resource Behaviors and Risk Mitigation

Critical Chain schedules address this question of lost safety in two ways. First, the usual system of task due dates itself is eliminated. The only dates in a critical chain schedule are launch dates for chains of tasks that have no predecessors, and final due dates associated with deliverables that are external to the project and which are protected by project buffers. Start dates of tasks are linked directly to the completion of their predecessors, and communicated through the buffer management project control process. If you have no due-dates, you have gone a long way in eliminating due-date behaviors and in repealing Parkinson's Law.

Secondly, the safety is moved out of the tasks to the buffers, thereby eliminating the idea of commitment that needs to be protected on one hand or that is good enough on the other. With the underlying assumption that the work of a task will take as long as it takes, no matter what the schedule model assumes, resources are directed to work on tasks without distraction until complete and handoffs are delivered. At least tasks won't be delayed by outside influences. More importantly, management also must support the ability to do so, avoiding unnecessary distractions or conflicting priorities. If resources run their leg of the relay race in an effective and efficient manner, some tasks will take longer than anticipated in the schedule and some will take less. The project is in a position to take full advantage of early finishes. In this way, the cumulative risk associated with due-date behaviors is replaced by the consumption and replenishment of buffers.

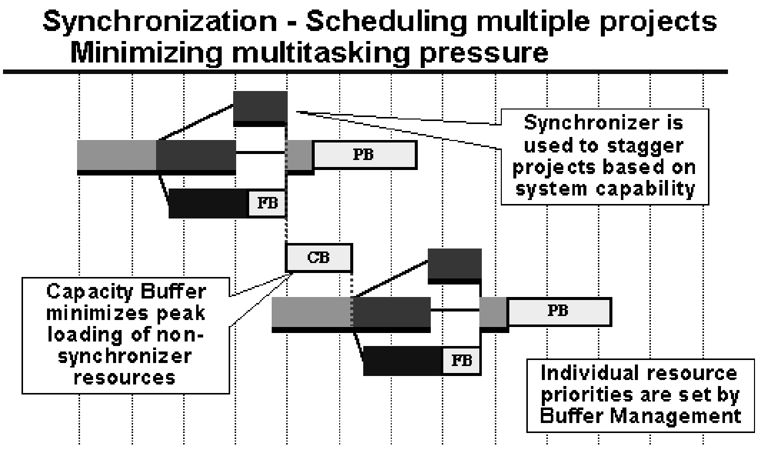
5.2.1 Synchronization - Scheduling multiple projects

The TOC multi-project solution recognizes that the effectiveness of individual projects can be threatened if the organization tries to push more projects through its pipeline than it is capable of. Scheduling that the actual promising of individual project completions must take into account any constraining aspects of that pipeline. While the common existence of practices like multi-tasking or due-date behaviors typically prove out to outstrip any actual resource constraint, the possibility of such a constraint is useful as an implementation tool for the multi-project aspect of the approach.

The process of synchronizing project launches to the ability of a commonly, heavily used resource to deal with those projects helps to minimize pressures to multi-task from the start. This process starts with a review of projects in the portfolio for the identification of potential candidates for the choice of a gating/synchronizing resource. The choice of one that is commonly used across projects and relatively heavily used compared to other resources will suffice.

The second step is to prioritize the current projects, in terms of criticality of current commitments, value to the organization, and use of the synchronizing resource. To the extent that there is no easy consensus of strategic priority for existing projects, basic TOC principles of throughput per constraint unit and throughput dollar days can be applied to this effort. The objective of this prioritization is to provide an order in which projects are scheduled through the synchronizing resource.

Once these priorities, procedures and processes are in place, individual project schedules can be developed and put into the calendar through the synchronizer schedule. If chosen correctly, and further protected with capacity buffers, the careful scheduling of this commonly, heavily used resource will result in a set of schedules in which any concerns about contention for other resources will be with the ability of buffer management to provide direction.



5.2.2 Synchronization and Risk Avoidance

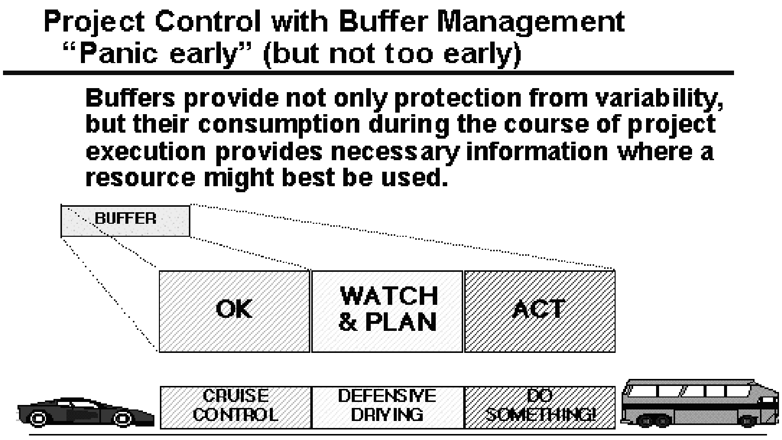
When you consider the duration-multiplying effect of multi-tasking, it should be clear that multi-project risks of cross-project interference could dwarf risks associated with the individual projects. If project value is time sensitive, the delays suffered by projects due to resource time slicing across projects can be very expensive indeed.

The replacement of systemic pressure to multi-task with synchronization, combined with the management of resources for "relay race" behaviors will go a long way to reduce programmatic risk and to speed project completions across the portfolio. The combination of the two will help avoid having to deal with hard-to-predict cross-project risks. In addition, the required careful consideration of the makeup of the pipeline and the active management of the critical resources identified and used as the synchronization mechanism will aid in understanding potential weak links for future improvement.

Most importantly, if combined with effective and supporting processes for planning, scheduling, and control, synchronization of a project portfolio serves to minimize the overall risks to optimum bottom line performance of the organization that owns the projects and their outcomes.

At several points in this paper, the need for and benefit of effective project control has been highlighted. Planning, scheduling and synchronization are all processes that will create a model of expectation for the project organization. But that model needs to be managed once it comes into contact with reality. Appropriate resource behaviors, especially the required focus on the most important task at hand, require the occasional guidance to clarify priorities in a shifting situation. And if the critical chain scheduling process is used, something needs to be used to replace task due-dates to assess the health of project promises.

5.3 Project Control with Buffer Management



The buffers introduced in the Critical Chain scheduling methodology do not only serve to protect project promises in a static manner. They also provide an ongoing view of the health of the project as reality impacts the expected model that is the original schedule. As tasks take longer than the schedule anticipates, buffers are consumed. As they take less time, those buffers are replenished. Awareness of project buffer consumption relative to the completion of the critical chain (and to the expected variability of the remaining work on the chain) provides an important forward-looking focal point for managing project execution.

A number of straightforward ways of assessing buffer consumption make it clear to everyone involved when and where corrective actions need to be taken. Effective Buffer Management is a critical factor in successful implementations of Critical Chain-based project management systems.

Buffer Management typically involves a combination of real-time access to buffer condition and periodic “buffer management meetings.” Real-time, daily updates of project and buffer status are feasible in a Critical Chain environment due to the simple data needed to update active tasks. That data requires only one number at the end of each day a current estimate of time to complete the task at hand. Immediate issues can be quickly identified through this process.

Periodic multi-project buffer management meetings, typically involving project owners, project managers, and resource managers, start with buffer status of the portfolio’s projects. Those with buffers “in the green” require little if any discussion. Those “in the yellow” or “in the red” are rightfully the focus of the meeting, with project managers highlighting identified opportunities and actions for buffer recovery. These meetings are also useful for supporting regular, forward-looking risk management as well, again with an eye to current buffer condition and to its ability to absorb the impact of identified risks.

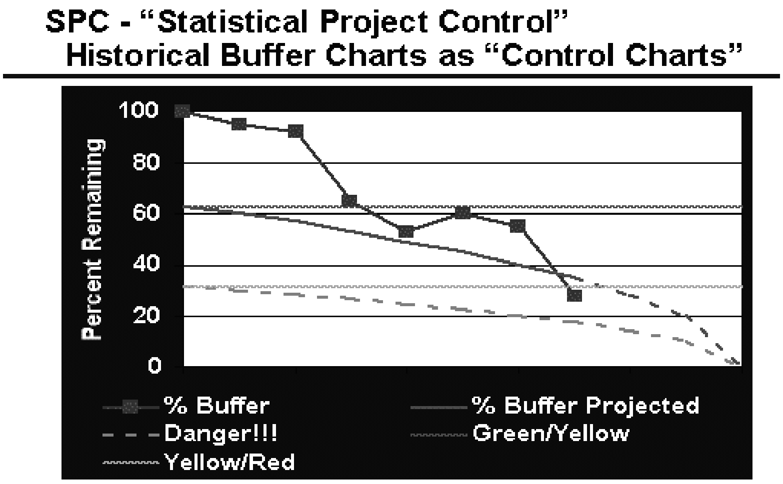
5.3.1 Buffer Management and Risk Identification

Consistent buffer management is a major contributor to the establishment of a risk management culture in a particular project environment. Risks and their positive flip side opportunities are, by definition, potential future occurrences that require a forward-looking approach to support their identification. The everyday process of developing an estimate-to-complete task status keeps short and immediate-term risks in the forefront of the mind of the reporting resources. In addition, the elimination of task estimates as commitments and the related transfer of safety to the buffer should support a greater willingness to raise concerns, if the buffer is there to absorb them and they are not expected to have to have an immediate solution to protect their personal performance.

Buffer management also provides a clear view of the cumulative risk effects of project performance. Buffer consumption at any point in time is the result of all previous work, which can eat away at the buffer quietly but insidiously as the project progresses. If buffer consumption is tracked against the amount of chain completed, or alternatively if buffer remaining is tracked against the amount of buffer required to protect what remains of the chain, trends of diminishing buffer condition or the crossing of pre-determined thresholds will serve to identify indications of risk for the project as a whole.

5.3.2 Buffer Management, Risk Assessment and Response Control

Once a possible risk is identified via its impact on buffers, assessment of whether is deserves further attention is required. There are two mistakes that can be made in dealing with identified risks not acting on them if action is indicated and acting on them if they don’t really matter. Project managers are probably sufficiently paranoid so that the risk of not acting is relatively remote. However, that same paranoia can sometimes drive analyses and actions that are not really necessary. With the unnecessary actions only appears to be distracted in terms of resources and management from getting on with the necessary work.



Buffer charts, tracking buffers condition against chain completion or buffer required for remaining work, can be utilized in a way that is not unlike the way control charts are used in statistical process control for production environments. For an identified risk, a “what-if” analysis can be easily performed, resulting in a view of the schedule or budget buffer after its run-in with the concern. If sufficient buffer remains for protection of the promise from the variation anticipated for the remaining work, then it is not worth the time and attention necessary to develop corrective actions. In this way, buffer management as risk response control has, embedded within it analysis useful for assessment of individual risks as well.

5.4 Buffer Management and Risk Mitigation

The quality of actions taken to avoid or mitigate identified risks is highly dependent on the quality of thinking that goes into their design. The quality of thinking applied to a situation is highly dependent on the environment in which it takes place. With buffer management as the primary project control mechanism, consideration of corrective action takes place when buffer status leaves what is commonly referred to as the “green zone” and crosses into the “yellow zone,” or when trends of accelerating buffer consumption are detected. These assessment triggers occur when there is still considerable buffer, and therefore allow the necessary thinking to take place in an environment that is not one of “panic.”

If, on the other hand, it does threaten to move the buffer “into the red,” then the required mitigation needed to protect the project promise in terms of buffer reclamation necessary to bring it back to “the green” provides guidance on the magnitude of the required corrective action.

5.4.1 Risk

Critical Chain-based Project Management and the Theory of Constraints Thinking Processes provide a range of tools and processes to support Risk Management and the protection of project value. A common thread them is a forward-looking approach to the management of projects. Planning with Network Building looks forward to the objectives of the project before considering the path of activities to get there. The Critical Chain Schedule looks forward to the final project deliverables without being distracted by intermediate task due dates that only serve to sub-optimize schedule performance. “Relay race” resource behaviors look forward with fine focus on the making timely handoffs with quality. Synchronization looks forward to the capabilities of the pipeline. Buffer Management eschews percent complete or earned value of completed work as water over the dam, and instead looks forward to the work remaining, and its variation and risks.

Management of uncertainty and risk in an effort to deliver promised project value with certainty is what project management is all about, and risk and uncertainty lie in the future. Critical Chain Scheduling and Buffer Management is not only a technique for the development and tracking of project schedules. It is a coherent and comprehensive approach to project management that encompasses and effects other processes and practices associated with project management as well. Most importantly, its implications for looking forward and taking appropriate actions for accepting, avoiding, and mitigating risk are significant and beneficial.

Summary - Risk Processes and related Critical Chain PM Processes

Risk Processes	CC Planning	CC Execution
Identification	▪ Network Building	▪ ETC Reporting ▪ Negative Branches
Assessment	▪ 2-Point Duration and Iteration Estimates	▪ Buffer Management
Response Development ▪ Avoidance ▪ Mitigation ▪ Acceptance	▪ Network Building ▪ Buffer Sizing ▪ Buffer Concept	▪ Negative Branches ▪ Conflict Diagram ▪ Network Rebuilding ▪ Buffer Management
Response Control		▪ Buffer Management

5.5 Project development role

Product development projects, like many other types of projects, often can exceed their planned schedule by 50% to 100%. Often this is attributed to uncertainty or the unforeseen. To compensate for this age-old dilemma, managers and project personnel have learned to compensate by adding additional time to their schedule estimates. Yet even when they do, projects still overrun their schedules.

The Critical Chain Method (CCM) or Critical Chain Project Management (CCPM) is an outgrowth of the Theory of Constraints (TOC) developed by Eliyahu Goldratt to scheduling and managing manufacturing. TOC focuses on identifying and fixing bottlenecks in order to improve the throughput of the overall system. Likewise, Critical Chain focuses on bottlenecks. For example, one pharmaceutical company was experiencing significant delays with drug approvals. After investigation, it found that the bottleneck was statisticians to analyze clinical trial data. The cost of hiring statisticians was more than offset by the revenue from getting products to market sooner.

Using the Critical Chain Method, projects can be completed more quickly and with greater scheduling reliability. The difference between traditional and Critical Chain scheduling is in how uncertainty is managed. In traditional project scheduling, uncertainty is managed by padding task durations, starting work as early as possible, multi-tasking, and focusing on meeting commitment dates. The following bullet points illustrate some of the problems associated with traditional project scheduling:

- Padding task durations (providing worst-case estimates) is done to ensure a high probability of task completion. The knowledge that there is so much safety time built into tasks results in various time wasting practices, e.g., waiting until the last moment to complete a task. As a result, all the safety time can be wasted at the start of the task so that, if problems are encountered, the task over-runs.
- Starting work as early as possible, even when not scheduled, is a response to worst-case estimates. When workers give worst-case estimates, they don't expect to stay busy with just one task so they multi-task, working on several tasks at once by switching between them. The result is that everything takes a long time to complete and very little completes early.
- With the focus on meeting commitment dates (start and finish), output from a task completed early will rarely be accepted early by the next person needing this output. So, any effort spent in finishing early will be wasted. Early delivery of one task can't be used to offset lateness on another. Lateness, however, is always passed on and the lost time can't be made up without cutting the specifications or increasing resources allocated to subsequent tasks, if possible.

In Critical Chain scheduling, uncertainty is primarily managed by

a. using average task duration estimates;
b. scheduling backwards from the date a project is needed (to ensure work that needs to be done is done, and it is done only when needed);
c. placing aggregate buffers in the project plan to protect the entire project and the key tasks;
d. using buffer management to control the plan.

The key tasks are those on which the ultimate duration of the project depends, also known as the Critical Chain. The specific steps to identify and manage a Critical Chain schedule are as follows:

- Reduce activity duration estimates by 50%. Activity durations are normal estimates, which we know to be high probability and contain excessive safety time. We estimate the 50% probability by cutting these in half.
- Eliminate resource contentions by leveling the project plan. The Critical Chain can then be identified as the longest chain of path and resource dependencies after resolving resource contentions.

- Insert a Project Buffer at the end of the project to aggregate Critical Chain contingency time (initially 50% of the critical chain path length)
- Protect the Critical Chain from resource unavailability by Resource buffers. Resource buffers are correctly placed to ensure the arrival of Critical Chain resources.
- Size and place Feeding Buffers on all paths that feed the Critical Chain. Feeding buffers protect the Critical Chain from accumulation of negative variations, e.g. excessive or lost time, on the feeding chains. This subordinates the other project paths to the Critical Chain.
- Start gating tasks as late as possible. Gating tasks are tasks that have no predecessor. This helps prevent multitasking.
- Ensure that resources deliver Roadrunner performance. Resources should work as quickly as possible on their activities, and pass their work on as they complete it.
- Provide resources with activity durations and estimated start times, not milestones. This encourages resources to pass on their work when done.
- Use buffer management to control the plan. Buffers provide information to the project manager, for example, when to plan for recovery and when to take recovery action.
- To support Critical Chain Project Management, specialized CCPM software tools are needed to implement this philosophy.

The Critical Chain approach is perhaps the most important new development in project scheduling in the last 30 years. Used properly, the Critical Chain approach is an extremely powerful means of gaining more predictability, productivity and speed from your project plans. It has been found to be an effective tool to protect projects from uncertainty and the effects of Murphy's Law.

Review Questions

17. Explain **Project Control with Buffer Management**?
18. What do you mean by **Synchronization of scheduled multiple projects**?
19. What are the factors that affect **Risk Mitigation**?
20. What do you mean by resource behaviour for timely projects?

Discussion Questions

Discuss the Project development role?

Application Exercises

13. Explain why Critical Chain approach is most important development in project scheduling?
14. What is **Critical Chain Schedules and Risk Assessment**?
15. What is **Integration Risk Avoidance**?

CHAPTER 6

Critical Chain Scheduling Methods

Learning Objectives

- To explain about Murphy's Law.
- To analyse the critical chain theory.
- To recognise Critical Path Method approach.
- To explain about **Bad Multitasking**.
- To identify monitoring a project.

6.1 Introduction

It all really boils down to the fact that the way we manage for uncertainty in projects is at the core of improvement of project performance, defined as getting projects done both faster and with better reliability of the promised final project due date. TOC/CC suggests the shifting of focus from assuring the achievement of task estimates and intermediate milestones to assuring the only date that matters that the final promised due date. As a matter of fact, the scheduling mechanisms provided by CC scheduling allow/require the elimination of task due dates from project plans. Its benefit is that it allows those who use it to partially avoid "Parkinson's Law;" i.e., work expanding to fill the time allowed. Take away the idea of time allowed, and you've got half the battle won. But how to do that is the question that requires us to look at some current common project practices.

Project tasks are subject to considerable uncertainty, from both the unknowns of the invention process (in development projects especially) and from the universal effects of "Murphy's Law." As a result, task estimates that make up project schedules can contain considerable "safety" in them to try to allow for these unknowns when planning the project. In addition, many project organizations are multi-project enterprises, with resources frequently working across projects on more than one significant task in any particular period of time. This practice of multi-tasking, unfortunately common in many project organizations in many industries, also leads to expanded project lead times because when a resource alternates between tasks/projects, the task times for an individual project are expanded by the time that is spent on the other projects' tasks. Project resources are aware that they're in this multitasking environment and so their task estimates are further expanded (even unconciously multiplied by factors of as much as two or three) to account for this practice in project task commitments. The combination of the effect of the multi-tasking environment and the need to cover uncertainty lead to "realistic" project task estimates that contain considerable "safety" above and beyond the actual work time required for a task, and subsequent project plans and commitments that include these expanded times.

The TOC approach addresses this expansion of project plans with two mechanisms. First, we remove the safety from the tasks, and aggregate it as "buffers" of time that are sized and placed in the schedule to protect the final due date of the project from variability in critical tasks and that protect critical tasks from variability in non-critical tasks that feed them. These buffers now allow us to shorten task time estimates to aggressive target durations, shortening the time within which resources strive to to achieve their tasks. These short target durations (approximately 50% confidence estimates, whose expected overruns are isolated from the actual project commitments by the buffers), also support the second mechanism. They are so short that the resources are uncomfortable succumbing to multi-tasking or other distractions. This behavior supports the additional requirement posed by the CC methodology for management to enable resources to focus on tasks and to eliminate the multiplying effect of multitasking on project lead times. This is intuitive to many of us we often isolate project teams from multitasking in special task forces or "skunk works" when projects are of special importance. What the TOC approach allows us to do is apply this common sense solution to the overall project environment.

Using the critical chain theory involves delaying activities' schedules until the activities are scheduled close to their late schedule instead of being scheduled to their early schedule as is traditionally done in scheduling projects. Because the late schedule essentially places all of the activities on the critical path, a buffer is placed into the schedule to allow delays in the project activities without delaying past the promised project completion date.

According to Goldratt, delaying the work of the project to more closely follow the late schedule has the advantage of allowing the project team to learn from the experience and knowledge gained in doing other parts of the project?

Traditionally, project schedules have four dates associated with each activity: early start, early finish, late start, and late finish. Most project managers use the early schedule dates to schedule their projects. This means that if all the activity work takes place in the early starts and early finish dates, that work is done as soon as possible. It also means that if anything goes wrong, there will be the maximum amount of time available to do the work needed to recover from the problem.

As we saw in our discussion on buffered schedules, scheduling without buffer and using the project activity’s most likely durations can have a 50 percent probability of completing the project on the promise date. It made sense to buffer the project completion by two standard deviations and creates a promise date that was two standard deviations later than the promise date predicted by the most likely durations.

Goldratt goes one step further in buffering schedules. Most schedules that we see in discussions like this one or in classroom situations are rather simple in comparison to real project schedules. One of the ways they differ is in the magnitude of float. In sample projects, for convenience, examples are given with relatively few activities and short, easy to understand schedules. In reality project schedules are longer and more complicated and frequently have large amounts of float in many activities. In fact, normal projects will have more activities off the critical path than on it. For this reason we need to pay more attention to the activities that are not on the critical path.

To use Goldratt’s terminology, a project schedule has critical and non-critical chains of activities. The critical chain of activities is the traditional critical path but includes the effect of resources on the schedule. This means that the critical chain is the list of activities that have no float after any resource conflicts have been resolved. This is really the definition of the critical path as it is normally used. It is somewhat misleading that nearly all of the examples, including ours, calculate the critical path without showing the effect of resource conflicts.

All the activities in the project that are not on the critical chain are, by definition, noncritical activities and have some float associated with them. In real projects these activities tend to group themselves together to form subprojects within the project. These are what Goldratt calls "feeder chains". The characteristic is that the feeder chains are relatively independent of the critical chain until an activity on the critical chain depends on them. In case of feeder chain and critical chain, feeder chain A, B, C, D has quite a lot of independence until the time activity P on the critical chain depends on it. The same is true of other feeder chains.

The other important point here is that the feeder chains in real projects frequently have large amounts of float as well. As projects grow, it becomes more likely that there will be groups of activities that can be thought of as subprojects. These groupings of activities are not likely to take as long as the activities on the critical chain and will therefore have considerable amounts of float.

If the feeder chains are scheduled to their early schedule dates, early starts, and early finishes, there is a disadvantage. The disadvantage is that if changes in requirements, risks, or other problems occur in the project, much of the work in the feeder chains will already be done and will have to be ripped out. This problem can be at least partially avoided by scheduling the feeder chains more toward their late schedule. Delaying the schedule of the feeder chains will also let us take advantage of lessons learned on the critical chain activities. These can be applied to the feeder chain activities.

Of course, if the feeder chains are scheduled to their late schedule dates, this essentially puts all the feeder chain activities onto the critical path. Remembering what critical path really means, the feeder chain activities will cause a delay in the project completion date if they are delayed. We don’t want this, so we need to apply buffers as well. To set our schedule correctly, taking all of these factors into consideration, we need to do the following:

- Calculate the critical chain of the project after resolving resource conflicts and all of the resource and other schedule constraints.
- Buffer the critical path by calculating a two standard deviation buffer and applying it by starting the project earlier than the early start date or promising the stakeholders a project completion date later than the early finish date of the project.
- Group the feeder chain activities into feeder chains.
- Calculate the two standard deviation buffer for the feeder chain and schedule the activities in the feeder chain according to their late schedule dates minus their buffer.

By scheduling this way the feeder chains have a 95 percent probability of being completed within their buffered schedule and not affecting the critical chain activities. The critical chain activities are also buffered so that the probability of missing the buffered promise date of the project completion is 95 percent.

Under this, we have to reduce the task estimates, but we still have these buffers that include the protection that was previously spread around and hidden in the tasks. As seen, it was mentioned that using 50% confidence estimates for the task durations which indicates that, if allowed to focus on the tasks, half of the time tasks will be done in less than the target plan and half the time they will take longer. Due to the statistical nature of this uncertainty of tasks, this leads those using the TOC approach to be able to use buffers that are significantly shorter than the sum of the safety that was spread around in the previous scheduling paradigm. After all, those that come in ahead of time will replenish the buffer that was consumed by those that took longer than expected, assuring the protection of the only date that counts -- the final project due date. So with the combination of reduced task estimates due to the aggregation of safety and the reduction of buffer size, overall project plans can be typically 20-30% shorter than traditional plans with similar initial risk.

There is also another benefit of the use of the buffers, beyond protection of due date performance. They aren't just passive chunks of time in the schedule, but a rather also provide the project manager and/or team with a clear indication of the health of the project at any point in time. The tracking of the consumption of these buffers provides warnings and indications of potential problems far before the project promise is in real trouble, allowing development of recovery plans in an atmosphere other than one of crisis. Once a project plan is implemented and underway, TOC's "Buffer Management" provides built-in risk management and therefore enhanced reliability of meeting the project due date, even with the shortened overall project lead time.

As a summary for individual projects, the TOC approach, by viewing the project as a whole system instead of simply as a chain of independent tasks, allows for both shorter project lead times and enhanced reliability. As explained, many project organizations are multi-project environments. How can TOC provide guidance for enhancing the ability of a multi-project organization to be more productive in the quantity of projects or new products undertaken and delivered?

Project and task times, due to focus and buffering, are shortened. Therefore, first we expect that the capacity hidden in and consumed by practices such as multi-tasking and task-based safety can be unleashed to simply do more work in the same timeframe. But even beyond that, the core of the TOC view of multi-project environments lies in recognizing that within a project organization, there is some resource that can be considered a bottleneck or constraint limiting the ability of the organization to do more projects. When we manage the individual projects using the TOC approach, the lack of multi-tasking and embedded safety makes it easier to ascertain the true capacity of project resources, and hence identify the constraint resource. Once the organization as a whole is managed with the constraint in mind, management attention becomes far more focused and decisions to further enhance project capacity are easier to justify and implement.

Shorter project lead times, improved reliability of project due dates, and increased capacity of the organization to take on more projects are not only predictable but have been observed in a number of organizations that have used this approach to projects in a variety of industries.

6.2 Concept

Critical Chain Method concepts are that which was first introduced in 1984 by Goldratt. The main factor for the success of these ideas is that it finds solutions to the classical problems we encounter once we plan following the Critical Path Method (CPM) approach. CCPM (critical chain Project Management) is basically a mix of the most recent best practices:

- PMBOK: Plan & Control.
- TOC (Theory of Constraints): Removal of bottleneck to solve system constraints.
- Lean: Remove waste.
- Six Sigma: Reduce any deviation from optimum solution.

6.2.1 The problems

Going back to CCM, the main problems it aims to solve are:

6.2.2 Over estimating

This is a problem that usually comes up when defining plans. In a few words, since:

- estimation are always cut,
- details, at the beginning of a project are not always clear;

tasks that have the biggest uncertainty are systematically over-estimated. We create contingencies, to protect us from the fact that things we don't know will go wrong. This process is then amplified because estimation are presented to many stakeholders, at many levels, and often each level put its own contingency so that at the end the project duration is usually over estimated.

6.2.3 Student Syndrome.

This happens in case of long projects or loose schedules: usually people will start working on a task not when planned but when the delivery time will be near. The reasons are linked both to the other issues we are presenting here (multitasking, parkinson law) and simply psychological: people will not start working till they will not fell the pressure.

6.2.4 Parkinson's Law.

This is a **notorious empirical law** *(*Work expands so as to fill the time available for its completion) in Project Management. In other words if you assign 15 day to accomplish a task that can be done in 10, then it will hardly happen that the work will be completed in 10 day, but magically it will be completed in 15. Evidences of this law are well known to PMs.

6.2.5 Bad Multitasking

When multitasking is not correctly managed, the result is wasting of time. This is another well know issue in real projects: when you assign more that one task to a resource, most of the time you will get inefficiencies, because jumping from one to the other, instead of completing one and then the other is only making the most critical task going late.

6.2.6 Handling of early finish

The problem in my opinion has even a theoretical reason in the CPM theory. In a few words, even if we would be able to close a task in advance we wouldn't be able to get the most out of this.

Indeed if the task is not on the critical path, closing it in advance doesn't give for sure a direct advantage (maybe you get some resources free, but without planning you wouldn't be able to use them) if on the other side the task is on the critical path, an early closing could not be so relevant (in the sens that we could have other tasks that become critical) and, taking the concept to the limit, we could need of replanning the project or part of it, finding maybe another critical path. In any case CPM doesn't give a natural way to handle early close in the project tasks, since it doesn't plan it.

6.3 Planning with CCM

CCM is trying to solve all the issues just present by proposing a new approach to the preparation of the project plan. The key points of this new approach are:

- Plans "Resource constrained" i.e. where the available resources are a constraint.
- Scheduling according to the "Late Finish" principle and direct definition of the critical path (here called critical chain).
- Usage of Buffers (added to specific tasks) so that we are able to avoid slipping in the schedule:
    - **Project Buffers** (PB): Time buffer added at the end of the project (usually 50% of the total duration of the tasks in the critical path).
    - **Feeding Buffers** (FB): Time Buffer added at the end of each sequence of non critical tasks.
    - **Resource Buffers** (RB): Time Buffer used as early warning to show that the resource will be used in a specific. Such alert can be put some days before a resource will actually start working.
- Removal of contingency time and cut of the duration of all tasks of 50%.

Somehow the project becomes like a relay race where the "baton" (project flow) goes from one task to the other, avoiding parallel runs and working only on completing the project, where any early close gives higher probability of an early close of the overall project.

- Define for each task dependencies and assigned resources

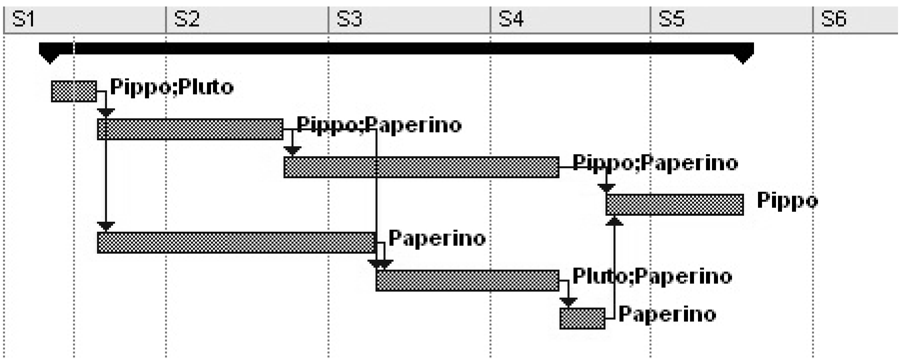


Fig 6.1

- **Plan backward and "as late as possible"**

In planning with CCM schedule is done starting from the target date (or from the last task) and adding the other tasks (according to the dependencies) in a backward process. Once we close this phase we get the maximum date according to which we can start working on the project without being late.

Please note that in this approach all tasks are added near the completion date. Sometime delaying the work can lead to some benefits, for example we minimize Work in Progress and reduce in initial costs.

- **Solve resources conflicts by eliminating multitasking**

In case of resource conflict, activities will be delayed or started earlier but will not execute in parallel, with the resource working on both. This means that if two activities use the same resource, they will be in sequence, instead of lasting more and being shared. Obviously the most critical activity will have the higher priority. At the end of the phase we should have for every resource a sequence of not overlapping task assigned.

- **Identify the critical chain**

Now we should be able to identify the critical path of the project. In CCM this is called critical chain.

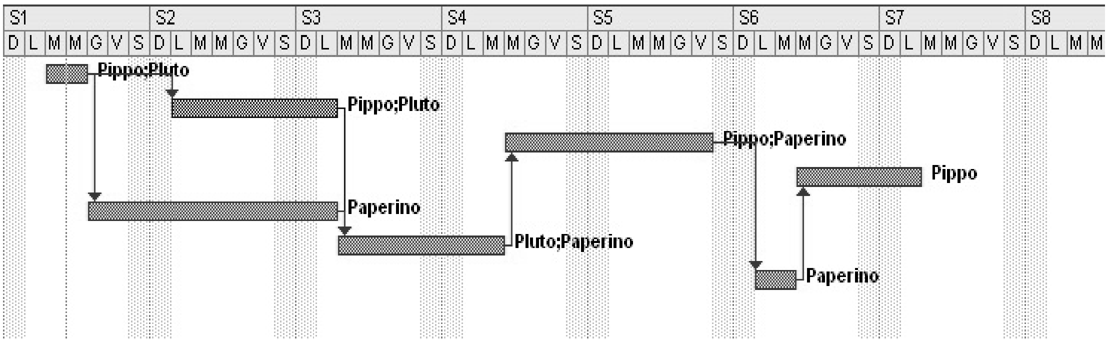


Fig 6.2

- **Cut every task by 50%**

All tasks will be correctly estimated (even better estimated using statistical methods) and then all estimation will be halved.

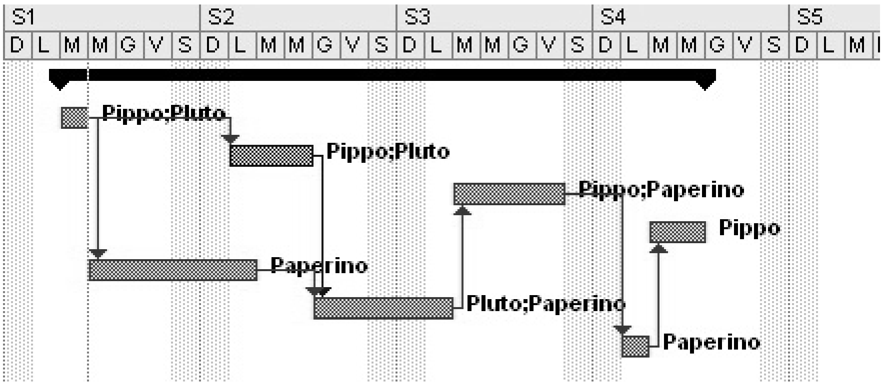


Fig 6.3

6.4 Introduce Buffers

After eliminating the resource contemptuous and the multi-assignment practice, the introduction of buffers is the second new idea of CCM: we introduce buffers, i.e. period of time that protect the project from the fact that if a deliverable is going to be late, the overall project will not suffer this delay.

CCM uses buffers in critical point of a project and among two or more projects (multiproject environment) with the idea of making the project steadier, against changes in it. Indeed without buffer, every change is going to modify the plan. it is exactly the role of buffer to stabilize the project, acting, somehow, as contingency.

As written up we use three kind of buffer:

- **project buffer** - We don't add buffer to the tasks of the critical path. We only add an unique final buffer that should take in account all the uncertainties within the tasks. This buffer should be around 50% of the duration of the critical chain.
- **feeding buffer** - these buffers are added at the end of chains of tasks, that are not part of the critical path, before connecting to critical tasks so that we take in account for uncertainties in task not critical.
- **resources buffer** - These are buffers added as "wake-up calls" to alert resources so that we are sure that they will be ready to work on task of the critical chain.

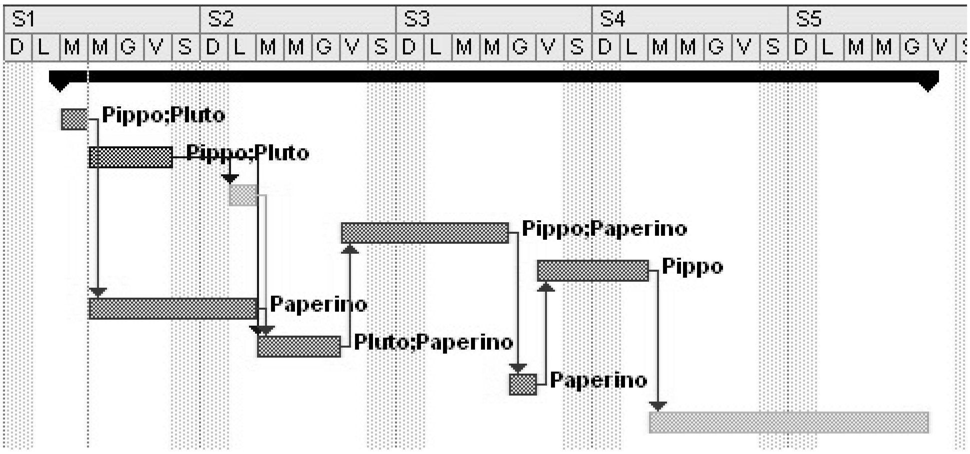


Fig 6.4

At this point the plan is complete. For comparison below you can see the picture of the same project as worked out by Ms Project by using a resource leveling.

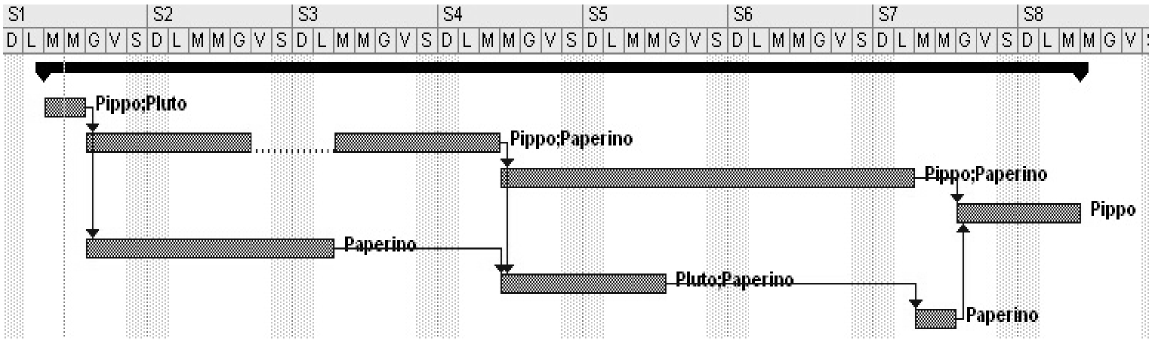


Fig 6.5

6.5 Monitoring the project

Monitoring a project where CCM has been adopted needs to be done using techniques different slightly different from the traditional ones. All tasks have a duration which is 50% of the original one, so it doesn't make sense to monitor if the task is closed within the planned date and to handle like "delay" if a milestone was missed. What makes sense to do, is monitoring the buffers that were created during the planning phase. As a matter of fact it's possible to build simple graphs that show the way buffers are consumed as the project goes on.

If the consumption speed of our buffers is low, we can assume that the project is "on target", if on the other side the speed is so fast that we can forecast that we will not be able to close the project without using more buffer that what we planned, in this case we need to perform some corrective actions, in the worst case to develop recovery plans or to completely replan the project.

6.5.1 CCM in multi-project environments.

Working in multi-project environment simply amplifies the multitasking problems:

- Multitask work generates inefficiencies
- Links and Constraints number becomes bigger, making complex to manage project changes
- Focus decrease

CCM approach multi projects with the idea to maximize the capability of completing project of a structure, based on the priorities and on the constraints coming from the resources. The way to do it is simple:

- Schedule the single projects, according to CCM,
- Solve all resource contention problems, working most on the resources most used among the projects and assuming that is the availability of resources that determines the speed of the project. Goldratt defines these resources (the ones around which project are scheduled) as “drum resources”
- Define the start of the projects according to priorities and boundaries.

With these principles we should be sure that projects are scheduled based on constraints and capacity of the organization. The final effect will be the one of a better resource usage and the delivery of critical projects in advance to what happens using traditional schedule methods. Following an example of schedule in traditional way

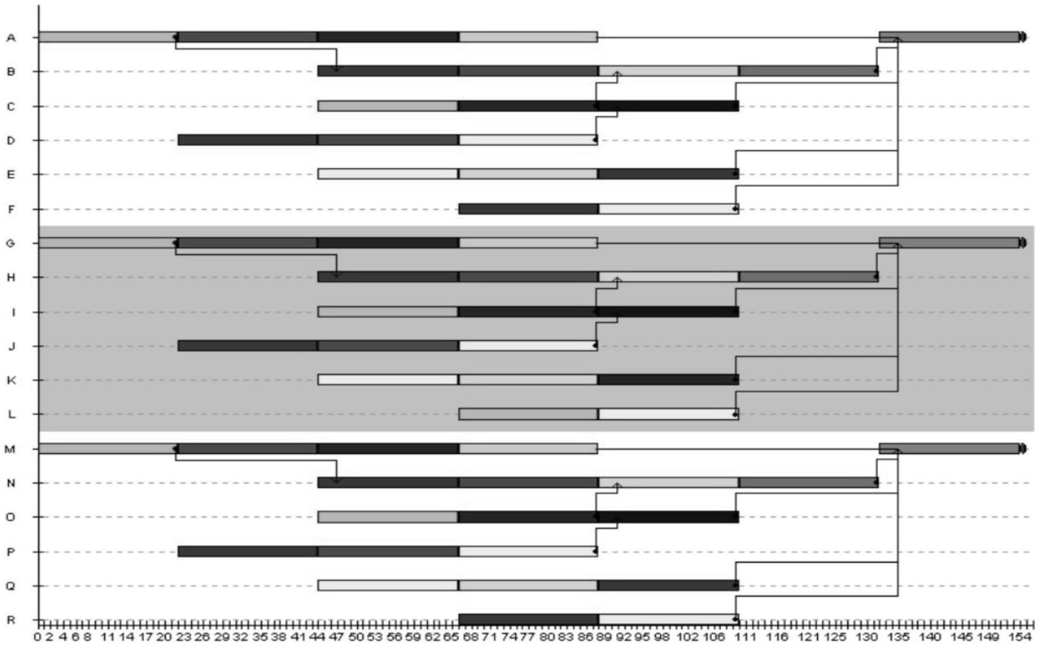


Fig 6.6

and the same example worked out by using CCM:

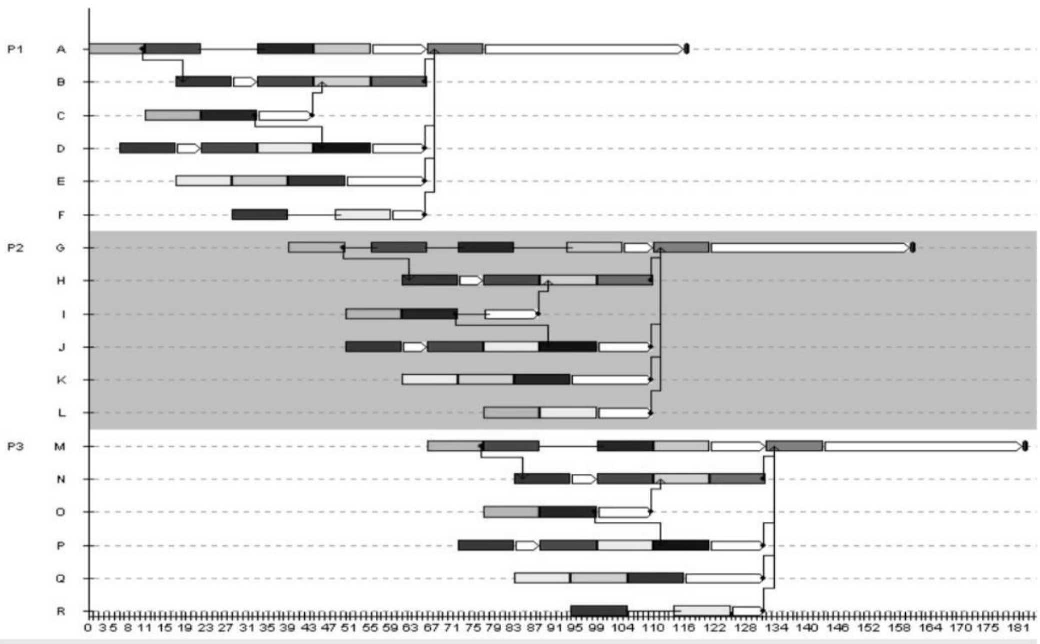


Fig 6.6

6.5.2 Conclusion

6.5.2.1 Project control

I'm quite positive towards CCM, especially in planning for software development; however one of the areas that is still not comfortable in the project control. Accordingly, CCM is still needs to develop specific tools in this subject. According to the literature, project analysis should be done by means of:

- Reporting on buffer usage
- Comparison of completed task in the critical chain agaist percentage of buffers used, in a way to estimate completion date of the project
- Checking of consumption speed of buffers (or as percentage or as absolute days)

Anyway, think that to control projects only by analyzing buffer consumption, is not such a strong technique, especially if compared to what is possible to do with CPM. As a matter of fact we should dig into this area and maybe develop some stronger (mathematical) tools.

If then we move to the area of project costs, we should find a way to expand the concept of buffer and introduce the "cost buffer", in a way to link the analysis of the cost of a project to the normal buffer, otherwise cost analysis will be too much random.

6.5.2.2 Risk Analysis and Buffer

In some articles we find that the analysis of buffer consumption can also be linked to risk analysis, however even in this subject it would be followed that a cautious approach at this level of maturity, should not integrate the risk management within the buffer analysis, but we should keep it separated.

6.5.2.3 Correct Estimation

Cutting estimation at 50% is a statement that we should analyze better. In the net it is possible to find, however in the opinion not all treat the matter clearly as 60% o il 40% could be good as well.

As suggested, it is important to use a series of estimation and statistical methods to find the duration of the tasks. Once we have this estimation it is possible to cut the activities in a way that will give us 50%, 60% or any other well determined percentage of likelihood of task completion. In this way we would also be able to give a statistical meaning to our plan, as it is possible to understand by looking at the next picture:

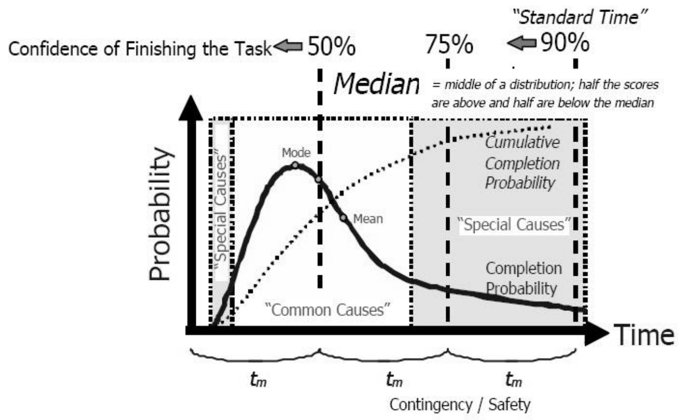


Fig 6.7

6.5.2.4 CCM compared to al CPM

Speaking of software development, CCM, especially at the beginning, can be used with advanced teams that are aware of risks and characteristics of it and in specific cases (when task are not fixed duration and don't involve an high number of resources).

As a matter of fact we have a new approach that gives a lot of advantages but deserves some attention points:

- looks easier but it's more complex

Plan with CCM is more complex than planning with CPM. Even tools that we may use are "calibrated" on CPM, so a bigger work is needed.

- You need to know better your project and its characteristics

First you need to have cleat tasks, durations, links and most of all resources. More it is necessary move from one approach where estimation is unique to an approach where estimation should be build on a statistical basis.

The statistics are much more important in CCM than in CPM: here the estimation process is quite important to understand how we approximate buffers estimation and how we handle them. Indeed buffer duration needs to be estimated as much correct as possible, since it is from this estimation that we should get the theoretical maximum duration of the project.

6.5.2.5 CCM should be used instead of CPM only when more convenient

Not all projects can be managed in a natural way with this methodology. In my opinion CCM is best suitable for projects where tasks don't have fixed duration. For example in a gap analysis project where meetings are the core of the project, the best way is to use the CPM, since usually it takes a lot of time to schedule all meetings and it is not easy to move them, in case of some delay or early finish of the meetings. Maybe using a mixed approach, where all the project is managed using CCM (or CPM) and some specific subprojects are managed with CPM (or CCM) could bring some improvement, but this need to be checked.

Regardless all this issues CCM is a good planning method and that it make sense to exploit it both in "real" (by starting with small software projects project, where there is a basic uncertainty on the duration) both on the theoretical side, by developing better tools for managing and controlling the project.

6.6 Estimating and Scheduling

Perhaps the most arduous task that afflicts project managers involves keeping today's aggressive project schedules on track. Because resources are continually restricted more and more and the highly skilled, high-priced resources are often required for multiple projects, resource constraints become one of the highest risks to the project schedule. To help ensure that project schedules are met, project managers have learned to concentrate on a project's critical path. They have also learned that the resources used along the critical path the critical chain of resources especially those resources shared among projects, must be proactively managed.

This is where Critical Chain Project Management (CCPM) can aid the project manager—by planning and managing a project's schedule through a unique optimization process that joins the task-dependent critical path with the critical chain—the resource-dependent tasks that impact the project completion date. The critical chain explicitly defines a resource-leveled set of tasks. If the quantity of resources is unlimited, the critical path and the critical chain are identical.

Unfortunately, the resource-leveling activity that identifies the critical chain often extends the project's end date. To meet the original, predefined end date, the new schedule must be optimized. Critical chain optimization, just like critical path optimization, looks at individual tasks to determine which time estimates can be shortened. Critical chain optimization, however, also focuses on a project's resources, keeping them levelly loaded through flexible start times and quickly switching among tasks.

Critical chain optimizing recognizes that the entire safety margin originally built into every project schedule might not be required and that all tasks, in theory, could be completed ahead of schedule. Keep in mind, though, that as long as the safety margins exist in individual tasks, the ability to shorten the overall project length is minimalized. Yet, if the safety margins are all removed and even one critical task exceeds its estimated length, the completion date for the entire project is jeopardized

6.6.1 Scheduling Buffers

CCPM methodology places safety margins—buffers—in the project schedule while pushing individual tasks to completion in the shortest time possible. The project manager applies and monitors four specific buffers that allow for contingencies where resource risks have the greatest impact on a project:

The project buffer protects the project from missing its scheduled end date due to variations along the critical chain. It places a portion of the safety margin time that was removed from each task estimate into a buffer task, thus moving the times of uncertainty from individual tasks to a pooled buffer task. The project buffer is inserted between the final scheduled task and the scheduled project end date. The critical chain starts at the beginning of the project and ends at the start of the project buffer, not at the end of the project. Time is added to or subtracted from the project buffer as the actual time required to complete each task changes.

The feeding buffer minimizes the risk that late completion of a non-critical chain task will affect the critical chain. The project manager inserts an amount of time at those points in the schedule where inputs from non-critical chain tasks merge with critical chain tasks. The result is very similar to a relay race where the speed of the race, in general, is able to be maintained by the overlap in runners at the hand-off point.

The resource buffer is an alert that is sent to critical resources to ensure that they have time to complete their current tasks and begin to prepare for the critical chain task so that work can begin on the latter task as soon as the former task is completed. This buffer can be implemented easily and provides immediate benefit with little or no cost.

The capacity buffer places on-call resources that are available to avoid schedule delays due to unforeseen issues into the budget. Because this buffer adds additional cost to the budget, it is, unfortunately, seldom applied such an expense goes against most organization's cost control principles. Obviously, the capacity buffer makes more sense in a multi-project environment, where the cost can be distributed over multiple project efforts.

The project manager focuses on managing these buffers during the monitoring and control phases. Frequently updating the time-to-complete for individual tasks while closely monitoring the consumption and replenishment of the buffers allows the project manager to track actual project progress against the original schedule. The project manager can effectively analyze current progress, implement corrective actions, and maintain focus on the most critical aspects of the project.

6.6.2 CCPM Process

At a high level, the CCPM process for developing and controlling a project schedule is composed of the following steps:

- Reduce individual task estimates dramatically. This is done either by slashing the estimate by 50 percent or by applying a three-point estimating process to each task.
- Resource level the project to remove resource contentions. At this point, the critical path is transformed into the critical chain.
- Aggregate a portion of the reduced task estimates into a project buffer, and insert this buffer at the end of the project.
- Insert feeding buffers at points where non-critical chain paths intersect the critical chain. The subordination of non-critical chain paths allows continued focus on the critical chain.
- Insert resource buffers where appropriate to reduce the probability that a critical resource is unavailable when scheduled.
- Insert capacity buffers where appropriate.
- Limit or eliminate multitasking.
- Schedule tasks with no predecessors to start as late as possible.
- Encourage tasks to be completed as quickly as possible. Emphasize the importance of start times and aggressive task completion rather than due dates.
- Manage buffers to support preventive and corrective actions.

6.7 Multi-project Environment

Even though CCPM concepts are often applied in a single-project environment, they take on additional significance in a multi-project environment. The most loaded resource shared across projects, also called the drum resource, affects the overall completion date or schedule of the individual projects because each project is forced to progress at the pace of the drum resource.

Consequently, the critical chain and the paths that merge with it may result from resource dependencies outside the scope of a single project. Providing visibility to resource conflicts that exist outside the individual project is necessary to get a true picture of the overall project management environment within any organization.

Conclusion

If your organization is highly networked, has a large number of projects requiring a few critical resources or a drum resource, and primarily operates by using time as the dominant leg of the triple constraint, then CCPM can be a meaningful addition to your project management toolkit. But every organization, regardless of size and project management inclinations, should consider gradually incorporating into its current project management methodology the individual CCPM principles that are applicable.

CCPM may be the most important new approach to project scheduling in the last thirty years. It is a method that can be applied to meet the ever-increasingly aggressive schedule requirements that every project manager is facing while, at the same time, helping organizations to maintain quality and productivity. It has been proven to be an effective method to protect your projects from the inevitable slippages that occur in every project.

Review Questions

21. Explain Murphy's Law?
22. What is critical chain theory?
23. What are the benefits of benefit of using the buffer?
24. What is Critical Path Method approach?

Discussion Questions

Discuss the Project development role?

Application Exercises

16. Explain **Planning with CCM**?
17. How many kind of buffer are used in CCM?
18. What is Monitoring a project **in CCM indicates**?

CHAPTER 7

Application of Critical chain scheduling

Learning Objectives

- To explain about Critical Chain Scheduling and Buffer Management.
- To analyse the Parkinson's Law.
- To recognise problems and challenges in CCS.
- To explain more about Murphy's Law.
- To generalized the idea about resource buffer.

7.1 Introduction

The approach to project management known as "Critical Chain Scheduling and Buffer Management" provides mechanisms to allow a "whole system" view of projects. It identifies and protects what's critical from inevitable uncertainty, and as a result, avoids major impact of Parkinson's Law at the task level while accounting for Murphy's Law at the project level.

Project managers and teams need to shift their attention from assuring the achievement of task estimates and intermediate milestones to assuring the only date that matters the final promised due date. Safety that is typically built into tasks to cover Murphy's Law is inefficient, leading to longer than necessary (or acceptable) schedules, and apparently ineffective, given the impact of Parkinson's Law from which many projects suffer.

7.2 Problems and Challenges

Project management must reconcile two conflicting aspects of projects that gives an increasingly important need for speed in project delivery and the equally important need for reliability in delivering the project as promised. Project management must deal with uncertainty in an attempt to deliver project outcomes with certainty. One way of thinking about how to deal with this conflict is to develop strategies to avoid expansion of project lead-time (Parkinson's Law) while protecting against Murphy's Law.

The way we manage for uncertainty in projects is at the core of improvement of project performance, defined as getting projects done both faster and with better reliability of the promised final project due date. In most projects managed with commonly accepted practices, this uncertainty is dealt with by focusing on delivery of tasks with the seemingly reasonable belief that if individual tasks come in on time, the project will as well.

Developed through the application of the Theory of Constraints to the subject of projects, "Critical Chain Scheduling" suggests the shifting of focus from assuring the achievement of task estimates and intermediate milestones to assuring the only date that matters--the final promised due date of a project. As a matter of fact, the scheduling mechanisms provided by Critical Chain Scheduling require the elimination of task due dates from project plans. One benefit is that it allows those who use it to avoid the significant impact of "Parkinson's Law;" i.e., work expanding to fill the time allowed. Take away the idea of time allowed, and you've got half the battle won. But how to do that is the question that requires us to look at some current common project practices and how they lead to "Parkinson's Law."

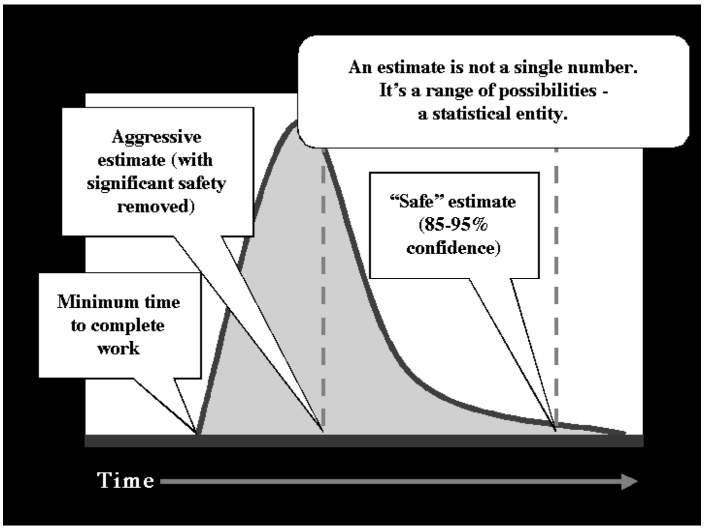


Fig 7.1

People usually derive schedules and their component deadlines from estimates of duration required by the various tasks that comprise the project. In many cases, project resources know that they will be held accountable for delivering against their estimate, and equally, that the organization needs to be able to count on their promise. Therefore, it is prudent that they include not only the amount of focused effort/time they expect the work to take, but also time for "safety" to protect their promise. This safety must deal with the uncertainty involved in the work (Murphy's Law), the impact of distractions and interruptions they live with in their organization, and, in many cases, the effect of dealing more than one such project at a time.

When looked at as a whole, these estimates are not really a single number, but rather they are statistical entities, reflecting the probability of task completion in a certain amount of time.

An aggressive estimate, reflecting only the amount of work required might have a 50% level of confidence, while a longer realistic estimate, one against which the resource is comfortable committing to, might be closer to an 85-95% range of confidence.

So task estimates have plenty of safety in them, above and beyond the actual expected time to do the work. Often this safety is the larger part of the estimate, doubling or tripling the amount of time the work would require if done in a vacuum.

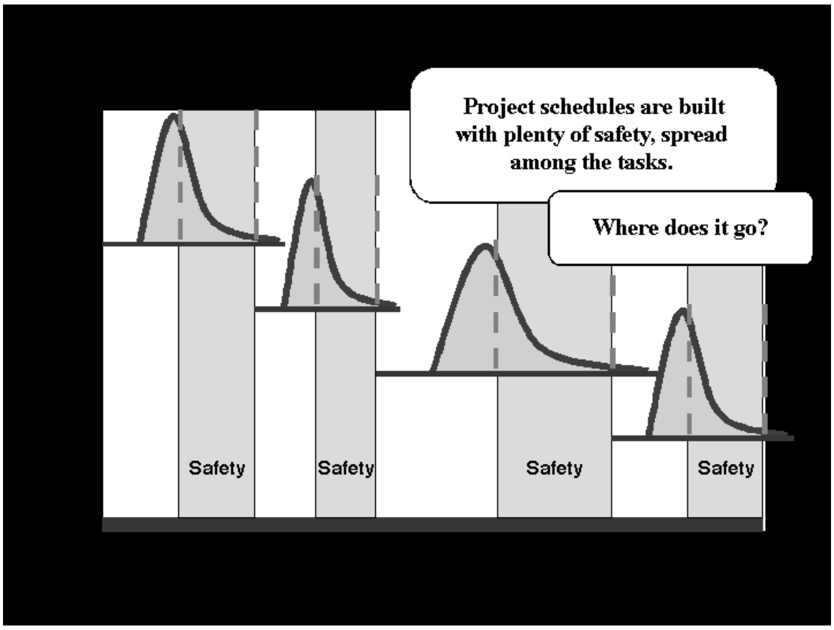


Fig 7.2

In some occasional cases, it may simply be an issue of excessive problems or erroneous assumptions overwhelming the safety, but the difficulty of bringing in projects on time is so common that there must be something else happening in the system contributing to the effect. Perhaps it's in the way the safety is used.

In most projects, estimates are turned into a project schedule a list of dependent tasks with associated start-dates and due-dates. People plan their work around these dates and focus on delivering their deliverables by these dates. They also try to plan other work so they are free to work on the project task at the start date.

The problem comes in when the scheduled time arrives. It often happens that there is other "urgent stuff" on one's desk when the task shows up in the in-box. And in any event, we have until the promised date to finish the work, which at this point looks like a long way off due to the safety included in the estimate. We are comfortable putting off or "pacing" the work in favor of other stuff because the due date is out there.

The "urgent stuff" takes precedence until we see the due date sneaking up on us, or, as the following graphic shows, the due date is within even the aggressive expected duration of the work itself. Sometimes it sneaks up quietly enough that when we look, we realize that it has now become urgent and gets our attention.

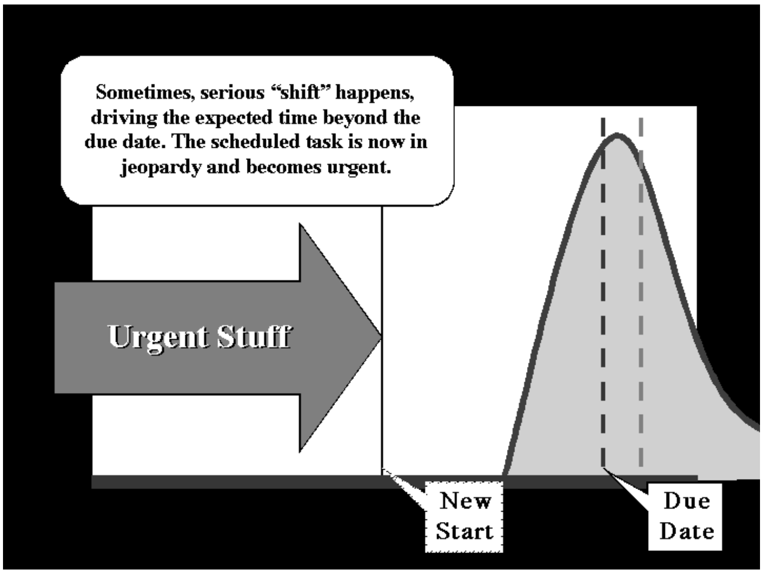


Fig 7.3

So now the originally scheduled project task is hot. If our office has a door, we close it. We let voice mail pick up our calls. We work at home to get the job done without distractions. The only problem is the problems.

The safety that we included was not only for the non-project distractions, but also for the unknowns (the "Murphy") associated with the task itself. We can't know what problems will crop up until we start the work. And we've started the work later than planned, after eating up most, if not all, of our safety attending to other important work. There isn't time left to recover from the problems in time to meet the due date, at least without heroics, burnout, or loss of quality.

So task deadlines are hard to meet...and cascade through the project, putting the promise of the final delivery into jeopardy, which creates new "urgent stuff" which impacts other projects...and so on and so forth.

Even if, by some miracle, you do finish a task early, since the next task is keying off your original deadline as a start date for their task, will the required resource be available to pick it up? Or will they feel an urgency to pick it up, since now they have not only their safety, but also your early delivery to protect their due date? I think not. So the project is pretty well doomed to meeting the final target date at best, but in all likelihood either missing it, or just making it with burnout heroics or compromised quality.

7.2.1 Parkinson's Law

This all occurs due to the combination of task due dates and realistic, prudent, "safe" estimates. We protect our project due dates by protecting task due dates with safety. Then, from the point of view of the project, we waste that safety due to the comfort it provides, and put the project promise in jeopardy.

If there were a way of managing projects without task due dates and the undesirable behaviors they instigate, it would have to deal with several non-trivial challenges:

- How can we systematically protect the promise date of an entire project from Murphy and uncertainty without nailing all the tasks to deadlines on a calendar, which brings Parkinson and wasted safety time into the picture?

- How can we systematically take advantage of early task finishes when they can help us to accelerate the project and maybe allow us to finish it early, freeing up the resources to address other projects?

- How can we manage the execution of a project -- how do we know what shape our project is in once it gets started, if we don't have due dates to track?

One solution to these challenges is found in the approach to project management known as Critical Chain Scheduling and Buffer Management.

7.3 Challenges

7.3.1 Achieving Speed and Reliability

How can we systematically protect the promise date of an entire project from Murphy and uncertainty without nailing all the tasks to deadlines on a calendar, which brings Parkinson and wasted safety time into the picture? Three things can help to avoid Parkinson's Law.

- Build the schedule with target durations that are too tight to allow/encourage diversion of attention.

- Get rid of task due dates.

- Charge management with the responsibility to protect project resources from interruptions rather than getting in their way with unnecessary distractions.

As previously mentioned, estimates typically include not only the amount of focused effort and time they expect the work to take, but also "safety" to deal with:

- The uncertainty involved in the work itself (Murphy's Law).

- The impact of distractions and interruptions they live with in their organization/environment, and, in many cases.

- The effect of dealing more than one such project at a time.

The Critical Chain methodology requires that the schedule be built with only the time to do the work without any safety. This is the time we expect the work to take if allowed to focus a full sustainable level of effort on it and if there are no significant problems. We usually describe this estimate in terms of having a 50% confidence level. In case of management paradigm shift comes into play because the resources are expected to strive for these "target durations," in no way can/should the be considered commitments. Otherwise, performance measurement pressures will result in building safety back in, re-expanding the estimates.

This now leads directly to and supports the second requirement for repealing Parkinson's Law which is the elimination of due dates. There's an almost Zen-like statement associated with project tasks that suggests that no matter what any estimate says, "The work will take as long as the work takes." If we're building a schedule on the basis of aggressive, 50% confidence durations, we can't expect people to meet them all the time, and therefore there is no way we can think in terms of due dates.

7.3.2 Early Completion

The first two challenges cross paths at this point. The preceding discussion begs the question "Without dates, how do we know when particular resources need to be available?" This is closely related to our second challenge, "How can we systematically take advantage of early task finishes when they can help us to accelerate the project and maybe allow us to finish it early, freeing up the resources to address other projects?" Early finishes are simply a special case of not having predictable dates to tie to our activities.

In the Critical Chain world, there are two kinds of resources; resources that perform critical tasks and resources that perform non-critical tasks. The ones we really have to worry about in this context are the critical chain tasks, since they most directly determine how long the project will take. We want to make sure that critical chain resources are available when the preceding task is done, without relying on fixed due dates.

There are two simple steps required to accomplish this. Step one: Ask the resources how much of an advance warning they need to finish up their other work and shift to interruptible work so that when the preceding project task is complete, they can drop what they're doing and pick up their critical task. Step two: Require resources to provide regular, periodic updates of their current estimate of the time to complete their current task. When the estimate to complete task A matches the advance warning needed by the resource on task B, let the B resource know the work is on its way and that it should get ready to pick it up.

Compared to traditional project management, this is a bit of a shift away from focusing on "what we've done" via reporting percent of work complete to focusing on what counts to assess and address project status of how much time is left to accomplish unfinished tasks.

This process puts us into a position such that we're no longer nailed to the calendar through due-dates, we can move up activity as its predecessors finish early, and we can avoid the impact of Parkinson's Law.

7.3.3 Dealing with Murphys Law

But we're not yet done with the first challenge, especially the part about protecting against Murphy's Law. We've now got a tight schedule supported by these resource alerts to assure that the critical resources are available when needed and that they can pick up the work when tasks are finished earlier than expected. The problem is that these "50% estimates" don't do too much to help us promise a final due date for the project. Through management support to allow focus, short target durations to maintain that focus, and no due dates or deadlines distracting us from what needs to be done, we've pretty dealt with Parkinson, but we've left ourselves wide open to suffer Murphy's slings and arrows. We need to protect the due date from variation in the tasks, again, especially critical tasks.

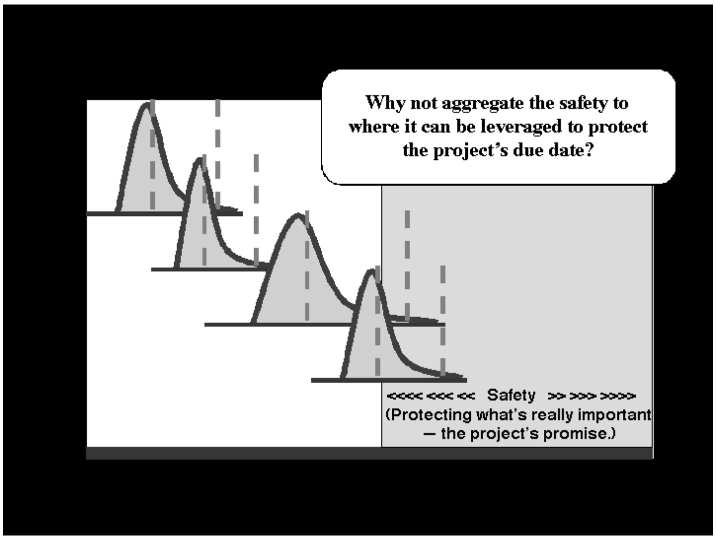


Fig 7.4

Let's look back at our original view of the task estimates -- what might be considered the "90% confidence" estimates that we have usually built our schedules on. The difference between our 50% and 90% estimates is safety. Instead of spreading it around, among the tasks, where it usually gets wasted, let's take a "whole system" view and concentrate it where it will help us. The safety associated with the critical tasks can be shifted to the end of the chain, protecting the project promise from variation in the critical chain tasks. This concentrated aggregation of safety is called a "project buffer."

There is an additional advantage to this aggregation of safety in the form of buffers. Because the tasks' target durations are 50% confidence estimates, we might expect that half the time they'll come in early and half the time they'll be late. Since the early tasks (which we were very rarely able to take advantage of in traditional project management) will help to offset some of the late ones, we don't need all the protection that used to be spread around. So the project buffer can be smaller than the sum of the parts. I won't go into the statistics here, but we can usually cut the total protection at least in half and still be safe, resulting in a project lead-time that can be significantly shorter than in the old paradigm for a project promise of similar risk.

Now let's turn to the non-critical tasks. Let's assume that they're also allowed to focus on the task at hand and pass it along as soon as it is done--which should be a universal way of life if we really want to get projects done in a timely fashion. But we don't want to micro-manage everybody to the degree we do the critical tasks with the resource availability alerts. Yet we do want to assure that, if things go wrong in the non-critical, we don't want them to impinge the ability of the critical tasks to stay on track.

The traditional approach is to start these tasks as early as possible, and hope that the slack or float is enough to absorb the variability. It might, but then again, it might not. Why not use the buffer approach like we did with the critical chain and the project due date? In this case, concentrate the safety associated with chains of non-critical tasks (again, reduced due to aggregation) as a buffer protecting the start of the critical chain task they feed into--"feeding buffers."

Note that the feeding buffers are also relied upon to deal with resource timeliness for non-critical tasks/resources; we don't use the "work-coming alerts" because even if the feeding buffer is consumed, the worst case is that the critical tasks are delayed and maybe eat some project buffer. The feeding, non-critical tasks are two buffers away from impacting the project promise. Also, you gain more by keeping non-critical resources focused on the work at hand and to assure they finish work that can be passed on to other resources rather than interrupt them for other non-critical stuff.

We have now built a Critical Chain Schedule. A major distinction from a schedule based on critical path methodology is the proactive approach of using feeding buffers to keep the critical chain critical up front rather than relying on reacting to a changing critical path. Another distinction is the use of a resource-constrained critical path as the project's critical chain.

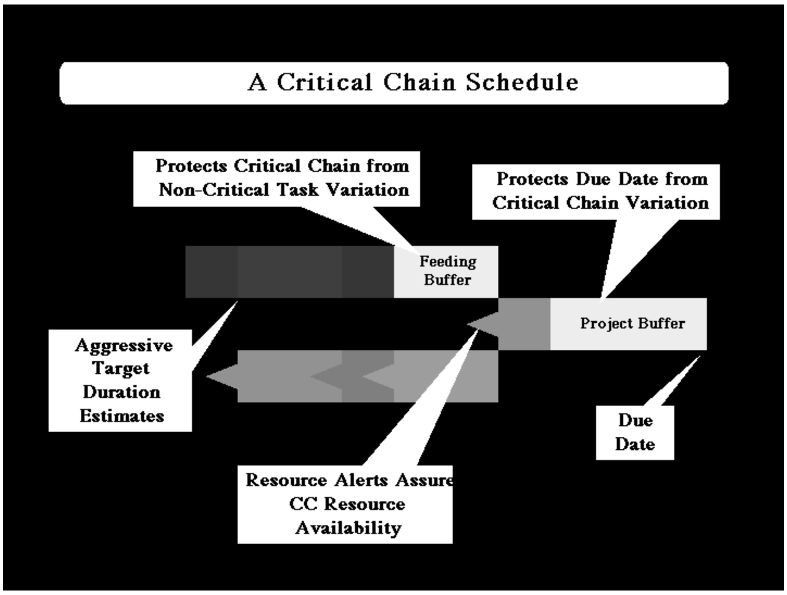


Fig 7.5

The Critical Chain Schedule avoids expansion from Parkinson's Law by eliminating due dates and allowing us to take advantage of early task finishes. This schedule is also protected against untimely availability of critical resources by the alerts of work coming from preceding tasks. The project promise is protected from variation (Murphy) in the critical chain by the project buffer and the critical chain is protected from variation in non-critical work by the feeding buffers.

7.3.4 Managing Execution

How can we manage the execution of a project -- how do we know what shape our project is in once it gets started, if we don't have due dates to track? The key is the set of feeding and project buffers and a process known as "Buffer Management."

As tasks are completed, we know how much they have eaten into or replenished the buffers. Because we are now getting updated estimates of time-to-completion from currently active tasks, we can stay on top of how much of the buffers are consumed in an ongoing fashion. As long as there is some predetermined proportion of the buffer remaining, all is well. If task variation consumes a buffer by a certain amount, we raise a flag to determine what we might need to do to if the situation continues to deteriorate. If it deteriorates past another point in the buffer, we put those plans into effect.

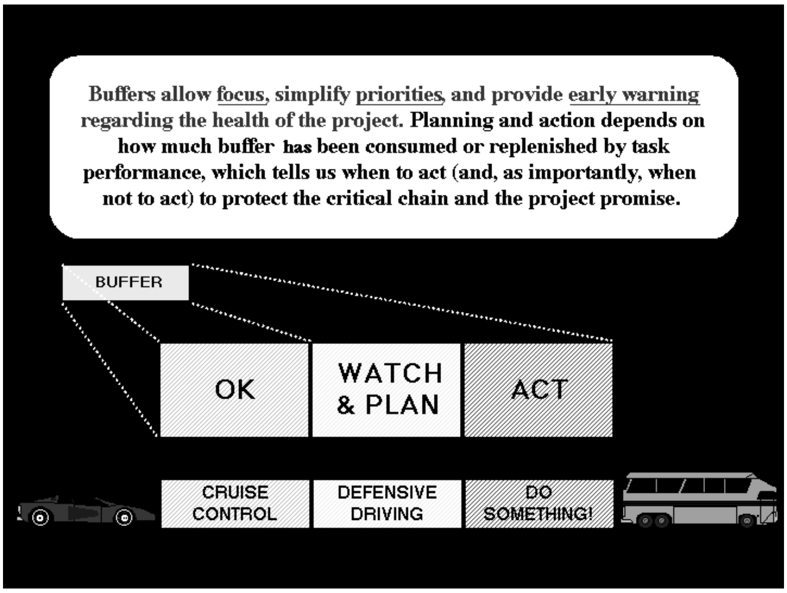


Fig 7.6

This process allows us to stay out of the way of the project resources if things are on track, build a contingency plan in something other than a crisis atmosphere, and implement that plan only if necessary.

7.4 Benefits

The preceding description of Critical Chain Scheduling and Buffer Management includes, embedded in it a number of benefits that can be obtained by projects that make use of the approach. These include the following:

- An aggressive target duration schedule, along with elimination of task due-dates, minimizes impact of "Parkinson's Law."
- Buffers allow resources to focus on work without task due-date distraction and efficiently protect against "Murphy's Law" with shorter project lead-times through concentrated safety protecting what is crucial to project success.
- Resource alerts and effective prioritization of resource attention allow projects to take advantage of good luck and early task finishes while buffers protect against bad luck and later than scheduled finishes.
- Buffer Management provides focus for schedule management, avoids unnecessary distraction, and allows recovery planning to take place when needed, but well before the project is in trouble.

There are additional benefits of this approach when the concepts that underlie it are expanded to multi-project environments. While beyond the scope of this article, suffice it to say for now that the use of buffers to prioritize resource attention will allow such organizations to allow the focus on the task at hand to speed projects in the context of multi-project programs. The Critical Chain approach to single projects allows the multi-project environment to avoid the lead-time multiplying effect of multi-tasking.

To achieve these benefits, it must be recognized that the implementation of Critical Chain Scheduling and Buffer Management is not a simple technical change of how we build and monitor projects, but requires broad management changes. Some of the significant shifts include:

- Stop spreading safety, hidden and wasted in the tasks. Concentrate safety in strategic places that protect what is important to the project from Murphy's Law. This can only happen effectively when resources trust management and project owners to accept that their tasks-- target durations are not commitments and that the buffers are sufficient to protect the project.

- Stop the behaviors that waste time in the project. Avoid task due-date focus and Parkinson's Law. Old habits are hard to break. Project managers must stop publishing date-laden project schedules.

- Avoid resource multi-tasking and the lead-time multiplication it results in. Focus on the task at hand. Management must take responsibility for protecting resources from competing priorities that drive multi-tasking.

- Account properly for resource contention. Project managers, when building project schedules must realize resource dependency is as real as task dependency when determining what is critical for the project.

- Track the consumption and replenishment of buffers. The project team must plan and act to recover when necessary, as dictated by buffer status, but only when necessary, in order to avoid unnecessary distraction of project resources who should be allowed to focus on their work.

Putting Critical Chain Scheduling and Buffer Management in place is not quite as easy as flipping a switch or turning on a new piece of software. It requires real change in how projects, resources, and priorities are managed. But if project speed and reliability are important to an organization, it may well be worth the effort to assess the potential benefits.

7.5 Projects

Product development projects, like many other types of projects, often can exceed their planned schedule by 50% to 100%. Often this is attributed to uncertainty or the unforeseen. To compensate for this age-old dilemma, managers and project personnel have learned to compensate by adding additional time to their schedule estimates. Yet even when they do, projects still overrun their schedules.

The Critical Chain Method (CCM) or Critical Chain Project Management (CCPM) is an outgrowth of the Theory of Constraints (TOC) developed by Eliyahu Goldratt to scheduling and managing manufacturing. TOC focuses on identifying and fixing bottlenecks in order to improve the throughput of the overall system. Likewise, Critical Chain focuses on bottlenecks. For example, one pharmaceutical company was experiencing significant delays with drug approvals. After investigation, it found that the bottleneck was statisticians to analyze clinical trial data. The cost of hiring statisticians was more than offset by the revenue from getting products to market sooner.

Using the Critical Chain Method, projects can be completed more quickly and with greater scheduling reliability. The difference between traditional and Critical Chain scheduling is in how uncertainty is managed. In traditional project scheduling, uncertainty is managed by padding task durations, starting work as early as possible, multi-tasking, and focusing on meeting commitment dates. The following bullet points illustrate some of the problems associated with traditional project scheduling:

- Padding task durations (providing worst-case estimates) is done to ensure a high probability of task completion. The knowledge that there is so much safety time built into tasks results in various time wasting practices, e.g., waiting until the last moment to complete a task. As a result, all the safety time can be wasted at the start of the task so that, if problems are encountered, the task over-runs.
- Starting work as early as possible, even when not scheduled, is a response to worst-case estimates. When workers give worst-case estimates, they don't expect to stay busy with just one task – so they multi-task, working on several tasks at once by switching between them. The result is that everything takes a long time to complete and very little completes early.
- With the focus on meeting commitment dates (start and finish), output from a task completed early will rarely be accepted early by the next person needing this output. So, any effort spent in finishing early will be wasted. Early delivery of one task can't be used to offset lateness on another. Lateness, however, is always passed on and the lost time can't be made up without cutting the specifications or increasing resources allocated to subsequent tasks, if possible.

Given these issues, it's not surprising that the most projects are always late. In Critical Chain scheduling, uncertainty is primarily managed by:

i. using average task duration estimates;
ii. scheduling backwards from the date a project is needed;
iii. placing aggregate buffers in the project plan to protect the entire project and the key tasks;
iv. using buffer management to control the plan.

The key tasks are those on which the ultimate duration of the project depends, also known as the Critical Chain. The specific steps to identify and manage a Critical Chain schedule are as follows:

1. Reduce activity duration estimates by 50%. Activity durations are normal estimates, which we know to be high probability and contain excessive safety time. We estimate the 50% probability by cutting these in half.
2. Eliminate resource contentions by leveling the project plan. The Critical Chain can then be identified as the longest chain of path and resource dependencies after resolving resource contentions.
3. Insert a Project Buffer at the end of the project to aggregate Critical Chain contingency time
4. Protect the Critical Chain from resource unavailability by Resource buffers. Resource buffers are correctly placed to ensure the arrival of Critical Chain resources.
5. Size and place Feeding Buffers on all paths that feed the Critical Chain. Feeding buffers protect the Critical Chain from accumulation of negative variations, e.g. excessive or lost time, on the feeding chains. This subordinates the other project paths to the Critical Chain.
6. Start gating tasks as late as possible. Gating tasks are tasks that have no predecessor. This helps prevent multitasking.
7. Ensure that resources deliver Roadrunner performance. Resources should work as quickly as possible on their activities, and pass their work on as they complete it.
8. Provide resources with activity durations and estimated start times, not milestones. This encourages resources to pass on their work when done.
9. Use buffer management to control the plan. Buffers provide information to the project manager, for example, when to plan for recovery and when to take recovery action.

7.5.1 All project managers have to deal with uncertainty as a part of their daily work. Project schedules, so carefully constructed, are riddled with assumptions, caveats and ,yes, uncertainties - particularly in task (activity) durations. Most project management treatises recognise this, and so exhort project managers to include uncertainties in their activity duration estimates. However, the same books have little to say on how these uncertainties should then be integrated into the project schedule in a meaningful way. Sure, well-established techniques such as PERT do incorporate probabilities into a schedule via an averaged or expected duration. But the final schedule is deterministic, and makes no explicit allowance for delays. Any float that appears in the schedule is purely a consequence of an activity not being on the critical path. The float, such as it is, is not an allowance for uncertainty.

Since PERT was invented in the 1950s, there have been several other attempts to incorporate uncertainty into project scheduling. Some of these include, Monte Carlo simulation and, more recently, Bayesian Networks. Although these techniques offer more sophisticated estimates of uncertainty, they don't really address the question of how uncertainty is to be managed in a project schedule. What's needed is a simple technique to protect a project schedule from Murphy, Parkinson or any other variations that invariably occur during the execution of individual tasks. Eliyahu Goldratt proposed just such a technique in his business novel, Critical Chain. Here we discuss the critical chain method, - a technique to manage uncertainty in project schedules. In a discussion, general characteristics of activity or task estimates is followed by a discussion on why the buffers or safety we build into individual activities do us no good - i.e. why projects come in late despite the fact that most people add considerable safety factors on to their activity estimates. This then naturally leads on to a discussion of how buffers should be added in order to protect schedules effectively. This is the heart of the Critical Chain method.

7.5.2 Characteristics of activity duration estimates

Consider an activity that you do regularly - such as getting ready in the morning. You have a pretty good idea how long the activity takes on average. Say, it takes you an hour on average to get ready - from when you get out of bed to when you walk out of your front door. Clearly, on a particular day you could be super-quick and finish in 45 minutes, or even 40 minutes. However, there's a lower limit to the early finish - you can't get ready in 0 minutes!. On the other hand, there's really no upper limit. On a bad day you could take a few hours. Or if you slip in the shower and hurt your back, you mayn't make it at all.

The distribution starts at a non-zero cutoff (corresponding to the minimum time for the activity); increases to a maximum (corresponding to the most probable time); and then falls off rapidly at first, then with a long, slowly decaying, tail. The mean (or average) of the distribution is located to the right of the maximum because of the long tail. In the example, t0 (30 mins) is the minimum time for completion so the probability of finishing within 30 mins is 0%. There's a 50% probability of completion within an hour, 80% probability of completion within 2 hours and a 90% probability of completion in 3 hours. The large values for t80 and t90 compared to t50 are a consequence of the long tail. OK, this particular example may be an exaggeration - but you get my point: if you want to be really really sure of completing any activity, you have to add a lot of safety because there's a chance that you may "slip in the shower" so to speak.

It turns out that many phenomena can be modeled by this kind of long-tailed distribution. Some of the better known long-tailed distributions include lognormal and power law distributions. A quick review of the project management literature revealed that lognormal distributions are more commonly used than power laws to model activity duration uncertainties. This may be because lognormal distributions have a finite mean and variance whereas power law distributions can have infinite values for both. In any case, regardless of the exact form of the distribution for activity estimates, what's important and non-controversial is the short cutoff, the peak and long, decaying tail.

Most activity estimators are intuitively aware of the consequences of the long tail. They therefore add a fair amount of "air" or safety in their estimates. Goldratt suggests that typical activity estimates tend to correspond to t80 or t90. Despite this, real life projects still have difficulty in maintaining schedules.

A schedule is essentially made up of several activities connected sequentially or in parallel. What are the implications of uncertain activity durations on a project schedule? Well, let's take the case of sequential and parallel steps separately:

- Sequential steps: If an activity finishes early, the successor activity rarely starts right away. More often, the successor activity starts only when it was originally scheduled to. Usually this happens because the resource responsible for the successor activity is not free - or hasn't been told about the early finish of the predecessor activity. On the other hand, if an activity finishes late, the start of the successor activity is delayed by at least the same amount as the delay. The upshot of all this is that - delays accumulate but early finishes are rarely taken advantage of. So, given a long chain of sequential activities, you can be pretty sure that there will be delays!

- Parallel steps: In this case, the longest duration activity dictates the finish time. For example, if we have three parallel activities of duration 5 days per activity. If one of them ends up taking 10 days, the net effect is that three activities, taken together, will complete only after 10 days. In contrast, an early finish will not have an effect unless all activities finish early. Again we see that delays accumulate; early finishes don't.

The discussion assumed that activities are independent. In a real project activities can be highly dependent. In general this tends to make things worse than a delay in an activity is usually magnified in a dependent successor activity.

We saw that dependencies between activities can eat into safety significantly because delays accumulate while gains don't. There are a couple of other ways safety is wasted. These are:

- Multitasking It is recognised that multitasking - i.e. working on more than one task concurrently - introduces major delays in completing tasks. See these articles by Johanna Rothman and Joel Spolsky, for a discussion of why this is so. Incidentally, I've discussed techniques to manage multitasking on my blog.

- Student syndrome this should be familiar to any one who's been a student. When saddled with an assignment, the common tendency is to procrastinate until the last moment. This happens on projects as well.

- Parkinson's Law states that "work expands to fill the allocated time." This is most often a consequence of there being no incentive to finish a task early. In fact, there's a strong disincentive from doing so because the early finisher may be:
  a. accused of overestimating the task
  b. rewarded by being allocated more work.

1. Consequently people tend to adjust their pace of work to just make the scheduled delivery date, thereby making the schedule a self-fulfilling prophecy.

- Any effective project management system must address and resolve the above issues. The critical chain method does just that. Now with the groundwork in place, we can move on to a discussion of the technique. The second, more general, case discusses the situation in which there is resource contention.

7.6 The critical chain - special case

In this we look at the case where there's no resource contention in the project schedule. In this (ideal) situation, where every resource is available when required, each task performer is ready to start work on a specific task just as soon as all its predecessor tasks are complete. Sure, we'll need to put in place a process to notify successor task performers about when they need to be ready to start work.

7.6.1 Preventing the student syndrome and Parkinson's Law

To cure habitual procrastinators and followers of Parkinson, Goldratt suggests that project task durations estimates be based on a 50% probability of completion. This corresponds to an estimate that is equal to t50 for an activity (you may want to have another look at the Figure 1 to remind yourself of what this means). Remember, as discussed earlier, estimates tend to be based on t80 or t90, both of which are significantly larger than t50 because of the nature of the distribution. The reduction in time should encourage task performers to start the task on schedule, thereby avoiding the student syndrome. Further, it should also discourage people from deliberately slowing their work pace, thereby preventing Parkinson from taking hold.

As discussed, a t50 estimate implies there's a 50% chance that the task will not complete on time. So, to reassure task estimators / performers, Goldratt recommends implementing the following actions:

- Removal of individual activity completion dates from the schedule altogether. The only important date is the project completion date.
- No penalties for going over the t50 estimate. Management must accept that the estimate is based on t50, so the activity is expected to overrun the estimate 50% of the time.
- The above points must be explained to project team members before you attempt to elicit t50 estimates from them.

7.6.2 The resource buffer

The alert reader may have noticed a problem arising from the foregoing discussion of t50 estimates: if there is no completion date for a task, how does a successor task performer know when he or she needs to be ready to start work? This problem is handled via a notification process that works as follows: the predecessor task performer notifies successor task performers about expected completion dates on a regular basis. These notifications occur at regular, predetermined intervals. Further, a final confirmation should be given a day or two before task completion so all successor task performers are ready to start work exactly when needed. Goldratt calls this notification process the resource buffer. It is a simple yet effective method to ensure that a task starts exactly when it should. Early finishes are no longer wasted!

7.6.3 The project buffer

Alright, so now we've reduced activity estimates, removed completion dates for individual tasks and ensured that resources are positioned to pick up tasks when they have to. What remains? Well, the most important bit really - the safety! Since tasks now only have a 50% chance of completion within the estimated time, we need to put safety in somewhere. The question is, where should it go? The answer lies in recognising that the bottleneck (or constraint) in a project is the critical path. Any delay in the critical path necessarily implies a delay in the project. Clearly, we need to add the safety somewhere on the critical path. Goldratt's insight was the following: safety should be added to the end of the critical path as a non-activity buffer. He calls this the project buffer. If any particular activity is delayed, the project manager "borrows" time from the project buffer and adds it on to the offending activity. On the other hand, if an activity finishes early the gain is added to the project buffer. Figure 7.2 depicts a project network diagram with the project buffer added on to the critical path (C1-C2-C3 in the figure).

What size should the buffer be? As a rule of thumb, Goldratt proposed that the buffer should be 50% of the safety that was removed from the tasks. Essentially this makes the critical path 75% as long as it would have been with the original (t80 or t90) estimates. Other methods of buffer estimation are discussed in this book on critical chain project management.

7.6.4 The feeding buffer

As shown in Figure 7.2 the project buffer protects the critical path. However, delays can occur in non-critical paths as well (A1-A2 and B1-B2 in the figure). If long enough, these delays can affect subsequent critical path. To prevent this from happening, Goldratt suggests adding buffers at points where non-critical paths join the critical path. He terms these feeding buffers.

7.6.4.1 The first definition

This completes the discussion of the case where there's no resource contention. In this special case, the critical chain of the project is identical to the critical path. The activity durations for all tasks are based on t50 estimates, with the project buffer protecting the project from delays. In addition, the feeding buffers protect critical chain activities from delays in non-critical chain activities.

7.6.4.2 The general case

Now for the more general case where there is contention for resources. Resource contention implies that task performers are scheduled to work on multiple tasks simultaneously, at one or more points along the project timeline. Although it is well recognised that multitasking is to be avoided, most algorithms for finding the critical path do not take resource contention into account. The first step, therefore, is to resource level the schedule - i.e ensures that tasks that are to be performed the same resource(s) are scheduled sequentially rather than simultaneously. Typically this changes the critical path from what it would otherwise be. This resource leveled critical path is the critical chain.

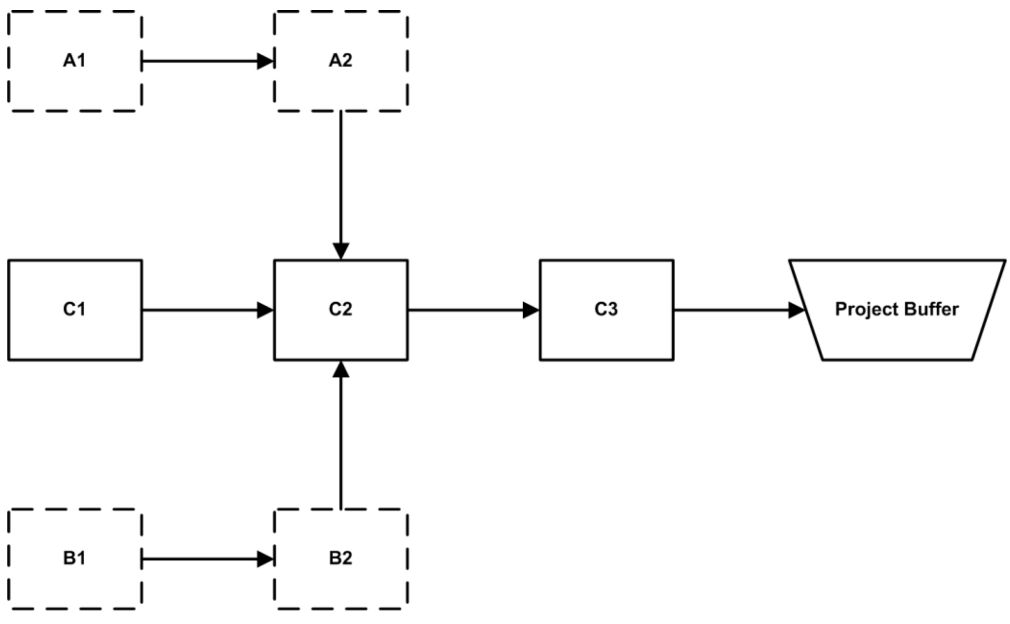


Figure 2: Critical path with project buffer

The above can be illustrated by modifying the example network shown in Figure 7.3. Assume tasks C1, B2 and A2 (marked X) are performed by the same resources.

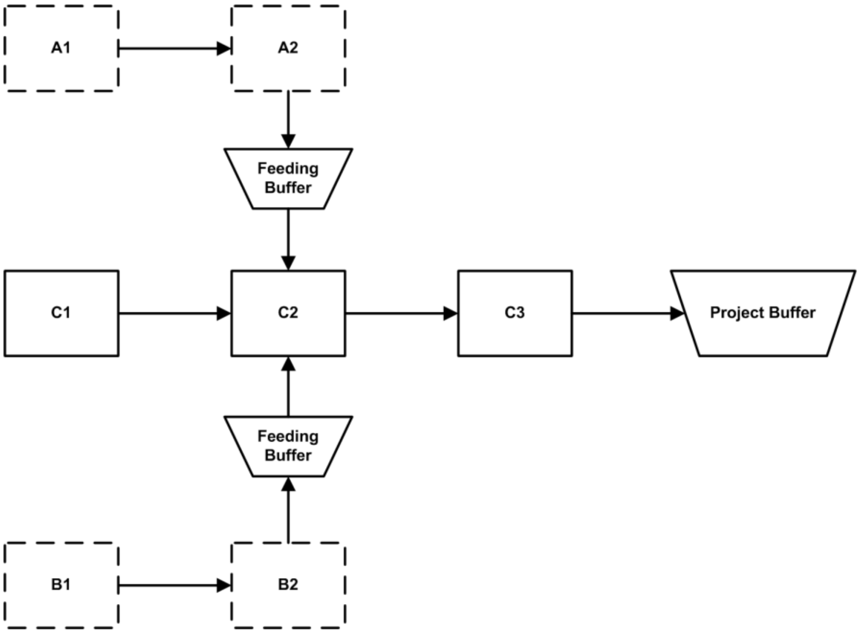


Figure 3: Critical path with project and feeding buffers

The resource leveled critical path thus changes from that shown in Figures 7.2 and 7.3 to that shown in Figure 7.4. As per the definition above, this is the critical chain. Notice that the feeding buffers change location, as these have to be moved to points where non-critical paths merge with the critical path. The location of the project buffer remains unchanged.

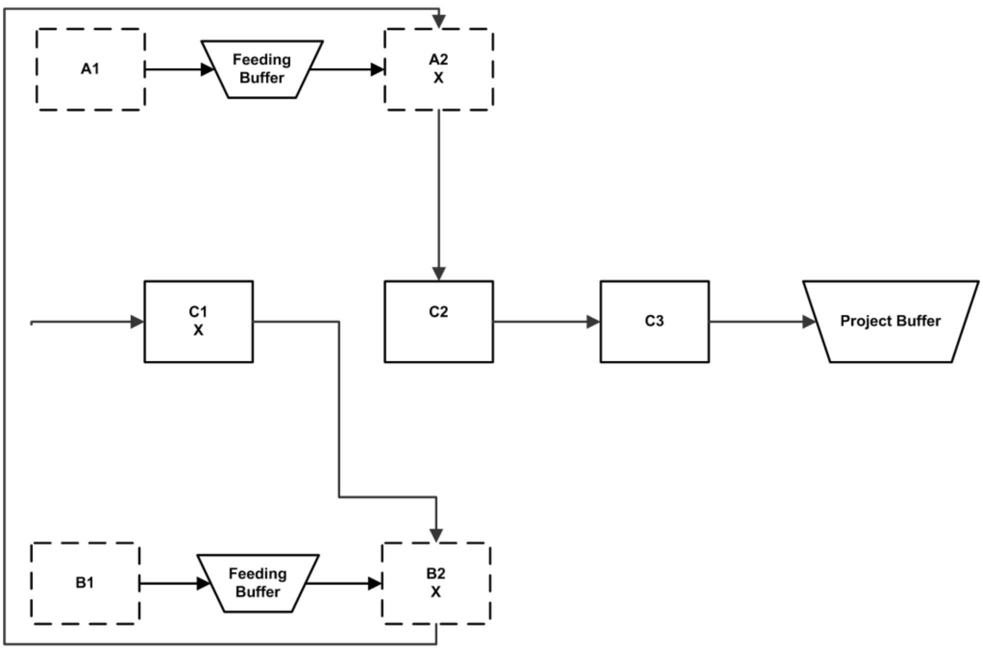


Figure 4: Critical chain

Review Questions

25. Will Critical Chain work with Earned Value?

26. How does CC-based multi-project management work?
27. How does Critical Chain fit with PMI's PMBOK Guide processes and knowledge areas?
28. Is there software that supports Critical Chain processes?

Discussion Questions

If Critical Chain comes from TOC thinking, what is the constraint that's involved?

Application Exercises

19. Explain Parkinson's Law?
20. Explain Theory of Constraints in critical chain scheduling?
21. Can Critical Chain concepts be used to manage project cost?

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