Project Management

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Week: 6

Lecture 27 - Goldratt's critical chain

Dear students, today's topic is Goldratt's Critical Chain. In the previous class, we have covered about resource leveling. Today, we will talk about this new topic called critical chain. So, the agenda for this lecture is, I will explain what is critical chain and what are the reasons for optimistic bias and do early finishes of an activity and late finishes of an succeeding activity will cancel out that we will see that. Then common chain of events, then we will discuss about important topic theory of constraints, which was proposed by Goldratt and how that idea has came from statistics. Then we will talk about the buffers proposed by Goldratt.

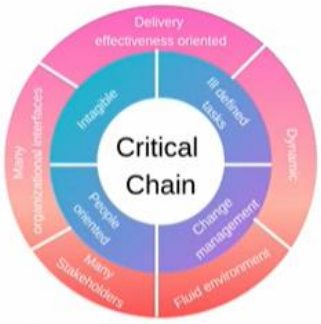
Agenda

- Goldratt's Critical Chain
- Reasons for optimistic bias
- Do Early Finishes and Late Finishes Cancel Out?
- Common Chain of Events
- Goldratt's theory of constraints - Inference from statistics
- Project Buffer
  - The Critical Chain
  - The Feeder Chain

There are two buffers we are going to discuss one is on critical chain buffer another one is feeder chain buffer. First we will see what is Goldratt critical chain. The problem of constrained resource scheduling of multiple projects could be reduced to the problem of scheduling activities using scarce resources in the case of single project. So, a project there may be different resources, but instead of focusing on all the resources, if you focus on only on the scarce resources, then it will be easy for managing the for scheduling the whole project.

Goldratt's Critical Chain

- The problem of constrained resource scheduling of multiple projects could be reduced to the problem of scheduling activities using scarce resources in the case of a single project.



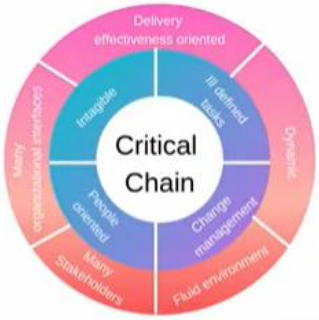
Constrained resource scheduling

- Constrained resource scheduling refers to planning and allocating resources in a way that considers various constraints and limitations.
- This concept is particularly relevant in project management where resources such as time, money, manpower, equipment, and materials are limited.
- However, the best-known attack on the resource-constrained scheduling problem is Goldratt's Critical Chain (1997).

So, that is the meaning of this Goldratt critical chain. So, what is the constrained resources? So, constrained resource scheduling refers to the planning and allocating resources in a way that considers various constraint and limitations, because there is there should be a capacity limitations, if it is a manpower, there may be a manpower limitations. So, we cannot add more resources there will be a limitation for each constraint. So, this concept of constrained resource scheduling is particularly relevant in project management, where resources such as time, money, manpower, equipment and materials are limited. However, the best known attack the way to manage this constrained resources is by using this concept of Goldratt's critical chain.

Goldratt's Critical Chain

- The celebrated author applies his "Theory of Constraints" to the constrained resource scheduling problem
- The original focus of the Theory of Constraints to project management was the single project case, but it, too, is just as applicable to multiple projects.



The celebrated author applies his theory of constraint to the constrained resource scheduling problem. The original focus of the theory of constraint to project management was a single project case, but it too is just as applicable to multiple projects. If we consider all the comments that we have heard about the problem of project managers, how to deal with on a daily basis, many are brought up over and over again.

Further, it is interesting to note that these statements which was made by the project managers in construction, manufacturing, software development, R&D, marketing, communication and maintenance. So, the list of industries could easily be extended because of the limitation on the resources.

Goldratt's Critical Chain

- If we consider all the comments we have heard about the problems PMs have to deal with on a daily basis, many are brought up over and over again.
- Further, it is interesting to note that these statements are made by PMs working in construction, manufacturing, software development, R&D, marketing, communications, maintenance, and so on and the list of industries could easily be extended.

For example, the following issues are raised with a high frequency and this shortlist is only an indicative not nearly exhaustive. What are they? Senior management changes the project's scope without consultation, without warning and without changing the project budget and schedule. So, that will lead to change in the project schedule. The second reason is project due dates are unrealistic and set with little regard given to availability of resources. So, what was happening many time in the projects, the schedules are fixed without considering the available resources and there is no possible way of accomplishing a project without exceeding the given budget.

Importance of Goldratt's Critical Chain

- For example, the following issues are raised with high frequency, and this short list is only indicative, not nearly exhaustive
  - Senior management changes the project's scope without consultation, without warning, and without changing the budget or schedule.
  - Project due dates are unrealistic and set with little regard given to availability of resources.

Importance of Goldratt's Critical Chain

- There is no possible way of accomplishing a project without exceeding the given budget.
- Project workloads and due dates are set by the sales group, not by the nature of the projects and the level of resources needed.
- Project due dates are set unrealistically short as an "incentive" for people to work harder and faster.

Sometimes situation may come that they may put a restriction on the budget. So, what we can do to complete the project, we have to exceed the budget. Another situation, project workloads and due dates are set by the sales group not by the nature of the projects and the level of resources needed. Many times the project deadlines will be fixed by the sales people because they may have committed to the customers without considering the resources availability. The another possibility project due dates are set unrealistically short has an incentive for people to work harder and faster.

Importance of Goldratt's Critical Chain

- It appears that these, and many other, problems are generic.
- They are independent of the area of application.
- Note that these issues concern trading off time, cost, and scope.

So, what will happen that the due dates are not practical and it was motivated by giving more incentives so that people can finish it early. These point appears that many other problems are generic what we have discussed so far. So, these problems are events are independent of the area of the application. Note that these issues concern trading of time, cost and scope. So, whatever point we have discussed so far the previous reasons.

So, if you want to manage this that we have to make a trade-off between time, cost and scope to deal with a strong optimistic bias. People are so optimistic about the project outcomes. So, to deal with this optimistic bias in many project schedule let us consider just a few of the things that tend to create it. So, what are the things that will lead to the optimistic bias? So, here optimistic bias refers to the cognitive tendency of individuals to believe that they are less likely to experience adverse events and more likely to experience positive events compared to others. So, what is the meaning here is optimistic bias in the sense they ignore the negative side, the risk of the project.

Importance of Goldratt's Critical Chain

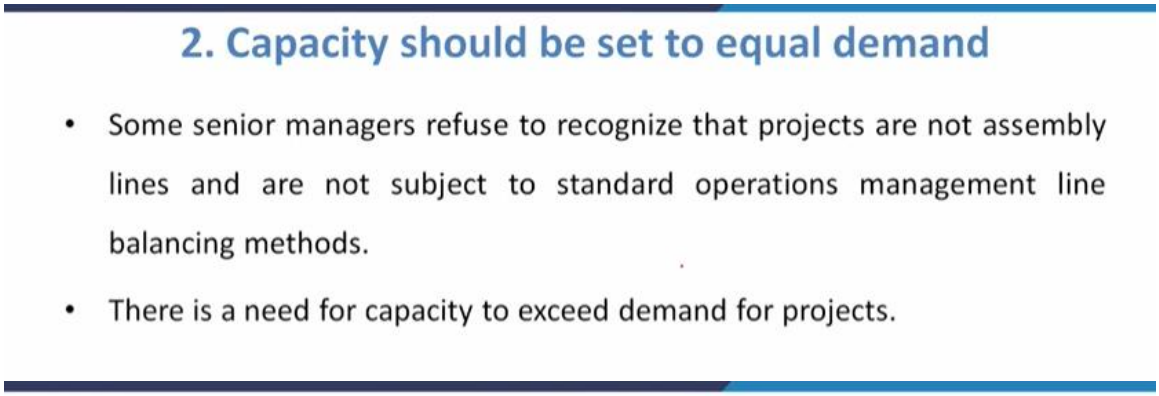
- To deal with the strong optimistic bias in many project schedules, let us consider just a few of the things that tend to create it.
- Optimistic bias refers to the cognitive tendency of individuals to believe that they are less likely to experience adverse events and more likely to experience positive events compared to others.

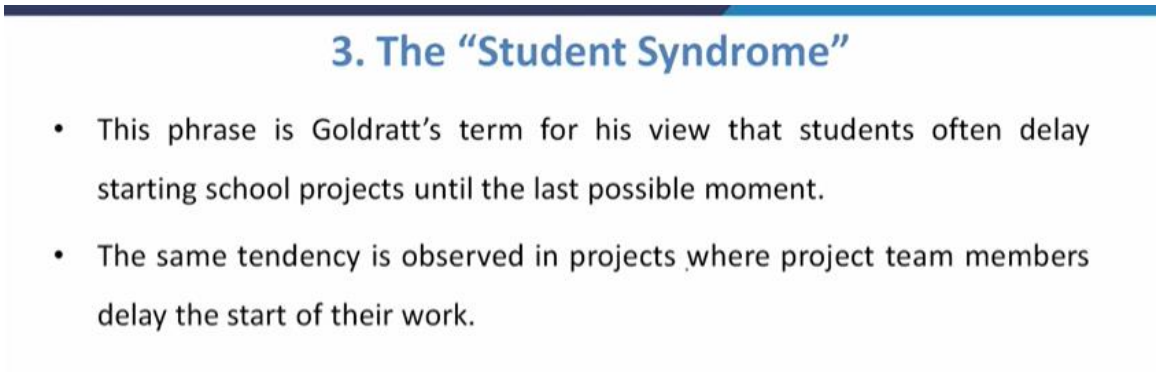
1. Thoughtless optimism

- Some PMs, apparently with a strong need to deny that lateness could be their fault, deal with every problem faced by their projects as strict exceptions, acts of chance that cannot be forecast and hence need not be the subject of planning.
- These individuals simply ignore risk management.

Some project managers apparently with a strong need to deny the lateness could be their fault. So, deal with every problem faced by their project as a strict exception and act of chance that cannot be forecast and hence need not be the subject of planning. So, these individuals simply ignore the risk management. So, the point here is that when they discuss about thoughtless optimism without considering the cost and resource constraint.

So, that will lead to the very dangerous outcome.



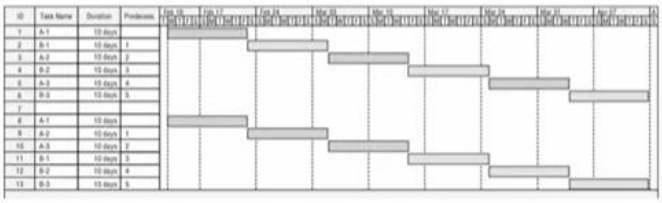


The reason is that they ignore the risk management. The second reason for optimistic bias is capacity should be set to the equal to demand. So, some senior managers refuse to recognize that the projects are not assembly lines and are not subject to standard operation management line balancing methods because it will change every project, it would not be linear in nature. So, there is a need for capacity to exceed demand for projects. So, sometime we have to extend our capacity whenever there is a demand is exceeding that point has to be taken into account.

Third one is the student syndrome. This phrase is Goldratt's term for his view that students often delay starting their school projects until the last possible moment, the same logic applicable to the project also. So, the same tendency is observed in projects where the project team's members delay the start of their week as long as possible, as much as possible. The problem with the delaying the start of the task is that obstacles are frequently not discovered until the work has been underway for some time. If you are not starting on the right time is very difficult to identify the possible risk.

4. Multitasking to reduce idle time

- Consider a situation where there are two projects, A and B, each with three sequential activities and with you as the only resource required by both projects.
- Each activity requires 10 days.
- In Figure, see two Gantt charts for sequencing the activities in the two projects.



Effect of multitasking on project completion given fixed activity times.

So, delaying the start of the task diminishes the opportunity to cope with these unexpected obstacles and increase the risk of completing the work late. The fourth point is multitasking to reduce idle time. People may think of that when you do the multitasking that will reduce idle time, but that will delay the other activities, the delay the overall project duration that we will see how it is. Considering a situation where there are two projects A and B with the three sequential activities with you as the only resource required for both the projects. So, there are project A, A1, A2, A3 is one project, B1, B2, B3 is one project.

So, each activity is going to take 10 days. You can see that two GANTT chart for sequencing the activities in the two projects. So, the darker one, the darker one is for project A, this is project A, this is for project A, this is project A. See the darker one is what I am shading, this is for project A. So, let us see what will happen this you see in the first GANTT chart every time the task is swapped.

4. Multitasking to reduce idle time

- Consider a situation where there are two projects, A and B, each with three sequential activities and with you as the only resource required by both projects.
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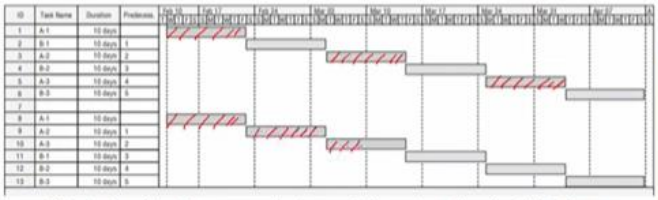
- In Figure, see two Gantt charts for sequencing the activities in the two projects.

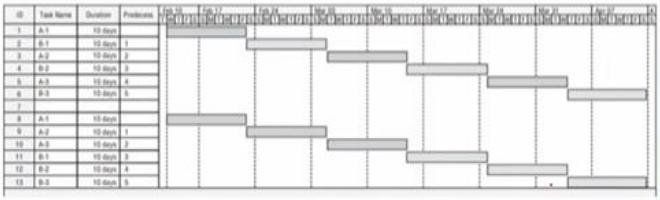


Effect of multitasking on project completion given fixed activity times.

First you do A1, next go to B1, then A2, then go to B2, then A3 and B3. This is one way of doing the project. The second way you do all the activities at a time for A project, then you start your B project, then do all these three activities for B at a time. So, what will happen in the first switch from project A to project B for each of the three activities that is carry out activity 1 for project A, then activity 1 for project B, then activity 2 for project A and so forth. So, it is alternatively first you do for A1, this is A1, then this you do, so this I am different this way, this is B1, then again A2, then this way it is B2, then again it is A3, this is B3.

4. Multitasking to reduce idle time

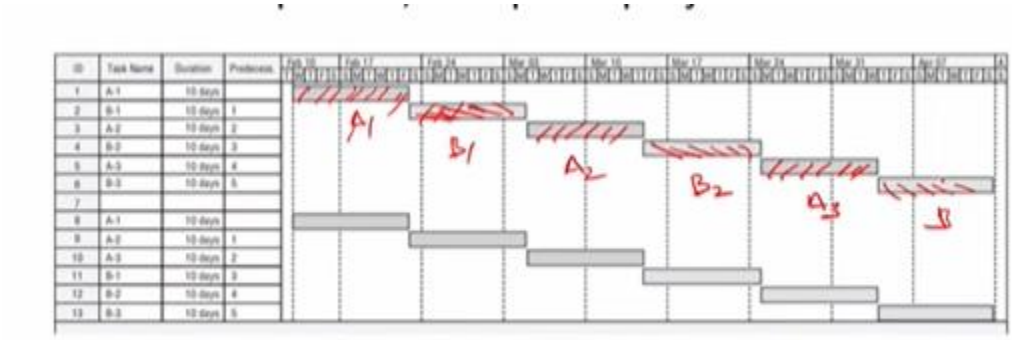
- In the first, switch from project A (dark) to project B (light) for each of the three activities, that is, carry out Activity 1 for project A, then Activity 1 for project B, then Activity 2 for A, and so forth.
- In the second sequence, complete project A before starting project B.



Effect of multitasking on project completion given fixed activity times.

In the second sequence, the bottom one here, here what is happening that complete the project A before starting of the project A. So, complete A1, A2, A3, then you go to B1, B2 and B3. In both the cases, the total time required will be 60 days for completing for both the projects. In the second, note that the project A is completed after 30 days, here you see here 10, 10, 10. So, project A will be completed after 30 days and project B will

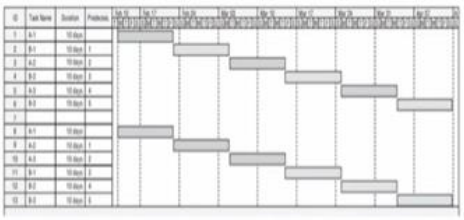
be completed after 60 days, this is 10, this is 10, this is 10.



Effect of multitasking on project completion given fixed activity times.

4. Multitasking to reduce idle time

- In both cases, the total time required will be 60 days.
- In the second, note that project A is completed after 30 days and B after 60 days.
- In the first chart, however, Project A will be finished after 50 days and B after 60 days.



Effect of multitasking on project completion given fixed activity times.

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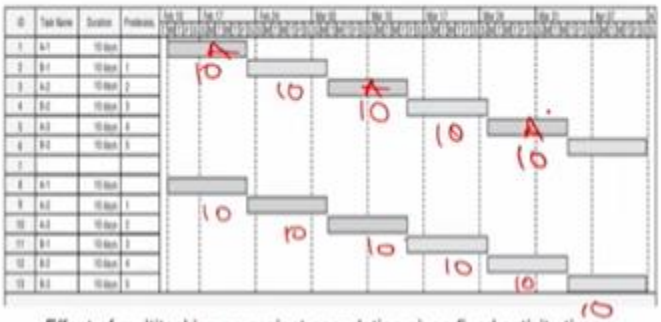


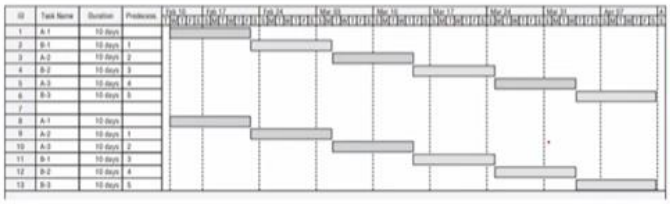
Effect of multitasking on project completion given fixed activity times.

But in the first chart, however, project A will be finished after 50 days, how here it will take 10 day. So, what will happen if you write in the cumulatively 10, 20, 30, 40, 50. So, here actually this is project A. So, the project A will be finished after 50 days and project B will be finished after 60 days. While the total time required is the same, project A has

been delayed for 20 days by the multitasking.

4. Multitasking to reduce idle time

- While the total time required is the same, project A has been delayed for 20 days by the multitasking.
- Further, this ignores the startup time and loss in efficiency that often accompanies switching back and forth between tasks.

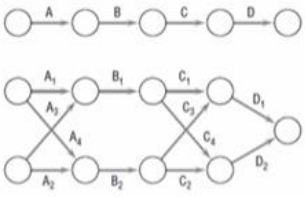


Effect of multitasking on project completion given fixed activity times.

The first one is example of multitasking. So, what do you do when you do the multitasking, there is an unnecessary delay due to multitasking. Further, this ignores that startup time and loss in efficiency that often accompanies switching back and forth between the task. Not only that, the project A is delayed for 20 days, but every time when you are switching from one task to another task, there is a more delay for setting up for changing the environment that is ignored here. So, if you add that the overall project delay will be increased.

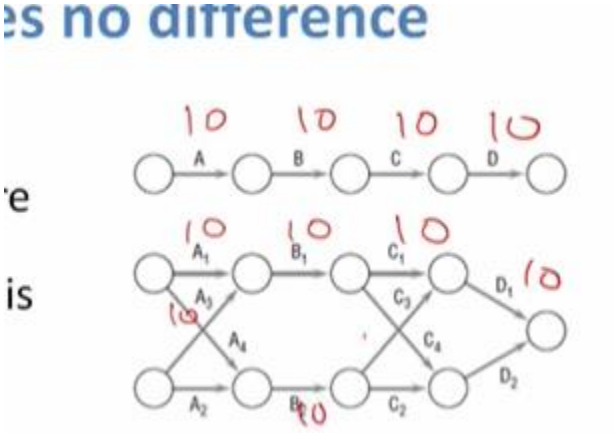
5. Complexity of networks makes no difference

- Consider two different projects, as seen in Figure
- Assume that each activity requires 10 days and is known with certainty.
- Clearly, both projects are completed in 40 days though one is considerably more complex than the other.



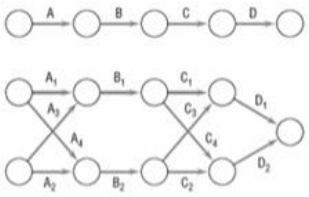
So, the point here is multitasking is good, but this is unnecessarily will delay your projects. Then complexity of network makes no difference. Now consider two different projects. Here there is one project is there. Assume that each activity requires 10 days and is known with certainty.

So, how many days you will take this is a 10, 10, 10, 10. So, certainly both the projects are completed in 40 days. You see here in this route also, anyway you go to take 40 days. So, 10, 10, 10, 10, any path you choose 10, 10, 10, 10, whatever path you choose, it will take 40 days, but in the bottom one is considerably more complex than the other one. But let us get into more accurate.



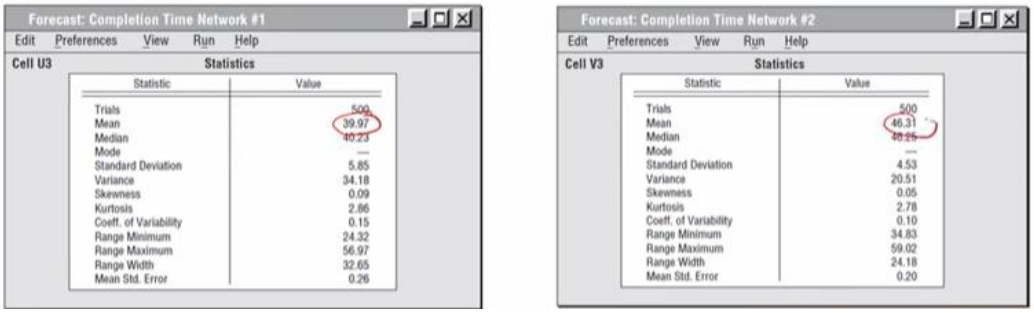
5. Complexity of networks makes no difference

- But let's get a bit more accurate.
- Assume that each activity is stochastic, with normally distributed times.
- The meantime is 10 days, and the standard deviation is 3 days.
- If we simulate the projects 500 times, we get the results shown in Tables.



Assume that each activity is stochastic with normally distributed times. We thought it is a 10 times. We assumed that is a 10 days for each activities, but assume that it follow a normal distribution with the mean is 10 days and the standard deviation 3 days. So, when you simulate these project activities for the project completion time, we are getting two type of result. You see that the mean is 40, here mean is 46.

Project Simulation Statistics for Simple Network #1



So, the point here is just by complicating the project, it would not affect the your project completion time. And the sixth point is people need a reason to work hard. So, senior manager argue that they have enough slack time in their activity duration estimates to make sure that they can complete the activities on time and without too much sweat. So, every time always the people prefer that some additional slack time. So, that no need to have extra effort to complete the task.

6. People need a reason to work hard

- Senior managers argue that have enough slack time in their activity duration estimates to make sure that they can complete the activities on time and "without too much sweat."
- Therefore, it makes some managerial sense to cut back on the time allowances until they can serve as an incentive to the project team.

6. People need a reason to work hard

- It has long been known that for people with a high need for achievement, the maximum level of motivation is associated with only moderate, not high, levels of risk of failure.

Therefore, it makes some managerial sense to cut back on the time allowances until they can serve as a incentive to the project team. So, somebody is working hard. So, there should be a reason for that. But what the people do that they will always go to more time than what is required. It has been known that for people with the high need of

achievement, the maximum level of motivation is associated with only moderate, not high, because considering the level of risk of failure.

So, the point here is that people having high need for achievement, they will not have a high motivation level, they will have only a moderate motivation level. Because if the motivation is very high, if something is failure that they cannot tolerate it. The next point is game play. This is possibly the most common cause for late project. It is certainly a major cause for frustration for anyone involved in the project.

7. Game playing

- This is possibly the most common cause of late projects.
- It is certainly a major cause of frustration for anyone involved in a project
- Senior managers, firm in the belief that project workers add extra time and resources to activity time and budget estimates in order to insure a safe and peaceful life on their portion of a project, routinely cut schedules and budgets.

Senior managers, they are firm in the belief that the project workers add extra time and resources to activity time and budget estimates in order to ensure a safe and peaceful life and their portion of your project routinely cut schedules and budgets. Because the senior manager knows that the lower level people always they ask more slack time, more additional time, but knowing that the senior manager generally they schedule the budget and they reduce the budget and they reduce the schedule time also. So, this is a game play. Project workers suspecting that the senior management will cut schedules and budgets without regard to any logic or reason. So, they increase their schedules and budget as much they guess will be allowed.

7. Game playing

- Project workers, suspecting that senior management will cut schedules and budgets without regard to any logic or reason, increase their schedules and budgets as much as they guess will be allowed.
- Each assumes that the other is not to be trusted.
- The outcome is simple.
- Rather than practice careful risk management, each blames the other for any lateness or budget overage.

The outcome is each assume that the other is not to be trusted. So, the outcome is simple. Rather than practice careful risk management, each blames the other for any lateness or budget coverage. The next point is do yearly finishes and late finishes cancel out. For example, assume that your project say project duration is five day, but you are finishing three day itself.

Do Early Finishes and Late Finishes Cancel Out?

- With a few exceptions, early finishes of current activity do not become early starts of the next activity
- This fact is ignored by most people involved with projects.
- Goldratt feels that project workers will avoid admitting that an activity has been completed early out of fear that future time estimates will be cut

You have two days. You are finishing the project two days earlier, but there may be another situation that the project has to be completed fifth day, but you are taking two days late. So, we want to say that by because already you finished two days earlier, but you are finishing two days later, whether this will be compensated or not. So, that is the point do yearly finishes and late finishes will cancel out. So, with a few exceptions, the yearly finishes of current activity do not become yearly starts of the next activity. The fact is many people are ignoring this fact is ignored by most people involved with the project.

So, Goldratt feels that project workers will avoid admitting that an activity has been completed yearly out of the fear that the future time estimate will be cut. Others point out that when the activity schedule is set, it is presumed that the activity will start immediately after the most likely finish data of its predecessors. The reason is simple. Its resources will not be available until that date and there is a logical explanation of why the start of and successor is usually delayed until it is a predetermined expected start time. So, some say that the project workers will not report finishes before the most likely duration.

Do Early Finishes and Late Finishes Cancel Out?

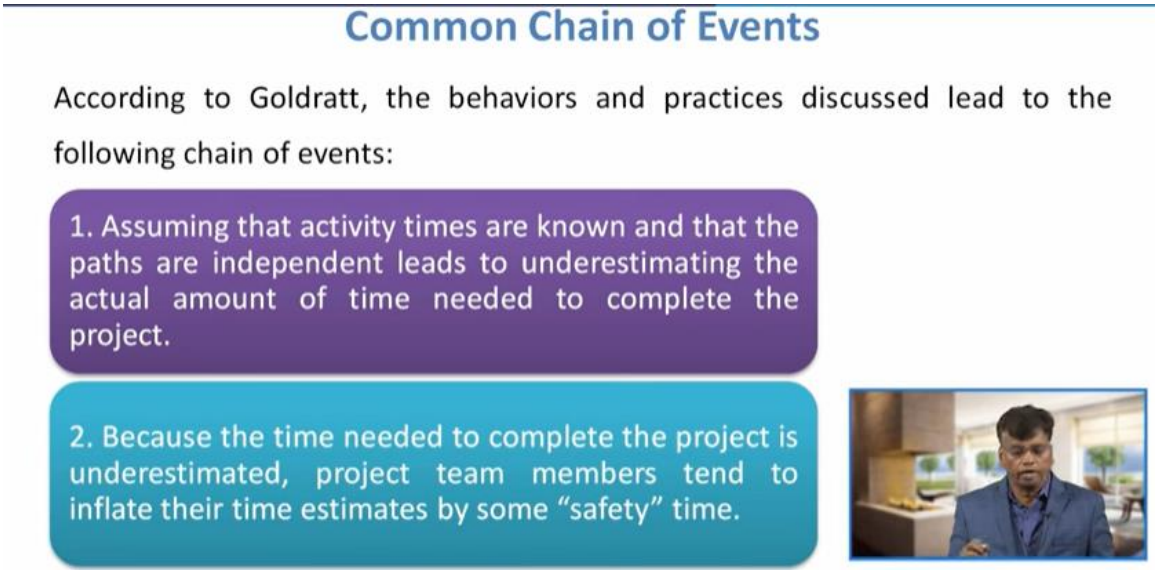
- Others point out that when the activity schedule is set, it is presumed that the activity will start immediately after the most likely finish date of its (latest) predecessor.
- The reason is simple—its resources will not be available until that date.
- There is also a logical explanation of why the start of a successor is usually delayed until its predetermined expected start time.
- Some say that project workers will not report finishes before the most likely duration.

Do Early Finishes and Late Finishes Cancel Out?

- The logic of this position depends on an inherent distrust between project workers and senior management.
- If an early finish is reported, workers assume that the shorter-than-normal activity duration will be the expectation for similar activities in the future.
- Senior managers do not really understand the uncertainty faced by project workers.

So, the logic of this position depends on an inherent distrust between the project workers and the senior management. If yearly finish is reported, workers assume that the shorter than normal activity duration will be expectation for similar activities in the future, so they would not report it. So, the senior managers do not really understand that the uncertainty faced by the project workers. Next, we will see the common chain of

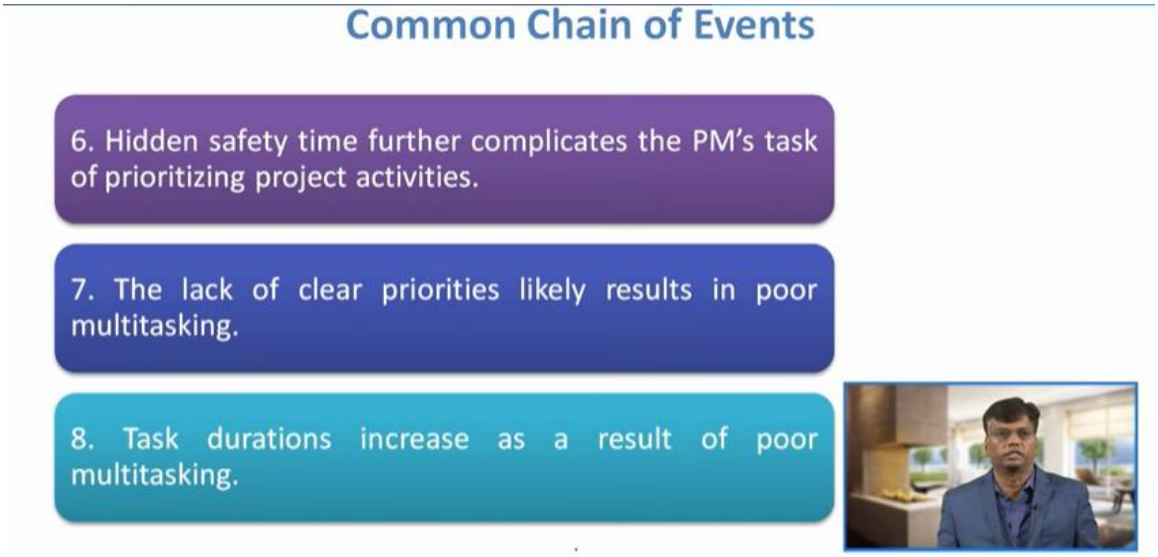
events. So, according to Goldratt, the behaviors and practices, what were discussed earlier, lead to the following chain of events.



First one is assuming that the activity times are known and that the paths are independent leads to underestimating the actual amount of time needed to complete the project. Second point is because the time needed to complete the project is underestimated, the project team members tend to inflate their time estimate by some safety time. Inflated time estimates lead to work filling available time, workers not reporting that a task has been completed yearly and the ever present student syndrome will occur. An important caveat is that the safety time is only visible to the project workers and is often misused. So, misuse safety times result in misused deadlines and milestones.

So, hidden safety times further complicate the project manager's task of prioritizing the project activities. So, the lack of clear priorities likely to result in poor multitasking. So,

task duration increases as a result of poor multitasking. So, uneven demand on resources, some overloaded and others under loaded may also occur as a result of poor multitasking. To utilize all resources fully, more projects will be undertaken to make sure that no resources are underutilized.



So, adding more projects further increases poor multitasking. So, these are chain of events which are interrelated. So, according to Goldratt, this chain of events leads to a vicious circle. So, specifically as work continues to pile up, the team members are pressured to do more poor multitasking. So, increasing the amount of poor multitasking leads to longer activity time.

Common Chain of Events

- According to Goldratt, this chain of events leads to a vicious cycle.
- Specifically, as work continues to pile up, team members are pressured to do more poor multitasking.
- Increasing the amount of poor multitasking leads to longer activity times.
- Longer activity times lead to longer project completion times, which ultimately lead to more projects in the waiting line.

So, longer activity times lead to a longer project completion time, which ultimately leads to more projects in the waiting line. So, determining when to release project into the system is the primary mechanism for ensuring that the right amount of work is assigned to the each person. If projects are started too early, they simply add to the chaos and contribute poor multitasking. On the other hand, if the projects are started too late, so key resources may go underutilized and the project will be inevitably delayed. So, consistent with the theory of constraint, so Goldratt suggested that the key to resolving this trade off is to schedule the start of new projects based on availability of bottleneck resources.

Common Chain of Events

- Determining when to release projects into the system is the primary mechanism for ensuring that the right amount of work is assigned to each person.
- If projects are started too early, they simply add to the chaos and contribute to poor multitasking.
- On the other hand, if projects are started too late, key resources may go underutilized and projects will be inevitably delayed.

Common Chain of Events

- Consistent with his Theory of Constraints, Goldratt suggests that the key to resolving this trade-off is to schedule the start of new projects based on the availability of bottleneck (scarce) resources.
- It might have occurred to you that one way to reverse this cycle would be to add more resources.

So, we have to start new projects only by considering the availability of bottleneck resources. It might have occurred to you that one way to reverse the cycle would be to add more resources. So, the appropriate response is to reduce the number of projects assigned to each person in any effort to reduce the amount of bad multitasking. Incidentally, a simple way to measure the amount of bad multitasking is to calculate the difference between the time required to do the work for a task and the elapsed time required to complete the task. So, when you see the difference, we can see the effect of poor multitasking.

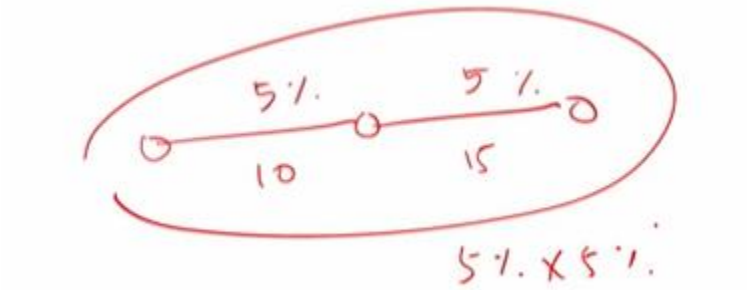
Common Chain of Events

- The appropriate response is to reduce the number of projects assigned to each person in an effort to reduce the amount of bad multitasking.
- Incidentally, a simple way to measure the amount of bad multitasking is to calculate the difference between the time required to do the work for a task and the elapsed time required to complete the task.

Inference from statistics

- Relying on elementary statistics, it can be easily shown that the amount of safety time needed to protect a particular path is less than the sum of the safety times required to protect the individual activities making up the path.

Now, we will take an idea from the statistics that we apply with the theory of constraint, when we will see what is the solution for that. So, relying on this elementary statistics, what is the point this elementary statistics is, assume that there is a project has two activity. So, this is going to take 10 days, this is going to 15 days. So, the probability of taking 10 days, the risk is say 5 percentage, this is 5 percentage. So, the risk of completing individual activity is 5 percentage and 5 percentage, but the overall the risk is multiplication of this 5 percentage and 5 percentage that will be smaller.



So, that point we are going to use this concept you are going to remember while using the theory of constraint. So, relying on the elementary statistics, it can be easily shown that the amount of safety time needed to protect a particular path is less than the some of the safety times required to protect the individual activities making up the path. So, point here is that instead of giving safety time for individual activity, if you give safety time for whole path, that will be the smaller value. So, the same approach is commonly used in inventory management, where it can be shown that less safety stock is needed to a central warehouse to provide a certain level of service level, level of service, then the amount of safety stock that would be required to provide this same service level if carried out at multiple distributed locations. So, the point here is suppose there are different distribution centers, here the safety stock level required is high, but if you aggregate into a centralized warehouse, so here the amount of safety stock required is very less.

Inference from statistics

- The same approach is commonly used in inventory management where it can be shown that less safety stock is needed at a central warehouse to provide a certain service level than the amount of safety stock that would be required to provide this same service level if carried at multiple distributed locations.

So, that is the if you aggregate it, the risk will be reduced. So, that point we are going to use it here. So, for example, what is the idea proposed by the gold rate? Imagine you have a big project to complete with many tasks. When people work on each task, they often add some extra time, just in case of things take longer than the expected. So, the extra time is like a safety cushion to make sure that they finish on time. But the gold rate suggest in different approach, instead of each person adding extra time to their task, he recommends reducing extra time to a bit, then take a portion of that saved time, then put it aside as a safety cushion for entire project.

The Project Buffer

- Imagine you have a big project to complete with many tasks.
- When people work on each task, they often add some extra time, just in case things take longer than expected.
- This extra time is like a safety cushion to make sure they finish on time.

- Goldratt, suggests a different approach.
- Instead of each person adding extra time to their tasks, he recommends reducing that extra time a bit.

The Project Buffer

- Then, take a portion of that saved time and put it aside as a safety cushion for the entire project.
- This overall safety cushion for the whole project is called the "project buffer."
- In simple terms, Goldratt is saying: "Don't add too much extra time to each task individually. Save some of that time as a safety net for the entire project."
- This way, you can still finish things on time, but you use your time more efficiently.

urce: Meredith, J. R., Shafer, S. M., & Mantel Jr, S. J. (2017). *Project management: a strategic managerial approach*. John Wiley & Sons.

So, instead of giving safety time for each activity, you can reduce some time from that activity, then you can give that work the cushion for overall projects. So, the overall safety cushion for the whole project is called project buffer. This was the idea proposed by the gold rate. In simple term, gold rate says, do not add too much extra time to each task individually, save some of the time as a safety net for the entire project. So, this way you can still finish things on time, but you use your time more efficiently.

The Project Buffer

- The amount of time each task is reduced depends on how much of a reduction is needed to get project team members to change their behavior.
- For example, the allotted time for tasks should be reduced to the point that the student syndrome is eliminated.

The Critical Chain

- Another limitation associated with traditional approaches to project management is that the dependency between resources and tasks is often ignored.
- More specifically, Goldratt argues that two activities scheduled to be carried out in parallel and using the same scarce resource are not independent as the traditional theory would assume.

So, the amount of time each task is reduced depends on how much of a reduction is needed to get the project team members to change their behavior. For example, the allotted time for task should be reduced to the point that the student syndrome is eliminated. Next, we talk about the critical chain. So, another limitation associated with traditional approach to the project management is that the dependency between resources and task is often ignored. More specifically, gold rate argue that two activities scheduled to be carried out in a parallel and using the same scarce resources are not independent as the traditional theory would assume.

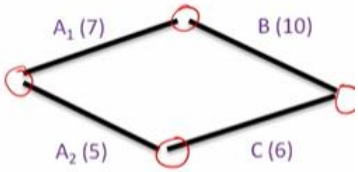
The Critical Chain

- If the supply of the scarce resource is not sufficient to allow both activities to be carried out simultaneously, then whichever of the two is given priority immediately lengthens the other activity's path but not its actual duration.

For example, assume that there are two activity A and B, these activities are independent, but the resources to execute these two activities is only one, then these activities is not independent. It is dependent on that scarce resources. If the supply of the scarce resources is not sufficient to allow both activities to be carried out simultaneously, then whichever of the two is given priority immediately lengthen the other activities path, but not as the actual duration. This concept I will explain with the help of one example. Now, I will explain the concept of critical chain and how it is this activities can be independent, but the scarce resources will make these activities dependent.

The Critical Chain

- If there is not enough of the scarce resource to fund both A activities, they must be done sequentially.
- If A1 is done first, A2 cannot start until A1 is complete, thereby adding 7 days to the A2 -C path, making it 18 days long and increasing the project finish date by 1 day.



- If A2 is done first, 5 days will be added to the A1 -B path, making it 22 days, a 5-day increase over its original 17-day duration.

So, there are two path A1-B it will take 17 days, A2-C it will take 11 days. Suppose, first A1 is done first, because it will take 7 days. A2 cannot start until 7 days, until A1 is complete, thereby that will add 7 days into A2-C path, already it is 11. If you add another 7 days, it will become 18 days and increase in the project duration, project finish date by 1 day, because instead of 17, you see it will take critical path is 17. Now, if you do it sequentially, it will become 18 days, the project duration will increase by 1 day.

Suppose if you A2 is done first, so 5 days will be added to the A1-B path. So, what will happen this one, so this 12 plus 10, it will become 22 days, a 5 day increase over its original 17 days. So, what I am trying to say is, if the resources are not enough to do these activities simultaneously, if you are doing this activity in a linear way, the project duration will increase. So, that means now A1, A2 is now it is a dependent event, because both the events are depending on the available single resources. So, using Goldratt's meaning of the word dependent, the activities of your project can be ordered into path based on their resources dependency, as well as and their technological precedence requirement. So, the longest of these path of sequentially time dependent activities is known as critical chain.

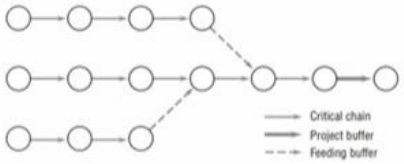
The Critical Chain

- Using Goldratt's meaning of the word "dependent," the activities of a project can be ordered into paths based on their resource dependencies as well as on their technological precedence requirements.
- The longest of these paths of sequentially time-dependent activities is known as the "critical chain."

So, what is the meaning of critical chain, we are considering the resources availability and we see what is the total time to complete the project. For example, in critical path, we consider only the time, we ignore the resources, but in the critical chain, we consider the resources availability also. Now, we will talk about the buffers for a project network. A project therefore is composed of its critical chain and non critical chain that feed into it, see the figure, for example, this path is critical path, longest path.

The Feeder Chain

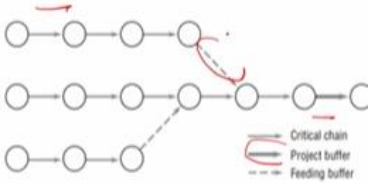
- A project, therefore, is composed of its critical chain and of noncritical chains that feed into it—see Figure .
- There are two sources of delay for the project.
- One comes from a delay of one or more activities in the critical chain.



So, this path is non critical path, because it is the smallest path duration. So, there are two sources of delay in the project, one comes from delay of one or more activities on the critical chain. So, delay may occur in this critical chain, this one, the second result from the delay in one or more of the activities on a non critical or feeder chain, this one, because such delays could delay activities on the critical chain. Now, we are going to talk about the project buffer, you see here this one project buffer thick arrow. So, a project buffer protect the critical chain and the feeding buffer, feeding buffer protect the feeder path. So, resources used by activities on the critical chain are given priority, so that they are available when it is required.

The Feeder Chain

- The second results from a delay in one or more of the activities on a noncritical or "feeder" chain because such delays could delay activities on the critical chain.
- A project buffer protects the critical chain, and feeding buffers protect the feeder paths.
- Resources used by activities on the critical chain are given priority so that they are available when required



So, when we are giving the buffer, we have to consider the buffer for overall project of that is for critical activities. So, then we have to think of giving buffer for the feeder chain that is non critical activities also. So, in this lecture, I discussed about Goldratt critical chain, then I have discussed about what are the reasons for optimistic bias, because that events are highly a chained event. Then we discuss about whether do early finishes and late finishes will cancel out. Technically, it has to cancel out theoretically, but in practically that would not cancel out.

Because you see the next activity even though the previous activities finished earlier, the next activity will be delayed as long as possible. Then we discussed about common chain of events that affect the project schedule. So, to overcome that the chain of events, the Goldratt has proposed the concept of theory of constraint. Then we discussed about Goldratt s two concepts, one is a project buffer. In that we discussed about the buffer for critical chain and the buffer for feeder chain. Thank you. Thank you.