Scheduling Techniques in Projects
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Lecture - 06
Resource-driven Scheduling

The title for today's lecture is Resource-driven Scheduling ok. So, let us see what are the contents I am going to cover in this class. Primarily, I will give a brief introduction on what is resource scheduling.

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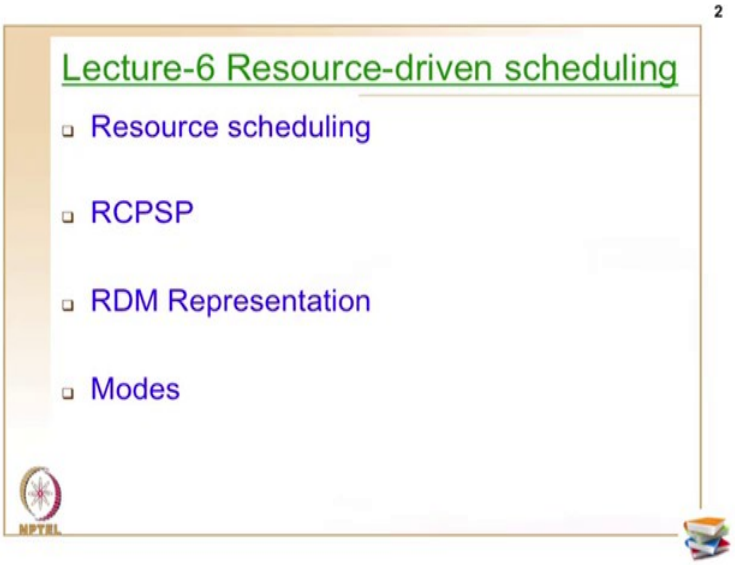

So, resource allocation or resource loading and so on, and little extend to resource leveling also you will understand in today's class. Then, we will move on to RCPSP. So, RCPSP is resource constraint project scheduling problem, introduction to that we will see. Then, RDM representation, I am just going to cover there are two means for resource scheduling: one is RDM representation which is relationship diagramming method and we are going to see the other form of modes other form of RCPSP which is a mode representations ok.

So, for all these cases I have shown you trial and error method on how to evaluate and find out the answers, but in real practice if you are having a large number of activities in a project it is very difficult to work out manually and work it out on trial and error method. So, we need to have heuristic methods or other combinations in order to solve

these sort of problems ok, but we will understand broadly on what is this resource schedules today.

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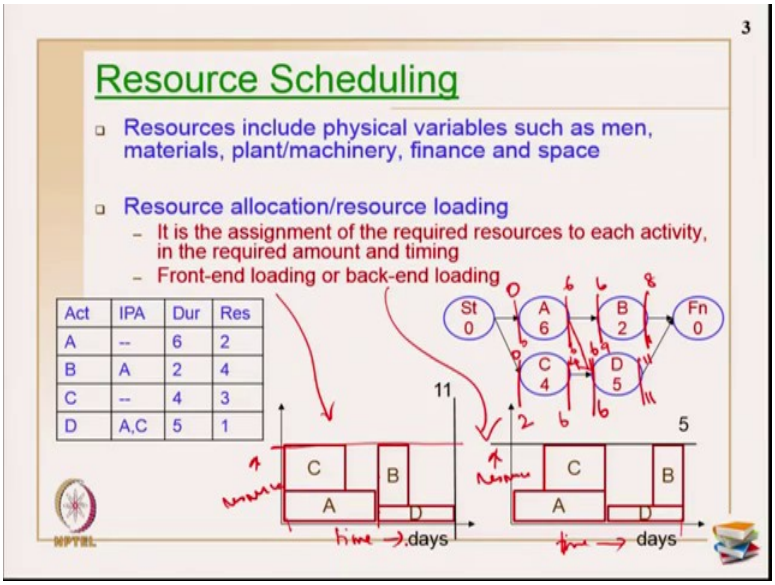

So, what do you mean by resource? So, resource can include any physical variable starting from man, material, machinery, sometimes even finance most of the time even space can be a real big issue when you are planning on resource schedules ok. But, in general what comes to peoples' mind is whenever you are thinking of resource schedules and resource leveling and so on, it is man and machinery only. Only manpower machinery that is all, others do not play a major role because materials you are not actually carried over in the long run. So, it is; so, it is not generally off very serious a concern.

The next is resource allocation or resource loading; both the names are really same. It is nothing but dumped in the resources on each activity to the required amount and time or duration of each activity and no need to do anything on reducing the resource or over allocating the resource and so on ok. Accordingly we have two types one is called frond-end loading and the other one is called back-end loading ok.

Now, let us see a simple example. I have taken a hypothetical example; four activities are there. Activity A and C are in parallel; I think now you know better on how to understand and interpret this. B and D are the sequence steps number 2 in the list ok. So, they are actually successors to A and C and the duration for all these are given, resource

required is given. The assumption is all these four activities share the same resource, then only you can do all the allocation and loading together ok.

Now, let me draw this network. So, how do I do? There should be an arrow mark from here ok. So, primarily this is my network. So, once A is done B is done, then after A and C are done D is done as per the predecessors relationships, this is a network and, now, if you see this network the resource allocation for all these activities are also given here and I am just going to show the front-end loading. What happens in front-end loading? Front-end loading is based on your forward pass ok.

If you do forward pass calculations for this let us assume I am only going to show on these activities. This is 0, this is 6, this is 0 and this is 4 ok, this happens to be 8 and this is now 6 and 8, this is now 4, 6 maximum is 6, 6 plus 5 is 11 ok. So, 11 days is a total time taken for my project for this small project, and if you see these resource combinations so, I am actually consuming a resource combination of this is my resource consumption until till 5 I am occupying.

Now, if you see here the front-end loading says I am actually dumping in resources based on my forward passes which implies yearly starts and the yearly finishes. So, as such A starting on 0 finishing on 6 ok; now B is starting as soon as A is done, so, 6 till 8. Now, activity C is starting on 0 until till 4 and D for D I have to wait for A and C to be over. So, D is starting on 6 and finishing until 11 that is primarily as we call it as a front-end loading resource aggregation chart ok. If you are working on a backward pass; so, this is 11 now, this is also 11, 11 minus 5 is 6, 11 minus 2 is 9. Now, this is also 6 for me 6 minus 4 is 2. Now, this happens to be 6, 6 minus 6 is 0 ok.

Now, I am actually employing my resources based on my late starts and late finishes. So, D is from 6 to 11, A is from 0 to 6, C is actually from 2 to 6 and B is also from 6 to 8 if you dump in the resource based on the backward pass then primarily you call it as a back-end loading of resource aggregation chart ok. So, this is the x-axis you have time in days and y-axis you have number of resources in the x-axis. Both these cases duration is finishing on 11 and the maximum resource taken up is 5 for both the cases ok.

So, primarily we call it as a resource allocation or loading. Again, there are so many ways of showing it. You can also show tabular form, you can also do like this or you can show day wise separately and even the order of these activities also need not be AD in

the bottom you can keep it on the top you can do whatever forms unless you are representing the number on each days are same ok.

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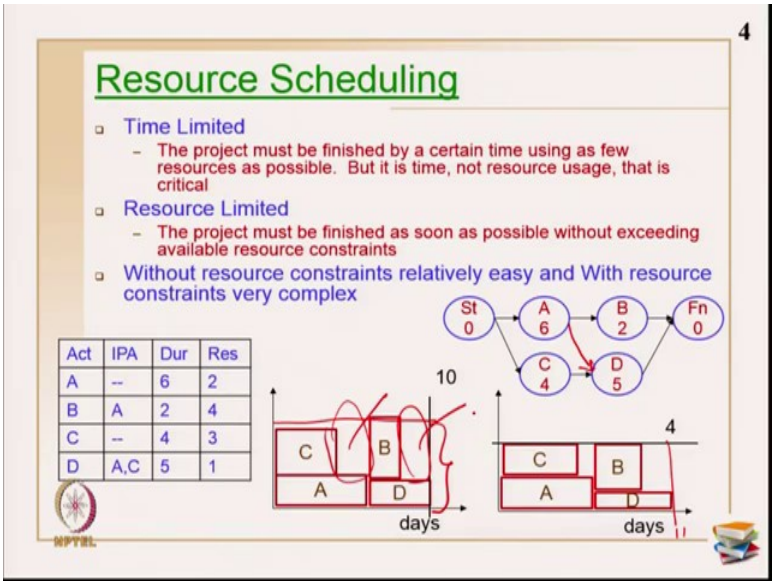

Now, let us discuss on resource scheduling. So, primarily there are two forms of resource schedules one is called time limited, and other one is called resource limited. So, what happens here is in resource scheduling why am I bringing in time every time because the number of resources determines the duration or the minute you fix the duration you have to decide on the resources. So, the resource and the time are actually interlinked with each other ok.

So, now when you are doing on resource schedules primarily I am working on scheduling part then there are two parameters which comes together; one is time constraints or do I have resource constraints ok. So, the project in time limited issues the project must be finished by a certain time using as few resources as possible. So, it does not mean since I have to crash my, it is not crashing. So, primarily you are finishing in the last example for instance I have to finish it on eleventh day ok.

So, but primarily you are going to finish the same project on eleventh day only with the few resources as possible. I am not going to delay my whole time and then use more resources and do something and so on. So, that is not primarily the whole concern, but it is a time and not the resource you would say which is critical in this particular phase of time limited constraints.

The resource limited case the project must be finished as soon as possible again there should be no delays or extended duration on any of the activities etc but, without exceeding the available resource constraints. So, in the earlier case maybe there was a constraint on resource 5. So, I could finish the project on 5 and there was nothing happened here ok.

Now, when there is no resource constraints and I have abundant resource with me then both time-limited or resource-limited is not a problem for me ok. Even if I slip one or two days still I could finish in the respective time or if I have more resources then obviously, I am not going to worry about how know meticulously to finish my whole project.

So, we both the issues will not be complicated at all when I have scarce resources, but in reality what happens in construction site, the resources are always scarce in nature. It is not abundant so, always your resource scheduling has a critical challenge there ok. So, here also so, there is a mistake here ok.

So, now, this is the same example. I have brought in the same network diagram also. So, now, what do you have to see is; so, this is time limited. So, you earlier we have seen we have to finish the project on eleventh day. So, finishing the project on eleventh day or tenth day, what happens is I am not disturbing anything here maybe I am using more resources whatever it is, but still the critical time at which I have to finish I am meeting that in place ok.

In the next case on resource limited again, I can finish the project on 5 with 5 resource maximum or with 4 resource. So, primarily I am finishing that, but I am not extending my duration from eleventh day to any other days. So, that is what is a whole meaning on time limited and resource limited ok.

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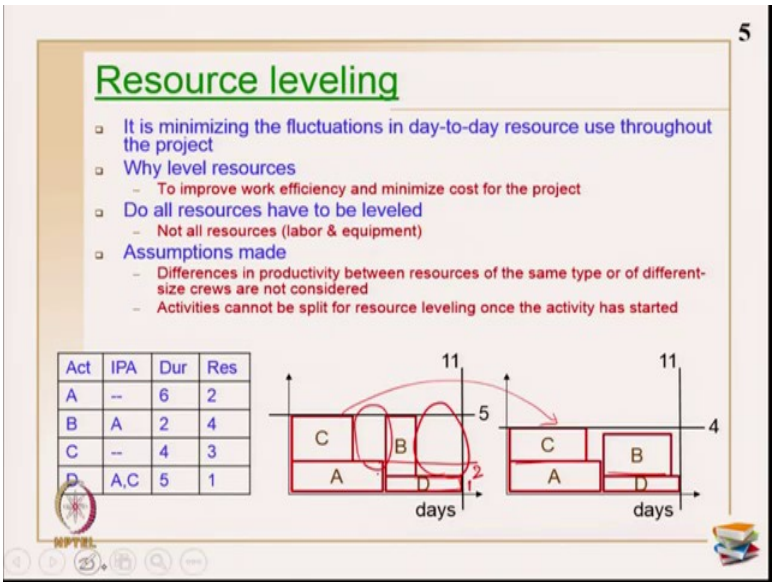

The next is resource leveling because whenever even in the last example you have seen here there are so much of idle time for workers. Suppose, if you want to schedule this project and then mobilize for the manpower, then you may have to call all the workers for all these days and what happens and you may have to pay for idle days of the workers. Suppose, if it is equipment you may have to pay the idle sitting time of all your equipments in the site ok. We generally it is like too much of cost overrun and which is actually a waste so, which you should avoid ok.

So, what is resource leveling? So, minimize the fluctuations do not call do not have an platform in which one activity I am calling. I need 4 workers on one day, 10 workers on 7 on second day then 3 workers on the third day, then 11 workers on the fourth day which is like too much of fluctuations I have in my whole project ok, seek to that am having utmost like uniform 7, 6, 5, 7, 6, 5 something like that which is close to each other which is an acceptable issue in the sites ok. So, resource leveling is minimizing the fluctuations in day to day resource use throughout the whole project.

Now, why should I level the resource to improve the work efficiency and to minimize the cost on the whole project. As I told you unnecessarily you may have to pay for the resource by keeping the resources in idle ok; in order to also what happens is the lethargic flow on one day and active work mode on the second day, again lethargic mode active mode also will obviously, you know start spoiling your work efficiency or

productivity and so on. So, for all these issues better to have a uniform peak load of workers on all the days of the project.

Can all resource can be leveled or all do resources has to be leveled. Not all resources, there is no point in actually looking at materials and other resources on leveling. So, only the labor and equipment or manpower and machinery are the only one resources which you have to think of in leveling.

So, now, what are the assumptions you have to make? So, one assumption is difference in productivity between the resources of same type or different type groups are not considered. So, I may have a crew called and a carpentry crew, I may have a crew called a masonry crew. The helpers in both the crews if you want to swap then you cannot think of difference in productivity between resources between a manpower of different work crews or within a masonry crew itself different workers can have different productivity levels and accordingly you may have a different duration and so on. That also you cannot consider when you are working on resource leveling problems.

The next is a real serious assumption. Activities cannot be split once the activity has started. So, if you are planning to start the activity on day 0, so, finish the completely loading the resources and you cannot stop the resource loading after 2 days and then continue after 3 days and so on which is not possible in resource leveling. Now, let us look at the same example ok. So, I have modified this example to show the fluctuations how it is done in trial and error practices in sites.

Four activities, same example ok. So, this is my first combination 5 resources. So, lot of know idle resources are here if you want to maintain the five fluctuations are there, some days I need 5, some days I need 2 and some days I need only half of the crew and so on. I need only one worker in the site and so on. So, some days I need 2 this is stands for 1, this is primarily 2 and this is still 5. So, that you still wanted to avoid ok. So, what I am going to do I am trying to minimize or level it at resource number 4 maximum availability I am going to call is 4.

So, what happened since because you are trying to cut down this then the duration for C and B will get extended because A and D is on the critical path. The general assumption in resource leveling is do not touch the activities in the critical path and you will have to always look at the non-critical activities in order to know minimize the resource and then

so that even if the duration is extended it is not delaying the entire project ok. So, what happens the C, B are the non-critical activities I am looking at the non-critical activities and I am actually extending the duration, so that my I am meeting my resource of 4.

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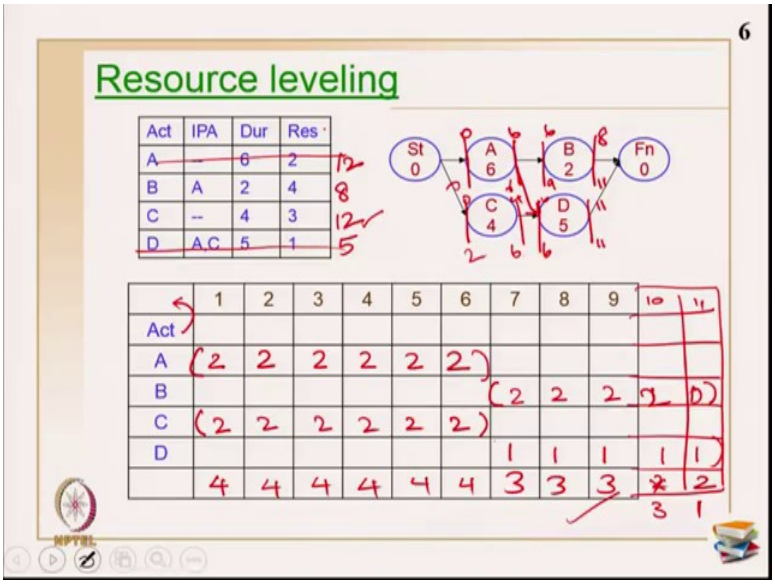

What happens if I go below 4 and so on, then the duration will obviously, slightly get extended which also we will see what sort of a problem it is. Now, for the same example let us see a trial and error method of how to do the leveling problem because I showed you with for small example I showed you, but there is a trial and error method. There are also scientific methods called minimum moment algorithm which is available in order to do the leveling exercise ok.

Now, for doing the leveling I need to know the early starts, early finish, late start and late finish. So, for forward pass, backward pass I have to work out. So, I will just quickly write this. So, this is 0 6, this is 0 4 here and this is 6 and 8 and this is my 6 and 11 working backwards. So, 11 minus 2 is 9. So, this is 11 minus 5 is 6. So, this is 6, 6 minus 4 is 2; this is 6 and 9 minimum is 6, 6 minus 6 is 0 ok.

Now, the critical path you obviously, know it is 6 and 5. So, this has to come here ok. So, 0 till 6 this activity A and activity D is 7 till A, 7 till 11 ok. So, now, this I have dumped in because I have to know where is my path until which I can dump in the resources ok. Now, here critical path obviously, you cannot do anything so, I am going to put the

resources. Resources for activity A is 2 on all these days. So, this becomes 2 and for activity D it is it is 1. So, this is now 1, 1 on all these days ok.

Now, what about my activity B? My activity B, I have actually a float from 6 until 11 and for activity C I have a float from 0 until till what date? Until 6 because it starts from early starts and late finish and also you should keep in mind you should not violate the logical relationship of the network as well ok. Now, what you should do? So, primarily I wanted to know what is my maximum crew composition, suppose if I want to increase or decrease a resources what is a duration with which I have to extend; that obviously, you have to understand ok.

So, for which you have to know what is the work content of all these activities. So, work content or total quantum of work. So, this is 12, this is 8, this is again 12 and this is 5 by multiplying the duration and resources ok. So, activity A is done and activity B is also done now you have to work with only these two activities ok. Now, what is the option available activity C? I have to finish how many 12 and so, what I am going to do instead of using three resources suppose I have done 3 resources it will be 3, 3, 3 and so on wherein you cannot do. So, what I am going to do I am going to use two resources on all these days. So, 6 into 2 becomes 12 so, which is tallying my combination ok.

Now, we will look at activity B. So, activity B, I am having 8 work content day. So, I have to finish the 8 on all these days. So, I am going to put 2 for few days and then I am going to use the 1, 1 for the remaining days. So, 2, 4, 6, 7 and 8 so, this becomes now 8. So, all my resources on all the days has been done. If you see here, so, this is 4, this is 4, 4, 3, 3, 3 and 2 and 2. This is not too much of fluctuation ok. It is actually uniformly decreasing ok. So, this is acceptable, but do not have too much of variations like 4, 3, 4, 3 and so on which is not that good.

Now, if you see here what about my logic after A after A, B is starting the logic is maintained and after C after C and A my activity D is starting. So, both the logics are actually maintained and there is no problem in dumping this resources. So, you have to look at the logic, you have to look at the work content has been settled. So, this is 12, this is 8, this is again 12, this is 5. So, that work content is also now settled. So, this is primarily a leveled diagram.

If you want to look at other combinations I think it is not possible either. What other option I can say is, you can keep this as 12 this becomes 0. So, this still becomes 3 and this can become 1. So, both are fine ok. So, these are the only options you have in this particular network. Now, what you will understand is in this case the resources were in such a way that I can actually you know swap the resources from activity A to B to C and D, I can share my resources on all the activities ok. And, what sort of examples can you see in construction site for these cases?

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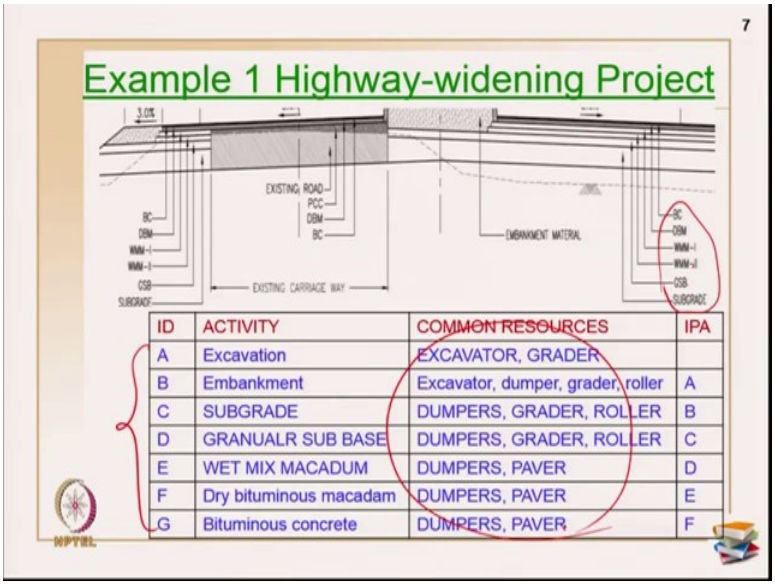

ID	ACTIVITY	COMMON RESOURCES	IPA
A	Excavation	EXCAVATOR, GRADER	
B	Embankment	Excavator, dumper, grader, roller	A
C	SUBGRADE	DUMPERS, GRADER, ROLLER	B
D	GRANUALR SUB BASE	DUMPERS, GRADER, ROLLER	C
E	WET MIX MACADUM	DUMPERS, PAVER	D
F	Dry bituminous macadam	DUMPERS, PAVER	E
G	Bituminous concrete	DUMPERS, PAVER	F

Now, let us take a highway widening a project this is example we have seen earlier for LOB or and so on. So, in this example what happens is this is a highway widening project. There is an existing carriageway here and this is primarily the carriageway which is proposed for widening and I have my embankment plan to be here and these are all the levels with which I have to fill my layers on the highways ok.

And, the order of activities is excavation, then embankment, subgrade. You will see the same thing here. The embankment is here, sub grade, granular sub base, wet mix macadam 1 and 2, then dry bituminous macadam and then bituminous concrete and then the highway is actually ready.

If you see the resources, now one thing the resource problems will be very common in repetitive projects because I am going to use the same set of activities. Now, this set of activities will be there for a stretch of 300 kilometers or so on. So, you may be having

repeating the resources on all the places on all the stretches. So, this combination itself is repeating ok.

Now, if you see at the individual activities also. I have so many resources which are repeating I have only dumped in the common resources ok. I need excavator and all these are serial activities which implies sequential in execution. Excavator and grader – excavator is again required it for embankment; grader is required for embankments upgrade and granular sub base. Dumper, I need almost for all activities except my excavation and roller I need for three activities embankments sub grades and granular sub-base. Paver I need for the last three activities like wet mix macadam, dry bituminous macadam and bituminous concrete.

So, if you see here there are common resources which you need. So, if you are planning if the number of resources are limited then you may have to execute one only one path or you may wait have to wait for the previous activity to be done and then only you have to go in for the next activity even in the sequential and only when full stretch is done then only you can go to the next stretch and so on. So, you have to have a so much of delays may happen when you are having common resource shares ok.

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Now, let us see a real example as to how this you are actually working in construction sites ok.

So, now this is an example, this is also a known example. I am bringing in all known examples to you and let us see the resource requirement here. This example I have brought for 3 tower units. I am going to show only 2 tower units as the earlier. Duration for all these activities are listed here. I have used same duration because that is the assumption we generally make in LOBs I have brought in the same duration and IPA for all these activities are listed here and if you see here the resource required I have different skilled workers, but I have same type of an unskilled worker 15 helper, 10 helper and 10 helper I have the same combinations in the three activities.

So, I am going to show you what is the option I have only for the unskilled workers right now and how the duration is getting changed or modified. So, the skilled worker we will see a little later.

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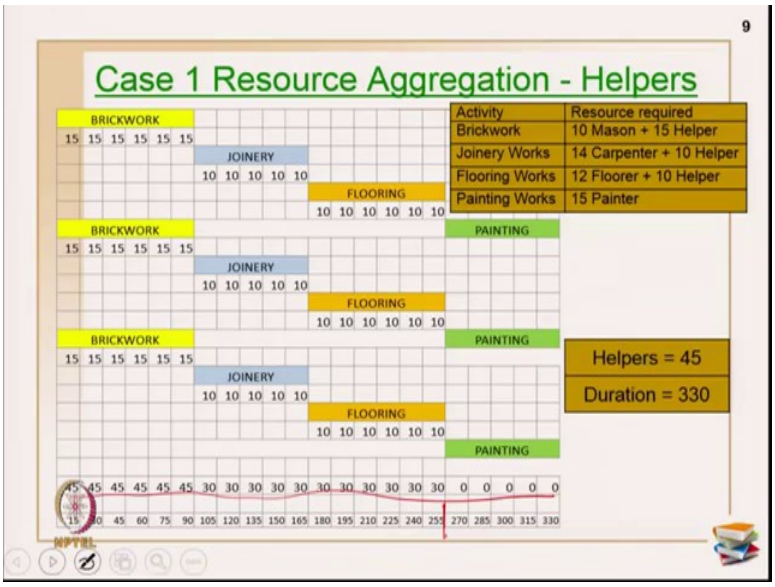

Now, let us see only for the helpers. This is a resource aggregation chart I have right now and I have placed this for activity as well as I showed you for the aggregation also ok.

Case 1: So, what happens let us assume I have almost the maximum number of crews I want I have with me. There is no problem, no constraints on resources. So, 3 towers have to be done. So, all the 3 towers can be done in parallel. So, what happens all the 3 brick work is done in parallel, all the 3 joinery are done in parallel, all the 3 flooring are done in parallel, all the 3 painting tasks are done in parallel because I have enough number of my skilled crews and workers ok.

So, if you see as I told you we are only going to see on helpers, if you see here the fluctuation of the helpers which is shown here. This is on helpers total 45, 45, 45 then 30, 30, 30. Then no workers are required for painting job and the duration for this entire project has consumed to be 330 for all the three towers until painting ok.

If you see so, for example, till level 2 at least if you want to finish, then you are stopping at actually 255 days I am finishing only for the three activities till level 2 ok. So, to have a fair idea on where we are. So, 45 workers I need at least for few days of my whole project.

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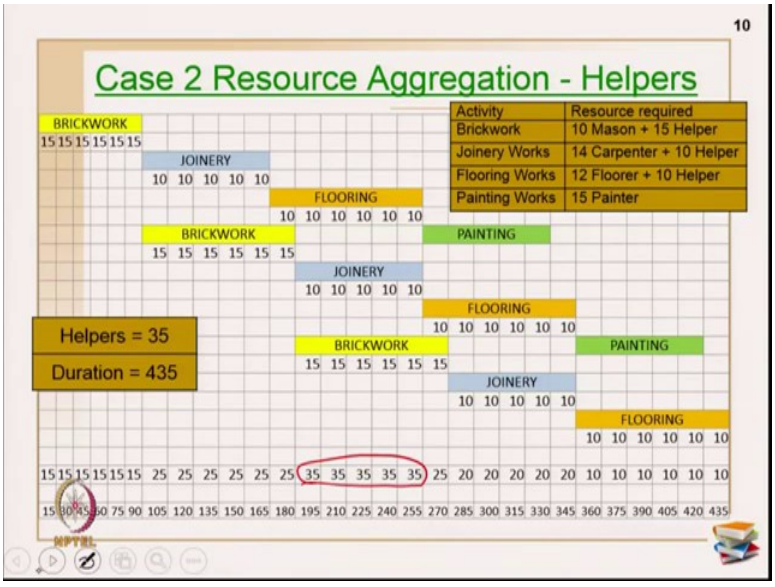

Now, let us assume I have very scarce resources I cannot go with 45 and the maximum I can do is 35 or something. Then what you have to do? You have to stagger the execution of the whole work. So, what I am going to do I am going to follow the little of the conventional repetition works how we do after one level of brickwork, the second level of brick work is done then the third level third tower goes. So, after joinery the first tower, second tower, third tower so, after the flooring first tower second tower and so on. So, this is a bar chart representation I have shown you for the same ok.

Now, the same only for the helpers I am see showing it here. This is the total on all the workers whom I have. If you see here the maximum limit I have is only till 35 ok. I have consumed only till 35. Now, what about the duration? So, until flooring for the three levels if you want to see, my duration for the entire project is coming out to be 435.

Now, in the earlier case when there was no problem or constraint on resources I finished until level 3, till tower 3, flooring activity was 255 ok, here I have stretched till 435. Now, let us see still I have more constraints I am going to reduce it to 25 workers only. What will happen?

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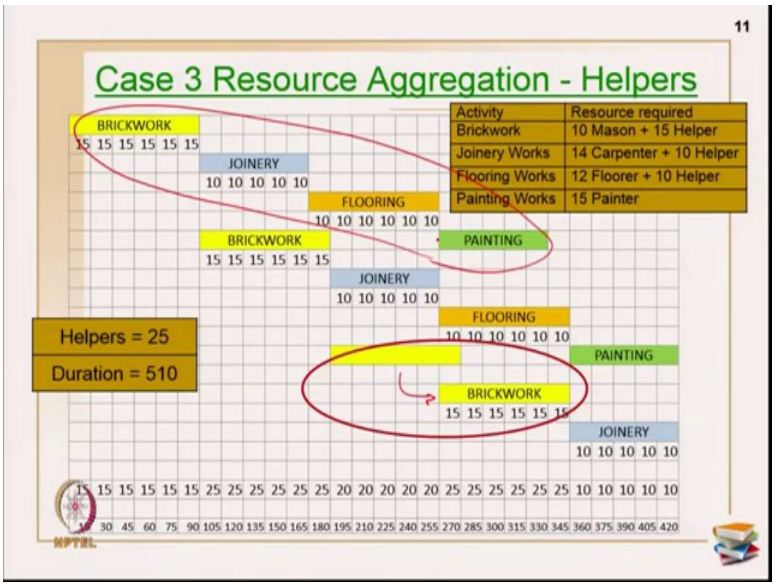

So, what happens, only in this place I need more than 20 workers or so. So, this brickwork cannot go in parallel at this particular time. So, I am just shifting the brickwork compared to the last place to this place so that I maintaining the maximum of 25 a limit ok. Now, what happens here I have not distributed the resources in the previous places and adjusted with 5, 5 and so on. So, the leveling really I have not done I have only shifted the work completely ok.

So, what happens here when I have stretched a little bit so, now, until till your flooring activity for all the 3 will go till 510 I have cropped only till joinery, if you add flooring painting and so on. So, it will actually stretch till 510 until flooring for the 3 towers which you are planning for ok. Now, this is what is the whole exercise all about.

Now, let us see further. So, what happens here is the logic you can actually you know this logic alone has to be maintained and you can actually move all the towers in parallel also if you have more crews. So, primarily the number of resources what is driving your duration which is what is the resource scheduling all about. So, starting from somewhere

around 330 days of duration ok, we are actually in to then 435 and then till 400 and 510 for this case.

So, we are having a large variation in the duration because of the number of helpers you have in the whole project ok. I am not even talking about the skilled workers now. So, now, what do you do? So, there is unique so, primarily this is not the hard logic it is only the resource relationships which you have to represent in the network.

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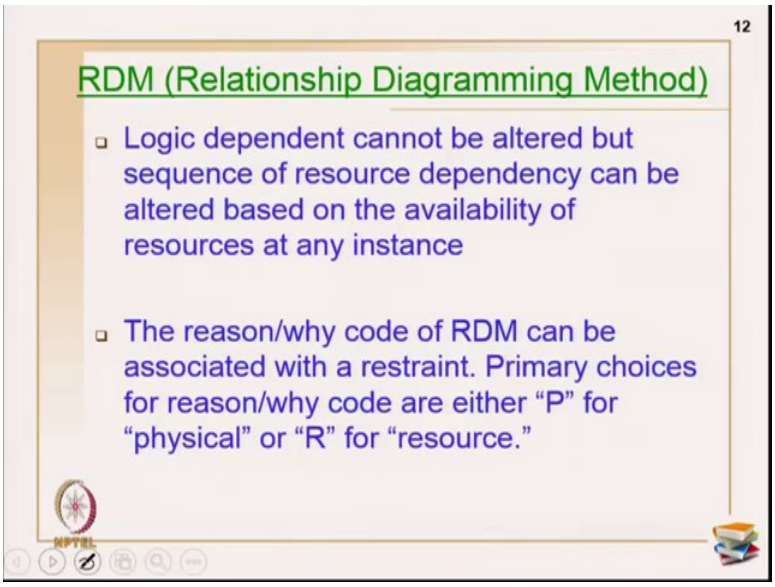

So, how do you represent the resource relationship?

Now, let us talk about the RDM diagrams. So, RDM is nothing, but Relationship Diagramming Methods. So, in any network diagram the logic dependencies is primarily driving the whole sequence. Now sometimes the logic dependence you cannot alter the logic dependence, but the resource dependence can be altered based on the availability of resource at any point of time ok. For example, in the same apartment exercise you can have all the 3 towers going on in parallel or little staggered or too much of staggered based on the number of resources.

But, as such if you want to draw a diagram and represent this how do you draw the diagram? Do you put a link or you show it as parallel? So, how do you really do ok. So, RDM is the only one way to show your resource dependency on a project ok. The reason why code on RDM can be associated with their constraints: so, primarily choice for the

reason why R either I go with the P for physical or R for a resource. So, primarily you have right on the network whether it is P then the P the violation on FS is never altered and if you are writing an R in the relationship based on the number of resources that you have the R can be made parallel or it can go sequential or it can go even pushed and then started. So, that is what happens here.

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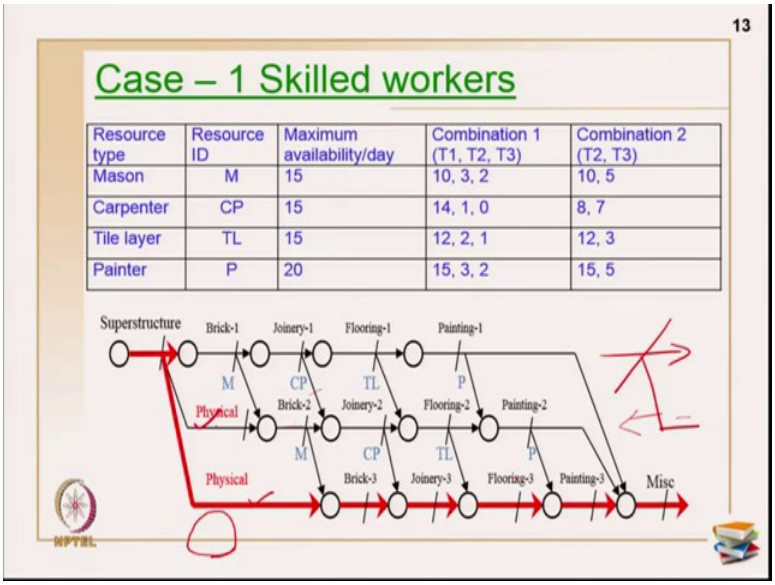

Now, the same example now I am going to show and on the skilled workers case ok. So, in the same example what happens let us assume because I am not worried about my helper I know I can easily get my 45 helpers or 50 helpers or how many ever I want in the whole project. I am only worried about the skilled workers because they drive the whole activities ok.

So, I have just marked only on the skilled workers here. So, maximum availability per day 15, 15, 15 and 20 that is what I have written here. And, so, what happens here? So, can you start all the activities in parallel if you look at what is the requirement of these workers I need 10, 14 for joinery works, 12 and so on.

So, primarily you can go with one activity, 1 tower at a time, but you cannot do 2 towers in parallel and what if since I have little more than 10 mason and little more than the 14 carpenters and so on, so, can a little more push some of the activities in the tower 2? Yes, it is possible. So, what I have done, I have used combinations 1, 2, 1 so on. So, accordingly you can do this diagram. This diagram is primarily called an RDM diagram

and you can still do calculations on what is your critical path and so on. So, in this case with this combination this happened the tower 3 happened to be the critical path ok.

Now, if you see here so, primarily what you have to do on the arrow mark put a slash and then from there you can write what is that relationship all about ok. If you see here I have written here physical here because after my superstructure only I have to do my brick work in tower 2 and I have to start my brick work in tower 3.

So, there is a physical relationship also here. This red is primarily the critical path. And after the brickwork in tower 1 and brickwork in tower 2 masonry is a resource which is governing there ok. So, if I have more mason I can do both the activities in parallel. If I have a few mason then accordingly this turns to be sequential in nature; accordingly the same you have for brickwork in tower 2 and tower 3 ok.

Now, same thing for your joinery works ok. So, I have my carpenter: so, carpenters is a resource for my brickwork and so on. So, what happens after my after my joinery work is done then these carpenters will be playing a major role for my resources ok. Same way for flooring I have tile layers, painting I have painters; so, more painters so, this piece is like a flexible relationship I have and this is a representation on an RDM network ok.

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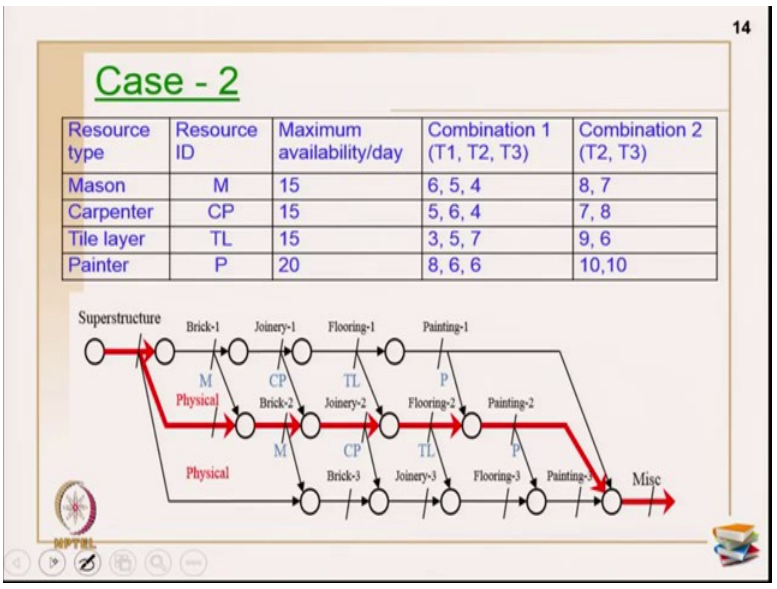

I am not showing the calculations here. So, when I change the combinations a critical path also changes and so on. So, that is primarily on this RDM.

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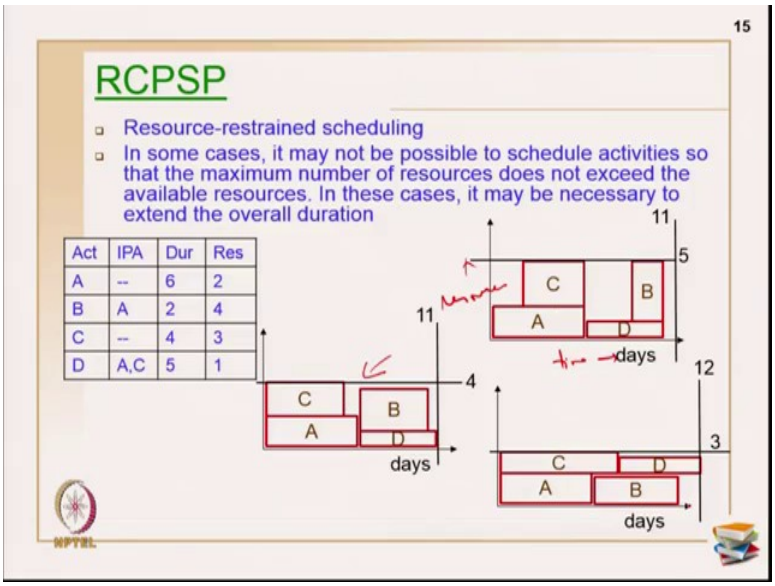

Now, let us see the resource constrained schedules ok. So, far we have seen schedules in which duration of the entire project was not altered even if it was time constraints or it was a resource constraint, resource which was constraints ok. So, you try to accommodate within that only.

So, now, the next case is this suppose if we have very scarce resources as a result of the very few resource the duration of each activity has to be stretched little bit and obviously, it slips off beyond the planned schedule of the whole project ok. Those particular cases we call it as a resource constrained project scheduling problem or resource restraint scheduling. In some cases it may not be possible to schedule the activities so, that the maximum number of resources does not exceed the available resources. So, in these cases it may be necessary to extend the overall duration ok.

Now, let us take the same case. So, the same hypothetical example which I showed you earlier. So, this is primarily it takes 11 days of duration ok. So, this is resources, number of resources and this is time in days ok. So, maximum I have taken 11 days and my resource was primarily maximum I have taken consumed is 5 ok.

Suppose, if I want to make it as 4, what happens? Still it is possible within with very little floors we can still make it possible and I could still adjust to 4. Till then you still call this problem as a resource leveling problem only because you have not extended the project duration any on any case. So, this we call still as a resource leveling problem ok.

The minute you start having very little resources maybe let us assume 3, what happens my duration of A or D gets stretched a little bit and what happens it may even extend my critical path durations ok. Now, it has gone till 12 and the number of resource consumed on the whole project was 3 here. So, these type of problems we call it as a resource constraint project scheduling problem.

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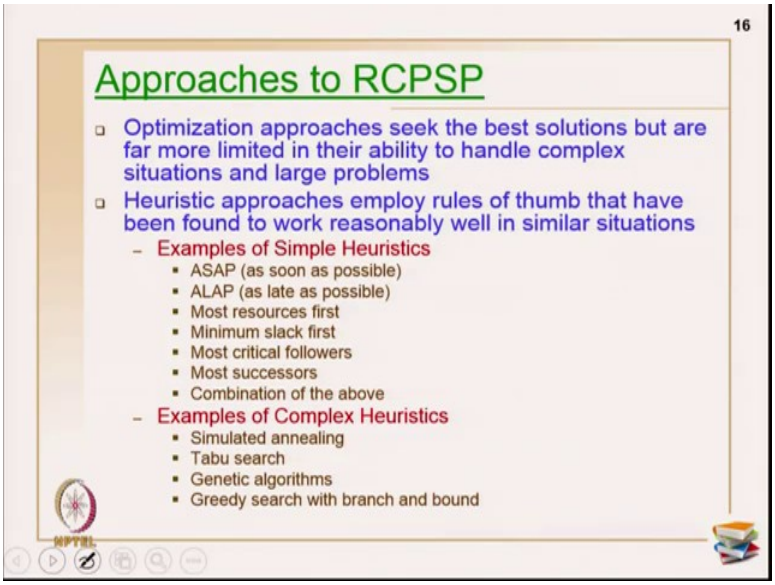

Now, what are all the approaches to RCPSP? There are so many approaches available. In broadly I have two methods for RCPSP; one is optimization approach, the other one is a heuristic approach. So, optimization approaches what does it say? It seeks the best solutions but, are very far from limited in their ability to handle complex situations and large problems. In heuristic approaches, they employ a rules of thumb that have been found to work reasonably well in similar situations.

So, a lot of heuristics are there; one is simple heuristics, another one is complex heuristics. Simple heuristics; so many rules are there in the form of rules as. ASAP as soon as possible; so start finishing up the activities as soon as possible. Then, yeah ALAP; so, primarily it is as late as possible; then most resources first; minimum slack first; most critical followers which implies whatever activities which have many successes, then those activities should be done first on the resources most successors, then combinations of any of the above also is possible ok.

Complex heuristics will simulated annealing and Tabu search, genetic algorithms and so on. So, so many methods are available on RCPSP modes ok, but this has to be know dealt in a different way in order to work it out on problems.

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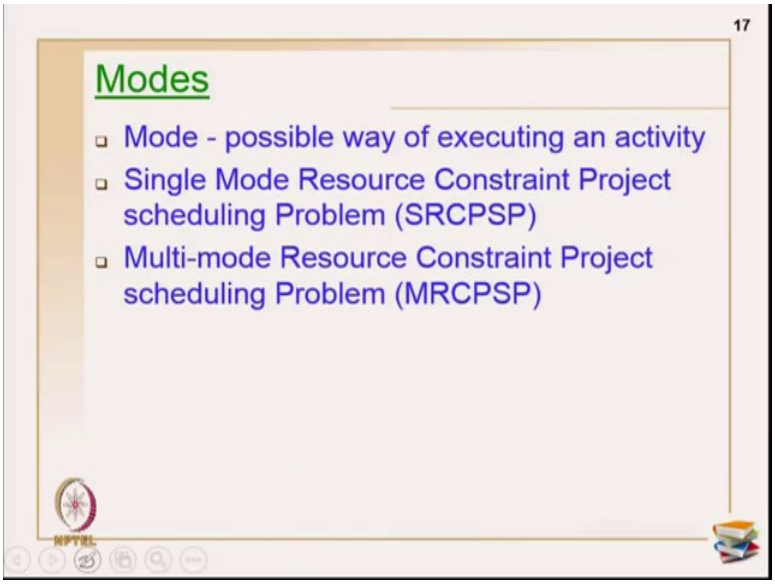

Now, let us see on modes. So, we are actually you know there is another simplistic way of working out on the RCPSP problems which is their existing for last 30 - 40 years and so on which we call it as a mode. So, what do you mean by mode. Mode is the possible way of executing any activity. So, I have two combinations here; one is called the single mode RCPSP problem and the other one is called multi mode RCPSP problem ok; accordingly you have SRCPSP or MRCPSP ok.

So, for any activity there is only one way of executing the activity, then we call single mode. Completely for the entire project generally people work it out on only one way of executions. Suppose that the resources are constraining too much why to look at those resources in a different combination maybe there are other resources which are not too much of a constraints is it possible to think of getting that resources and then doing the scheduling in a different way, that is primarily called the multi mode options ok.

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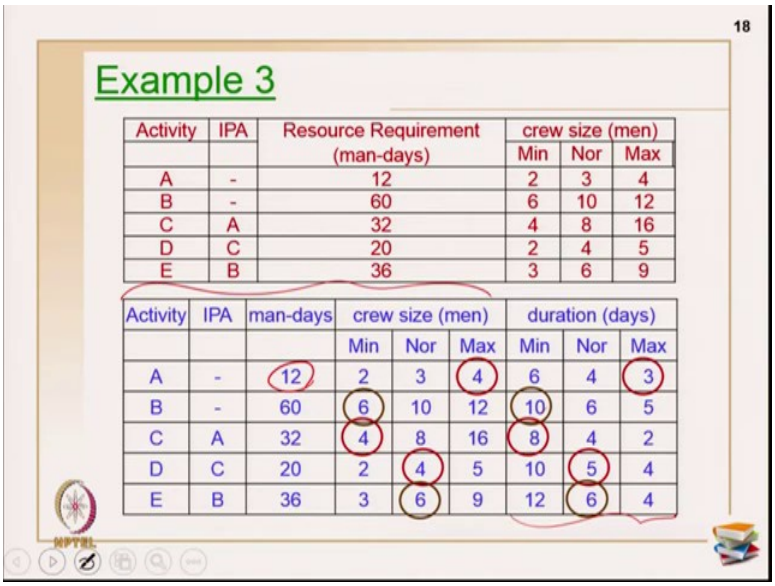

I will show you with an example. Now, this is an example hypothetical example just to show you on how to do the whole exercise ok.

Now, this is the example. I have a list of activities here. These are the IPAs for the activities. Resource requirement in a man-days is given like. This I have a crew size. The 3 combination crew size; primarily the 3 mode options I have; minimum normal or maximum; I am taking it as my 3 modes right now and the man-days are given here. Now, according to the same problem which I have here what can I do? I can calculate the duration for the whole exercise ok.

You know what is the crew, what is a work content, what is a crew size if you know so, based on this you can really calculate the duration for all these activities on the minimum normal and maximum crew size. Now, I have got the duration for all my activities ok.

Now, let us choose some combinations now. Now, what am I going to do if you see this example it looks like A, C, D is on one path and activity B and E is on the other path. That is how the relationship goes through. After the A, I have C, then I have D, so, A, C, D is on one path and B and A is on the other path. Can you think of critical path and other combinations here?

You cannot think of anything here because it is like you can choose any options you want ok. Whenever you are working on mode there is nothing called critical path calculations in when you are working on mode calculations.

So, I am going to choose a crew size on 4 because I had a common number in all the three activities. So, I have taken up that as a 4 and what happens I am going to choose those duration so, which implies 3, 8, and 5. So, when I am choosing a resource combination on 4 along one path. So, 4 on A, C, D my duration for the A, C, D will be 3, 8 and 5 which is nothing, but 816 ok. Now, when I am choosing so, same way I am going to choose a common resource on B and E. So, I am going to choose 6 and 6. So, accordingly what happens my duration is 10 and 6 which is again 16 here ok.

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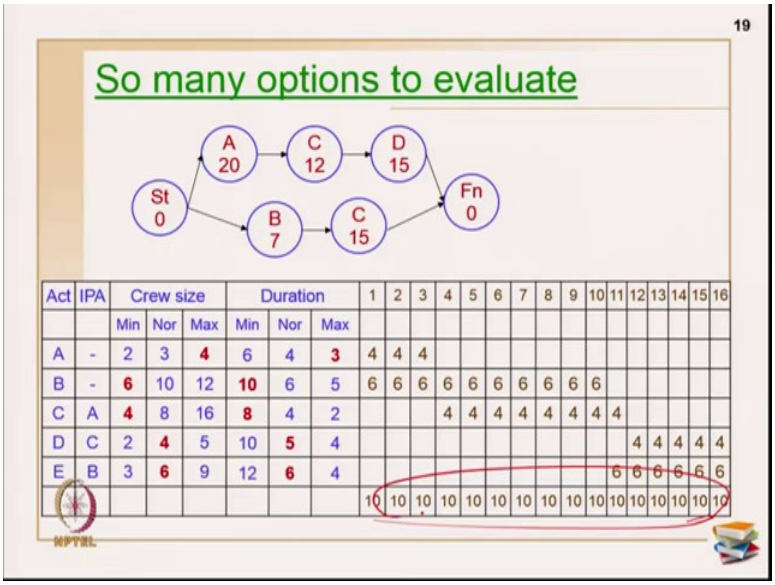

Luckily, I had a very good levelled path here with the duration of 16 and my resource combination is actually 10 here ok. What happens, the same options I have taken here and so, these are my activities I have done and this is my complete till 10 is my resource, ideal resource combination I have got and my duration have come until 16.

Suppose, if you want to use more resources and you wanted to reduce the project duration or you wanted to use more resources or you want to reduce a project duration in any of these combinations what happens is you may have to know you may have to have a unleveled combinations will be there, but you will have so many options in order to evaluations.

So, in real world practice what happens, just I am taking on one resource here and I have shown how to do, luckily I got in the first trial itself. You may have to do so many trials to see what is options or evaluate all the possible three options for all the 5 activities and then see what is the best combination for you ok. This will turn out to be the best ideal fit for you in any case.

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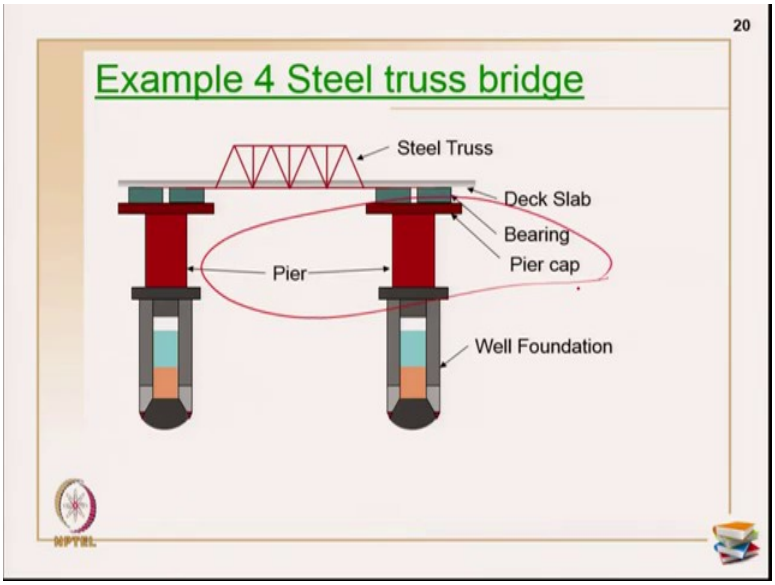

Now, let us take this another example in order to show the complexity with many resources coming in ok. This is a steal truss bridge ok. Primarily what happens, this is a simple steel truss. So, I have a steel truss here, this is my deck slab, these are my bearings I have a well foundations here, this is a pier cap and this is a pier. So, primarily I am going to look at pier and the pier cap activities only just concreting ok.

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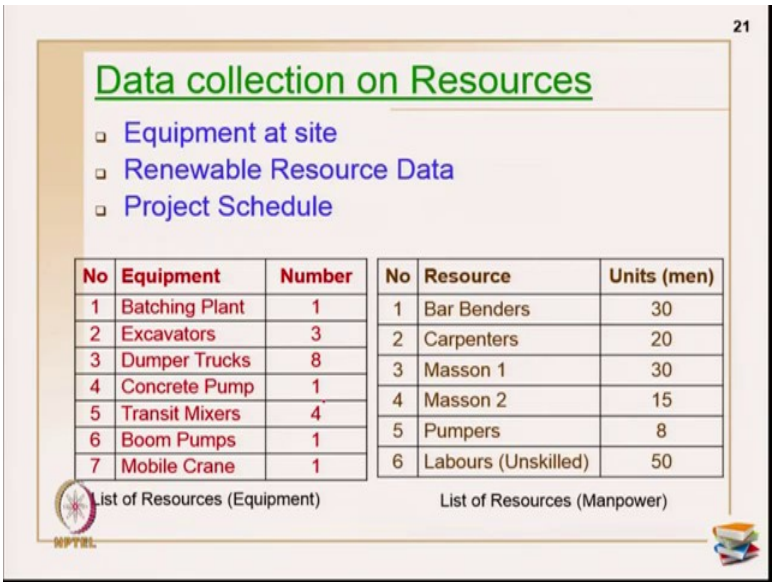

So, I have taken I am going to look at the activities only on the piers and pier cap, only the concreting activity alone equipment at site. So, these are the equipments I have a batching plant, 3 excavators, 8 dump trucks, 1 concrete pump, 4 transit mixers, 1 boom pump and 1 mobile crane I have in the site ok. Resource on manpower I have 30 bar benders, 12 20 carpenters, 30 mason first grade, 15 mason second grade and 8 pumpers and 50 unskilled workers I have in the particular case ok.

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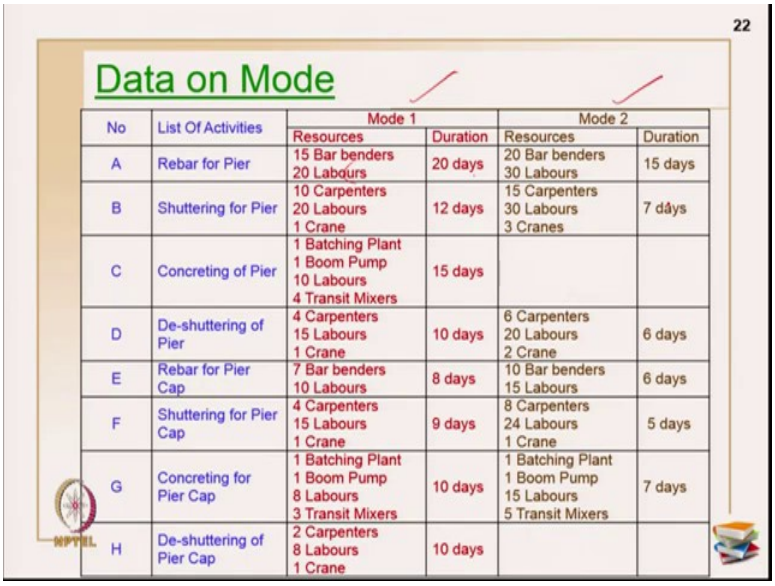

Now, I have four activities for these two four sub-steps or sub-activities for the main component one is pier and other one is pier cap ok. So, rebar for pier, shuttering for pier, concreting of pier, de-shuttering of the pier ok; again rebar for pier cap, shuttering for pier cap, concreting for pier cap and de-shuttering for the pier cap ok. Now, I have two combinations here; one is mode 1 other one is mode 2 and for the different resource combinations I am getting a different duration.

So, this data you can get from past projects from the experts, when you go to the expert they will actually have an option second alternate option of evaluating the same activity when the first option does not work out. So, this is primarily the preferred option and this is an alternate option data which we have on the site ok.

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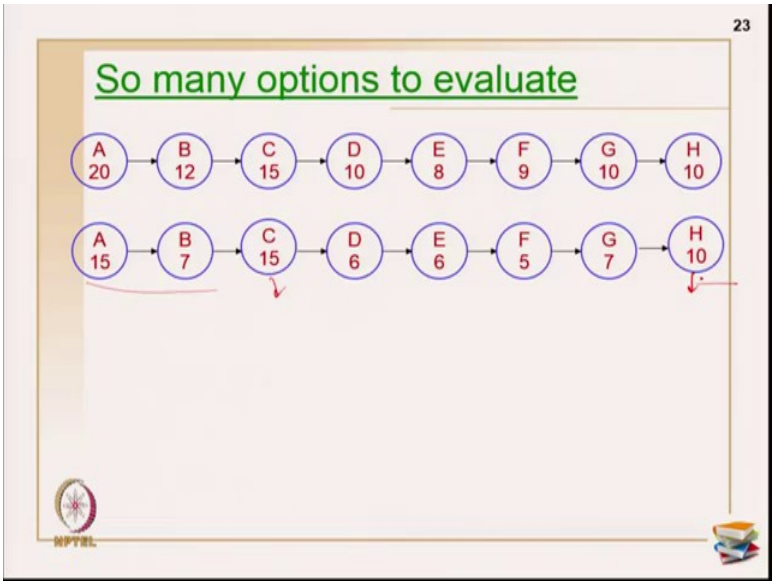

Now, what you have to do, you may have to evaluate all the options to in order to evaluate what is the best cut scenario. One option is to consider all the activities in the first mode, other option is consider all the activities in the second mode and maybe this activity C and H there was no other option, second option was there so, I have taken that. So, accordingly choose combinations on activity A first mode, activity B second mode so, activity C primarily only one mode is there, now D you choose one time first mode, one time second mode.

So, you will have n number of combinations available and you may have to explore all of them if you are not going with the simple heuristic methods there ok.

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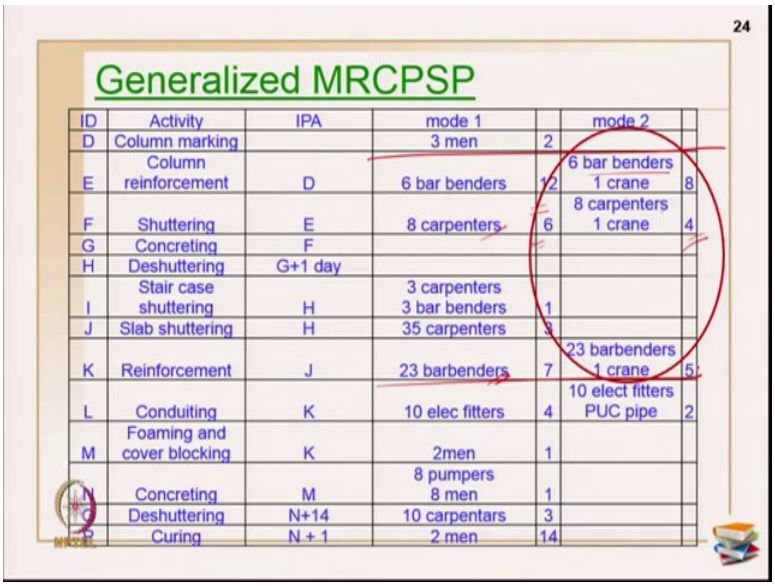

Now, what happens in certain cases? In some cases what happens is even the resource types also vary what we call it as a generalized multi-mode resource combinations ok. If you see this example that this is this is also a simple activity example in the housing project ok.

So, I have column marking, column reinforcement, shuttering concreting, de-shuttering, staircase shuttering, slab shuttering, reinforcement, conduiting and so on. If you see here I wanted to highlight you only on the mode 2 only for these particular combinations ok. Column reinforcement I can do with 6 bar benders, it takes 12 days. I can also have a combination of 6 bar benders and 1 crane duration of 8 ok. Shuttering; 8 carpenters it takes 6 days, I can still do the same with 8 carpenters and 1 crane with a duration of 4 days. Reinforcement; 23 bar benders or 7 day combinations or 23 bar benders does an 1 crane on 5 day combinations ok.

So, now, what happens here, in the first case any activity can take any resource. Problem was too simple. So, resource scheduling, scarce resource itself is a real complex problem ok, little simplistic case is any activity I can dump in any resource then it was still an easier case. For example, in these activities, all the activities whatever are there they are having a different type of skilled worker and so on, here you cannot really shuffle the resources ok. So, then the problem was little complex.

The next case came in wherein I had multiple options to execute and I had a constraint in my resources and I have multiple options to execute still you can look at options in order to see what is the minimum duration and with my constraints on my resources what is my best fit operation available option for me you can go ahead with ok.

Next option is even in the same modes I may have different types of resource combinations also for my modes. For example, I can do painting by using a brush manually or I can use and spraying for mechanism for spraying and painting in the whole case ok.

Now, I have two options. So, based on the type of resource what happens if I have many constraints on my painting resource on my painter I can still go with them you know; I can still avoid my manual method of painting and I can go with the other resource. So, what happens resource constraints is really solved, but another case can crop up which implies the cost part.

So, what is the cost if I use another crane in the whole setup only for doing few activities? Duration can go less, I am having actually no constraints on my resource, I am able to finish fast, but my cost can go up ok. So, primarily you are scheduling in this case you have to look at the combination of time, resource and cast together then only you will have a very success in projects ok.

So, with this I am stopping for today's class. So, today's class on resource schedules. I showed you a few trial and error methods only because the scientific methods are little complex in nature. So, I have not covered and interested people can go through research papers when you are interested ok.

Bye.