Project Planning & Control

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Lecture - 49

Project Monitoring and Control (Earned Value Concepts), Uncertainty in Project Schedule (PERT) Course Summary

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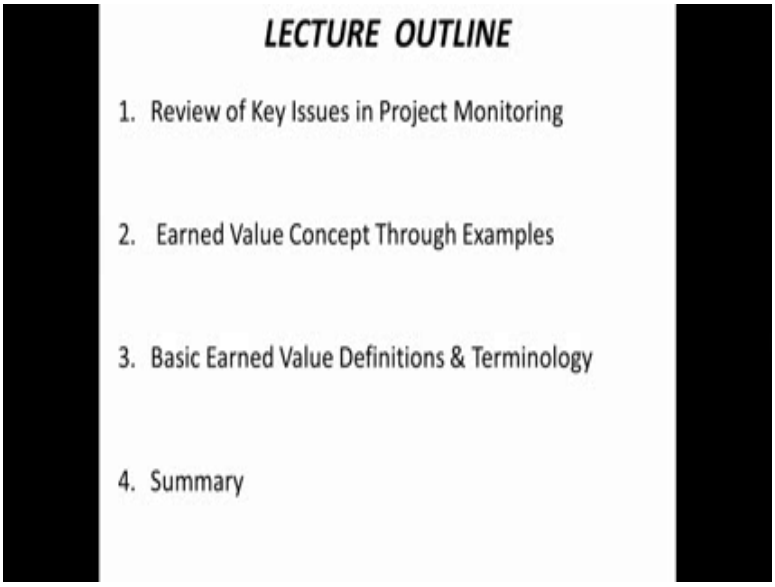

Hello everyone, welcome to this second lecture on project monitoring and control. And in this lecture, we will cover the concepts of earned value. This is a very important concept, and it is being widely used by the professionals today. And let us get to understand a little bit of the basics of what earned value means. So, in this lecture, the outline is as follows. We will first just review the key issue of project monitoring; then we will get into the earned value concept through an example. So, I will try to introduce the concept through an example, because the concept as such as reasonably intuitive; there are a lot of definitions and terminology associated with the concept which we will then cover. And see, if from the example which we covered, we will be able to derive the definitions and the terminology; and then I will finally summarize what we have covered.

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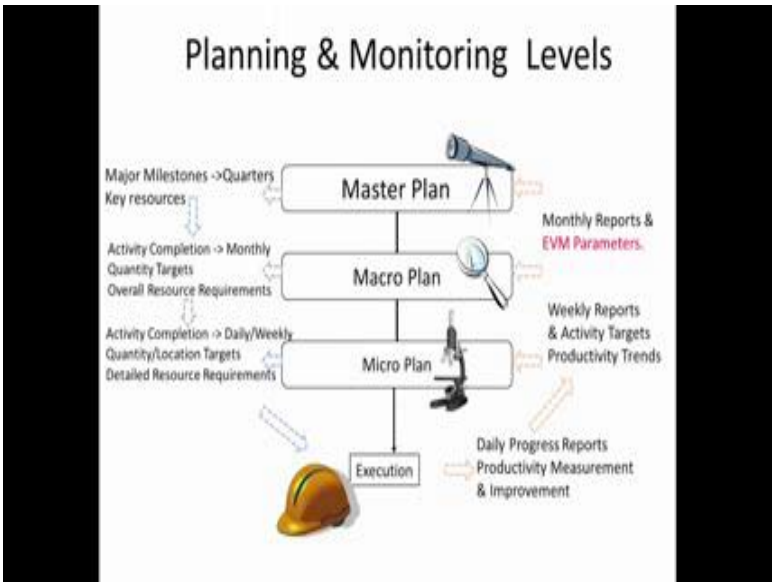

Now, when we go back to the previous lecture, this was the slide; kind of very comprehensive slide which showed both the planning and monitoring levels. And we looked at several of the planning issues that came through the master plan, macro plan and micro plan. We talked about, how executions relies on these plans. And then the feedback comes from execution through the daily progress reports, productivity measurement and I mention that in in this class, we are not looking at this level of detail; but there are other courses which we cover this level of detail, but here we then we are mostly looking at the macro plan level. So, based on the DPR, we get data which gives us weekly reports and basically the weekly monitoring of the project before we covered to some extent in the last session.

Then, as we go beyond the weekly, we go from the macro plan; we have to generate reports for management and typically this can be in earned value format. So, it need not be in earned value format, there are several companies which have..are not necessarily using earned value management techniques today, but when we go through some other basic of this, you will see that there are several advantages of using earned value techniques over you regular monitoring based on cash flow or things like that. So, the tool recovering today in terms of EVM belongs to the planning engineer when he is actually making project-level reports. And when he or she is looking at the overall project, the work packages, how are we going to understand the performance and based on this performance apply control parameters.

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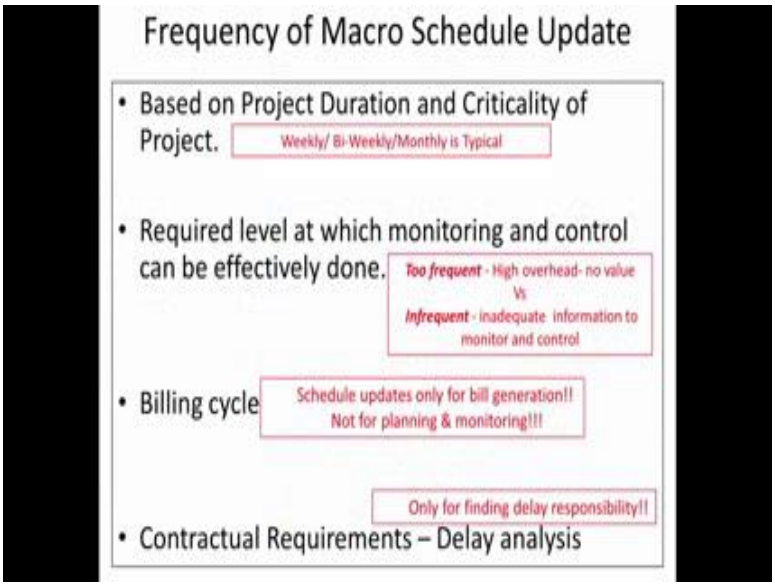

So, when we look at this with respect..with reference to the frequency update, we had talked about weekly, biweekly or monthly being typical; the weekly or biweekly is typical for the lower levels of the plans; that is the micro and between the micro and macro. Earned value is usually on a monthly basis because it is rather tedious to do it on a more frequent basis. And this is, we discussed about being too frequent and we do not necessarily get better control because we monitor it a very frequently because of the overhead that is required. And all of these certainly depend on the needs of the project. And like we discussed in the last class, if there is a critical shutdown project, I might have to actually monitor the progress hourly and but then the criticality of projects mandates that kind of requirement.

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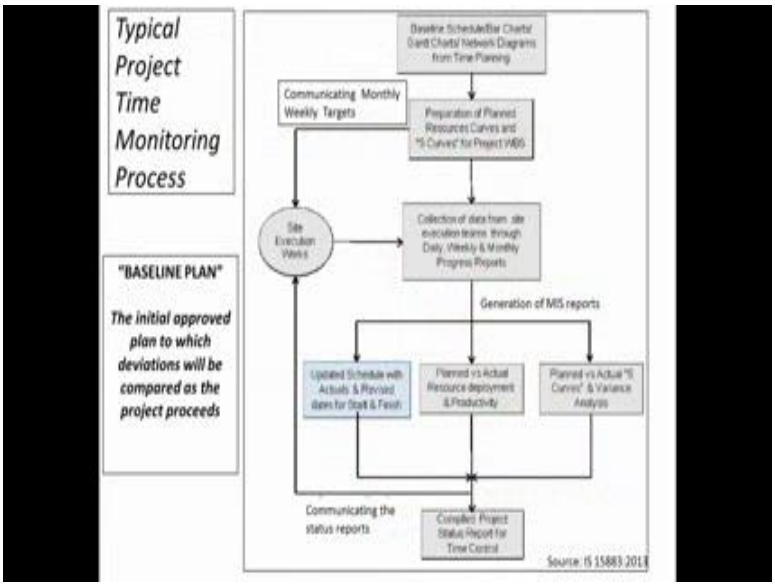

We also looked at the BIS standard and it kind of had to show us on how we do project monitoring, and where we looked at how the various elements of the standard look at planning, execution and the reporting. As far earned value is concerned, we are looking primarily again of generation of reports, and you here you can see planned versus actual, S-curve ,variance analysis. So, this is a form of a report which we will be reviewing and looking at how the earned value concepts contribute to this.

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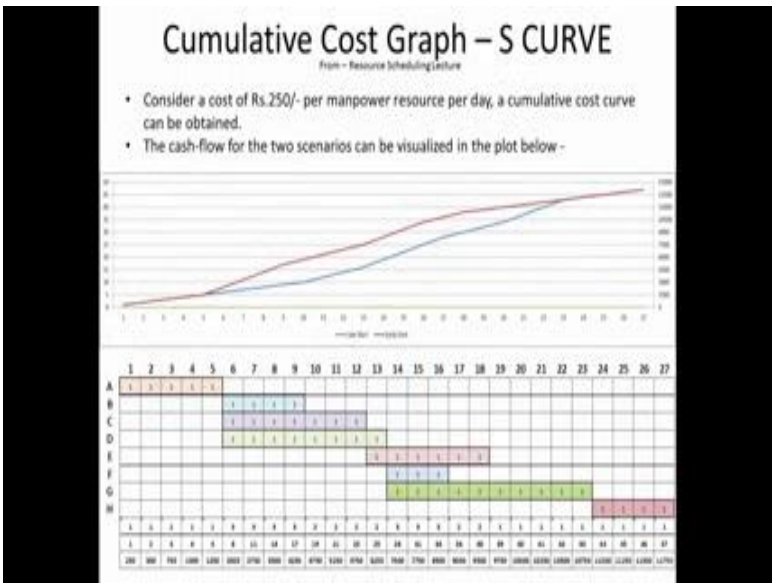

Now, when we to start with the earned the basic introduction to it, I think you are all familiar with this. So, this is something we plotted when we did the resource scheduled lecture. And if you recall we called as the S curve, and we had, I mean, in when we do

this for this particular lecture, we just plotted the manpower, the number of people and the cash flow; the cash flow for the cost for the people. So, this was the S curve and we did it by actually scheduling the tasks in this bar chart like this loading it with resources. We had the total resource numbers; we converted the resource numbers to cost. And based on the cost, we then we have here, for example, cost on this axis, the resources on this axis, and we get a curve which is the cumulative cost curve. And this we remember, we called it the S curve and these forms are very this kind of curve the S-curve forms a very important basis for planning we are aware of that.

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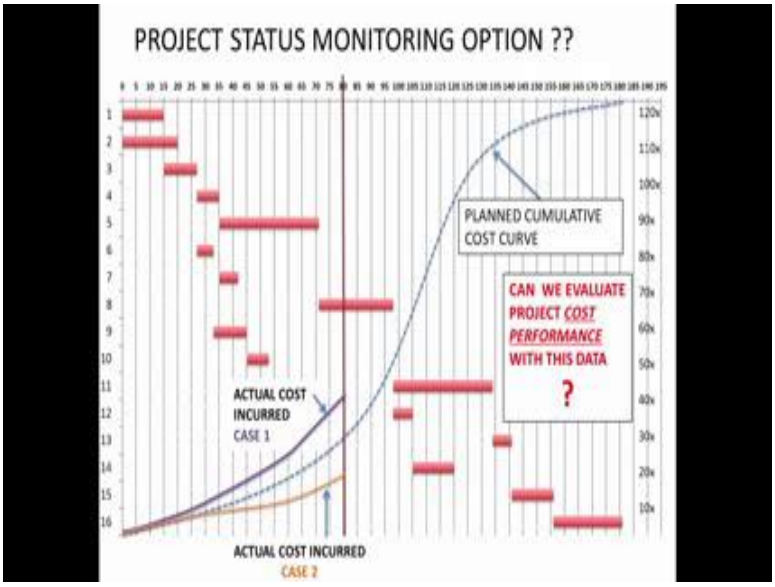

Now if I take this S curve and kind of show a conception S curve on a bridge problem, so this is what we get we have the activities, for the two-span bridge, and I have just shown in concept an S-curve which could be the cumulative cost of this project as it goes. Now, I want to actually find the status of this project. I want to know.. I want to be able to do periodic updates; we talked about this doing this periodic updates in the last session. And we talked about how we get the work done and we talked about how we measure percentage complete etcetera., based on different methods. And we also discussed how these percentage completes can very depend on the method used. Now that is at the micro level.

Now, we come to the next step this is at project level I would like to take an update at say day 80, and I would like to know how am I doing with respect to my plan. So, for example, one of the easy ways to do is probably do, is to be able to get the actual cost. So, I had planned to spend this much money, but I have actually spent this much money

on day 80. Can I make any kind of conclusion based on this? That something to think about. Or , if I have a second case where I say no, no I mean it was not I mean my case two, I actually spent less than what I had planned to spend on day 80. This is kind of, what you say, because we always measure the amount of money we spent on the project through accounting systems, this kind of comparison is easy to do, but does it really reflect the state of the project. , can we actually evaluate the project cost performance with this kind data is something which we need to think about it. And the answer is no, because what we are doing in terms- we could have actually spent a lot of money without doing the work; and if you spent money without doing work, this will not be indicative of what is actually happening on the field.

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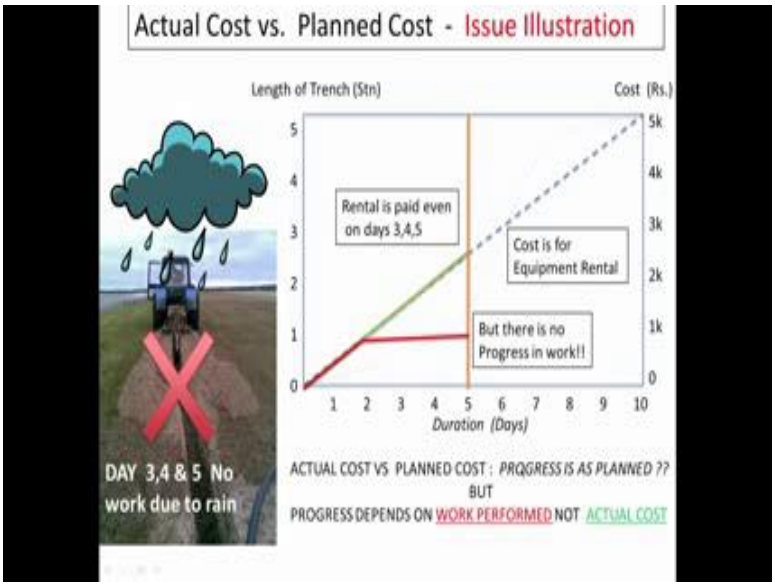

So, let me illustrate that with an example. So, let us take a very, very simple example to illustrate. So, let us say there is a trench that we need to be excavated and this is the.. shows the progress of so this is kind of an illustration of this simple very simple trench which I am using in this example. I have a duration in the x-axis here; I have the length of the trench on the y-axis. So, assuming it is a linear progression and I have cost here. Assuming, it is a linear progression and my cost is proportional to the length, I get my S-curve in this, this case takes a straight line. And this is primarily for the cost of equipment rental, because I have to rent this piece of equipment every day and I am paying for it, and I am just making that the most expensive part and the primary cost component and making that the cost of equipment and the operator that comes with it making that the planned. So, this is my S-curve.

Now let me say that I want an update on day 5, I come to the projects about half way through the project, it is a 10 days project; I come to the project, and I want to update on day 5. Now one straight forward way or one way we might thing is on day 5, I might have spent about half the money and if I spent about half the money, I would like to assume the project is 50 percent complete, but if I look into the project field book, I might find that actually there was rain and there was rain on day 3, 4, 5 and there was no work that was actually done due to rain. So, although money was spent on keeping the equipment and the operator, there was actually no progression of work on that day. So, in which case, if my progress is actually this, I could work till day 2; and these three days, I did not make any progress on the project; although I continued to pay for the rental cost of the equipment. So, I actually spent money on the project, but not got any work done. So, my actual amount spent is ,as per the planned value, but the work is actually not been completed.

So, we will see that even though the rental is paid on these days, there is no progression of work. So, obviously, it is from a common sense point of view we can make out that project is not going as we had planned it, but if I choose to see only the actual cost money spent, the project will indicate it is going to planned which is incorrect. So, we can see here actual cost versus planned cost, we will see the progress is as planned, but we know this is not correct. So, progress actually depends on work performed, not actual cost and we have to somehow bring the work performed into our metric for monitoring. We should not base it just on money spent. So, this is critical I know it is basically a lot of common sense in what we are discussing here, but you will find that in several projects, especially for small projects it is just easier to measure the money that is spent, and people tend to use money spend as a metric for progress, which as you can see here is not indicative a progress.

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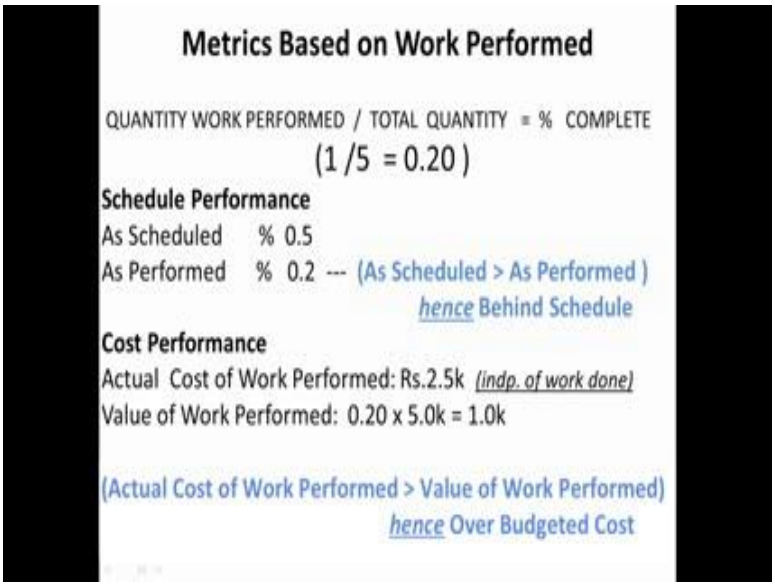

So, let us take this example, little further. Now I want to find percentage complete for this which is fairly easy because it is a single activity. So, I have finished one out of five, so it is 20 percent complete. And if I am going to look at the performance for my schedule which is something which we need, I will see that on my fifth day I should I have been at 50 percentage, but I am only at 20 percent as per my measurement. So, I am certainly behind schedule. Now as per my cost performance, now you can see that we can we know that we have actually spent to 2.5 k; that was because we spent it on the rental the equipment all though work was not done we spent it on the equipment, it was there we had to pay the rental. So, the actual cost work performed is this much, but now what is the value of the work performance. So, we only did one, one out of what was done which was 20 percent we have actually done only 20 percent of the work and for the value of the work performed is a twenty percent into the total value of the project which is 1 k. So, this is a very important metric we have brought in the value of the work performed in order to be able to under to monitor a project.

So, we are able to now make a comparison of the cost performance, and say the actual cost of work performed is greater than the value of the work performed that means, there are actually spent more money than I have got value for the work that is performed. So, the over-budget cost. So, this is a very simple way of introducing the fact that we had to measure the value of work performed. Now here we have given, so from this we understand that we are able to measure schedule performance, we are able to measure cost performance through this basic metric.

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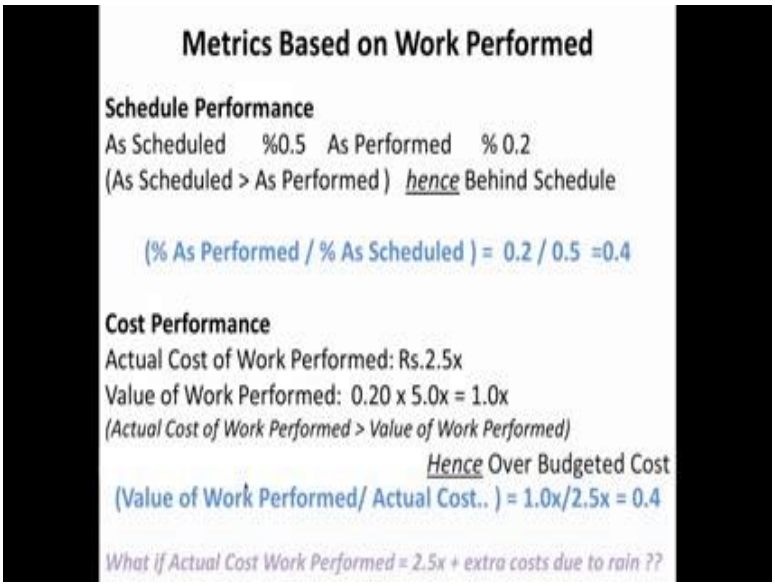

If we are able to take this into a little more formalized form, I can say we have when you look at schedule performance, I can say we have as scheduled, it was supposed to be at 50 percent, but as performed is the 20, so because as schedule is greater than as performed - behind schedule. I could come up with a metric that is a percentage as performed divided percentage as scheduled, which will give me a numerical value of my scheduled performance. So, we will come to more details on this later, but I think you can intuitively see how this number can control or indicate the level of scheduled performance. And similarly for cost performance, we have the actual cost of work, we have the value of work, and we can now have a ratio of the value of work performed divided by the actual cost performed. And this ratio will give us an indicator of cost performance of the project. Now, in this particular case they happen to be equal, but that need not be so as we will see later. So, in taking this extending this case, let us say because everything was linear they happen to be equal, but say there were extra cost during the rainy period and my actual cost was more than just the rental; in which case you will see that this value will change; it will need not be equal to this.

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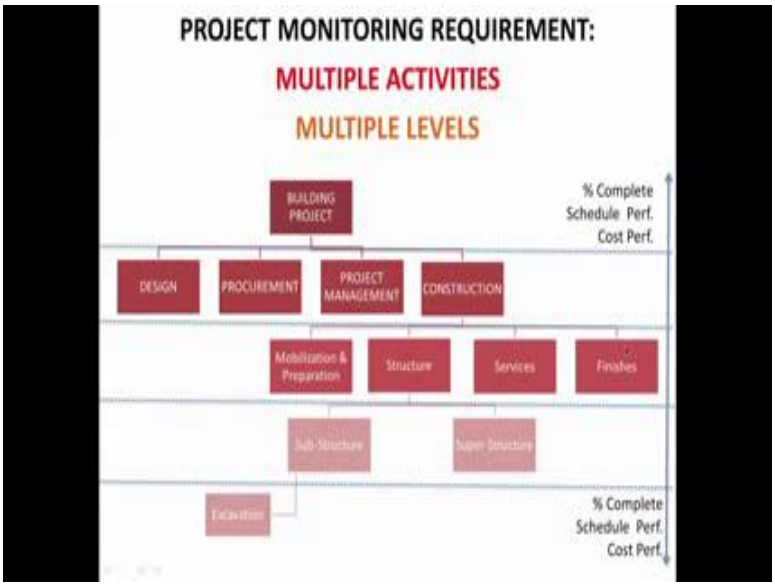

Now, with this simple example, the key concept there which was..which we have introduced is the fact that you need to look at the earned value; the value of work performed how much value did you earn from this. So, that that concept is now.. we applied it was single activity, but we have to actually extend it. So, here we applied it to a single activity, we found percentage complete, we could get a feel of what schedule performance was or cost performance was. But, when we get into larger project we cannot keep applying at the activity level alone, we have to not only applied at the activity level, but at each level of the work breakdown structure. So, here I have the activity level, here I have the project level, I would really like to estimate percentage complete of the project - the entire project, at my monitoring phase I would like to know scheduled performance of the project, I would like to know the cost performance of the project. So, this would be at the highest level of the project.

But similarly at each package, so here you have my WBS at each level of the WBS, I would like to estimate these parameters and that is really the monitoring cycle. So, I will be able to estimate, for example, here if the excavation of the substructure level, I will be able to calculate all of these parameters and the superstructure, for the superstructure , before the different elements, you can see here- Mobilization structures, services as a project is progressing at each phase, I will be able to calculate these parameters, and then make a judgment on my schedule and cost performance of the project.

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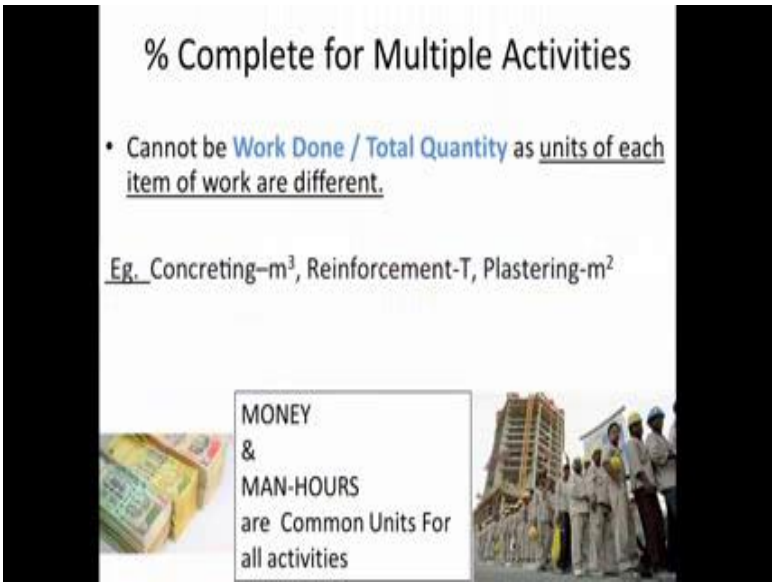

Right now, we saw the percentage complete for a single activity and we could see that we can measure it based on quantity. Now if we take multiple activities, so as we when obviously, we took a single activity here, if I want measure percentage complete at any level higher than a single activity when there are multiple activities, I cannot use the work done by total quantity, the quantity installed by total quantity as a unit, because the.. as my indicative of a percentage complete because units are all different. For example, if I have concreting in meter cube, reinforcement in tonnes, plastering in meter squared, and I cannot add these values and divide by total quantity because certainly, the units are different. So, what we do is, the only the common unit for all of this, all the types of activities that come into a project is basically the money or man-hours. And these are typically the common unit; that is the.. how many work hours are my people spending on the project, this is man-hours, not absolute hours, this is man hours or the money spend.

Now, so I can use either metric as my indicator for my value of work earned or the earned value. And in this, for the remaining of this lecture, we will use money as an indicator, we will continue of an example of money as an indicator or discussion of money as indicators although man hours is also used. And towards the end of the lecture, I will kind of give you an insight as to why should be making this choice, and what are the implications of this choice.

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Now, let us take up a little more detailed example to illustrate more aspects of the earned value analysis. So, here I have a project; there are 6 packages I would say involved. So, in this project might be, there the packages would be, at say level here; there are six packages involved. I have given you the estimate of the quantity of each package say earthwork for example- 5000 cubic meters, concreting, formwork, for reinforcement brickwork. I have also given the unit rate the cost per unit for the different items of work or the different packages. And based on this, we have actually looked the cost we got a value of work and the total value of this project. So, I have also given you the project duration is 10 months and we would like to monitor the status of the project every month. So, this is a given; now based on this let the project start.

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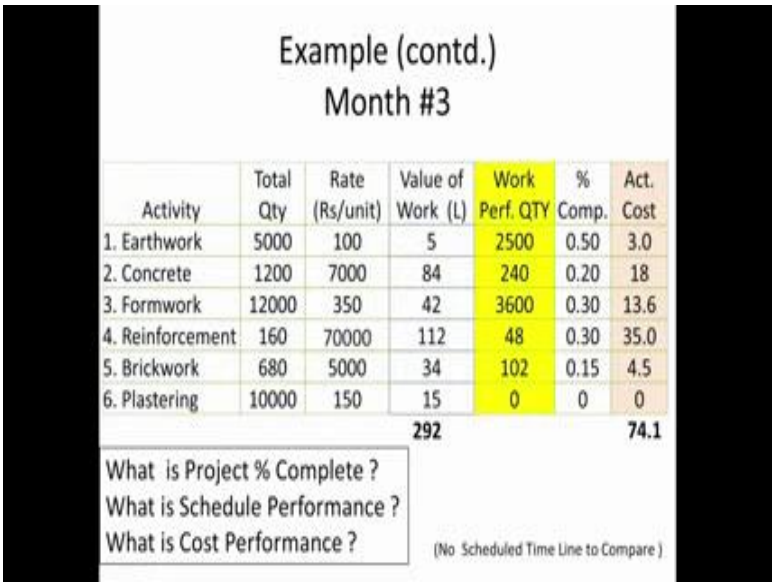

And I would like to see on month 3, I have jump month 1 and 2 for a specific purpose; for month 3, I would want to do an update. So, actually go, so all of this is the same input ;what I now calculate I actually go and measure the work performed at the project. I look at the quantity. So, I then update my quantities is here; remember this is done from the micro level, might be a DPR all of these I would get the work performed, from DPR data I would get all of this. And then I can calculate my percentage complete for each of this. Now when I am calculating my percentage complete for each item of work, the unit is the same. So, it is my work done by total quantity; unit is the same I can calculate percentage complete without a problem. I, also in addition to measuring the work performed, I go to my accounts group and get the actual cost of work, and here is the actual money spent, the cost of what I paid for the work.

So, here I have the total value of work; here I have the amount of work that was done during.. in this period, and I have entered the quantity is here; using this and this I calculate the percentage complete for each item, and independent of this, I have money spent money on it, and this is the money. So, if I am given this kind of an update, will I be able to answer these questions. What is the project percentage complete? What is the scheduled performance? What is the cost performance? Now, you can see the first question project percentage I can actually calculate all the individual items percentage complete here; but how would I calculate project percentage what is the status of the project today? That is not so based on the information I have here, I am not able to immediately see how do I calculate project percentage completely. What about my

schedule performance? I mean I know that I am the third month; I know I have done this much of work, but I have no way of benchmarking it. I do not have scheduled time line to compare to find what is my scheduled performance. And if I try to think my cost performance is my actual cost compared with my total cost, from the earlier example that does not necessarily give us an accurate value of cost performance. So, we have to think through and see, what do I need to do. So, the first thing is actually to develop a scheduled time line.

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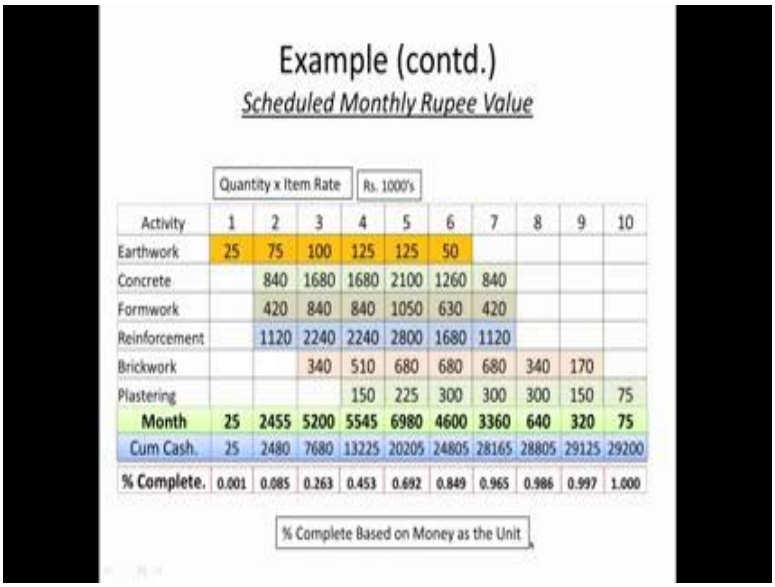

Activity	1	2	3	4	5	6	7	8	9	10
Earthwork	25	75	100	125	125	50				
Concrete		840	1680	1680	2100	1260	840			
Formwork		420	840	840	1050	630	420			
Reinforcement		1120	2240	2240	2800	1680	1120			
Brickwork			340	510	680	680	680	340	170	
Plastering				150	225	300	300	300	150	75
Month	**25**	**2455**	**5200**	**5545**	**6980**	**4600**	**3360**	**640**	**320**	**75**
Cum Cash.	25	2480	7680	13225	20205	24805	28165	28805	29125	29200
% Complete.	0.001	0.085	0.263	0.453	0.692	0.849	0.965	0.986	0.997	1.000

So, here based on all the concepts you have covered so far, the planning team needs to go in and, do this put each activity on a bar chart or on a timeline like this. You can use a network analysis to give you the timeline, ased on your resources availability, all the concept you have covered. So you have actually finally, the output we have we have realized in this form. So, I have here, this is the quantity. So I am scheduling the quantities of earthwork as such, concrete as such, formwork, these are the quantities; and based on these quantities, I then schedule the expenditure, the scheduled expenditure for each quantity. So, all that I have done is multiplied the quantity into the item rate, which we had earlier, and based on that the money to be spent. So, this you are familiar with from our resource loading sessions. So, all this reflects is the money to be spent for each item of work, and the month in which the planned money is to be spent.

Now once we get this, I think you are all familiar with the fact that we can calculate now. Now, I can add up; I can add up monthly because my units are money because my units are money, my units are the same, I am adding it up and this is now my planned monthly

expenditure. I convert that to my cumulative monthly expenditure or my cumulative cash flow, and I have actually now, from based on our earlier discussion, we basically have a plan in place. I can convert this cumulative cash flow into a percentage complete of cash flow. So, this is my final final total. So, basically this is twenty-five by this value and so on; I get my percentage complete in a cumulative form. And this basically forms the, so here we have to say that this percentage complete is based on money as a unit; remember I could also use man hours, but I am choosing here to use the money.

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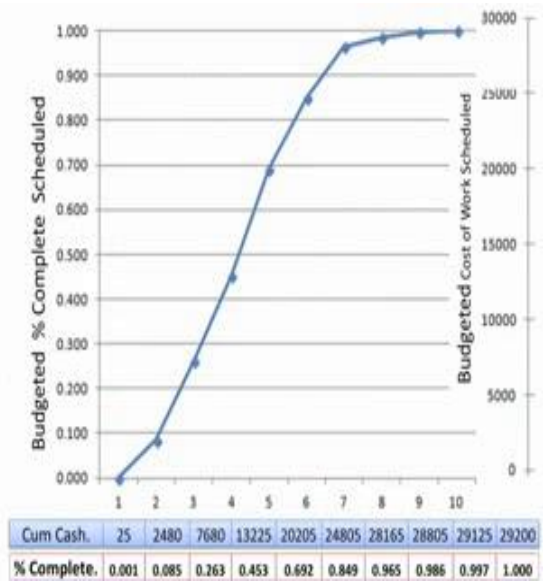

And we then get this S-curve. So, basically, what the S-curve is- on this side on the y-axis I have that cost of work schedule. So, this is the cost of work schedule and on this side of the y-axis, I have the percentage complete, they are proportional because what we are..we are measuring percentage complete here the planned percentage – the budgeted percentage complete here in.. as a proportional of the cost which I have scheduled for, the cost of work scheduled. So, this forms a basic S curve, and this now gives me a benchmark to be able to compare my progress work. So, I come back; now here is the table which I had earlier, but now I have a scheduled time line to compare. So, when I am doing monitoring, this forms the benchmark or the baseline for me to do my monitoring.

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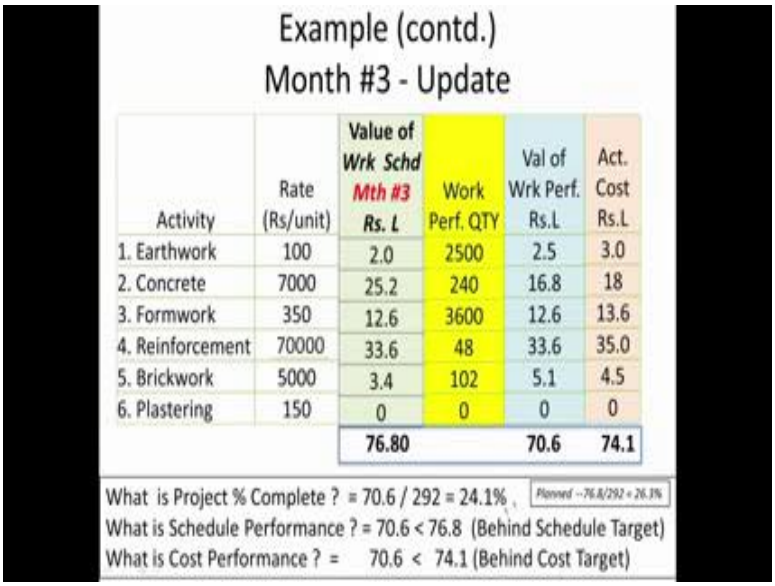

So, how do I use this baseline? So we had the earthwork, we have the rates given here. Now on month 3 update, what I do is I am now show showing the planned or the budgeted value of work schedule for month 3, this is coming from my S-curve. This specifically is the value of work I have budgeted at month 3. So, this is the point which I am interested in. So, you can see this is continuous over all the months as it is planned, but in my third update, I am looking at this particular value. And, this is the value of work scheduled for month 3, now I have done my measurements as earlier; I have got my quantity of work which is a same as earlier. And I am now calculating here: what I am calculating here is the rupee value of the work performed; for this quantity of work what and based on my estimated unit rate what is a value of work I have done in terms of money. So, this is, remember our trenching example, this is actually the value of work. We are looking at what is the value of work that done. So, this is basically the rate of the quantity of work performed is giving us the value of work.

Now, in addition, I also have my actual cost of work performed which is independent of value. Again, go back to the trenching example, you remember we spent money even though it was raining, there was no further work done, but there was money spent. So, these two can be independent, they are ..need not be related to the, ideally, it should be related, but because of the uncertainties and issues that occur on a project, they are independent. So, here we kind of reviewing. I have looked at my work scheduled, the monthly the plan and taken what I had expected on month 3; my earthwork would be so much would have been spent on earth work, so much on concreting, so much on

formwork, this is from the budgeted cost of work scheduled on month three. And this is what I had actually performed.

Now, one thing we can do now is we can see that we are able to add up these values. So, this is my total value of work as it is scheduled for month three. This is the value if I add up these values, earlier I could not add up the percentage complete, because they had all different unit is; here it is all money unit is here it is all money unit is I can add it up, and I get the value work performed 70.6, and the actual cost of work performed is 74.4 and what I had scheduled is 76.8. So, now, I will be able to answer some of the questions I had posted earlier. For example, in answer to the question what is the project percentage complete, the value of work performed is 70.6, and remember 292 was the total budgeted value of the project; the total budgeted when we go to month ten. So, the current project percentage complete is the ratio of this which is 24.1.

And I could also find what is the schedule performance, so here in my schedule performance I am looking at the value of work performed is 70.6. But, actually on month 3 based on the plan, I should have been at 76.8. So, 70.6 being less than 76.8, I am behind scheduled target. Similarly, if I want to look at what is the cost performance, I have to compare these two values - the value of work actually performed on the field is only 70.6, but I have paid out of, I have actually paid 74.1. So, I have got less value which means my low budget cost target; that means, have 74.1 for work that was only worth 70.6 based on my original rate. So, I am again behind my cost target. So, this is the basis of your monitoring based on earned value management from a very basic and intuitive sense.

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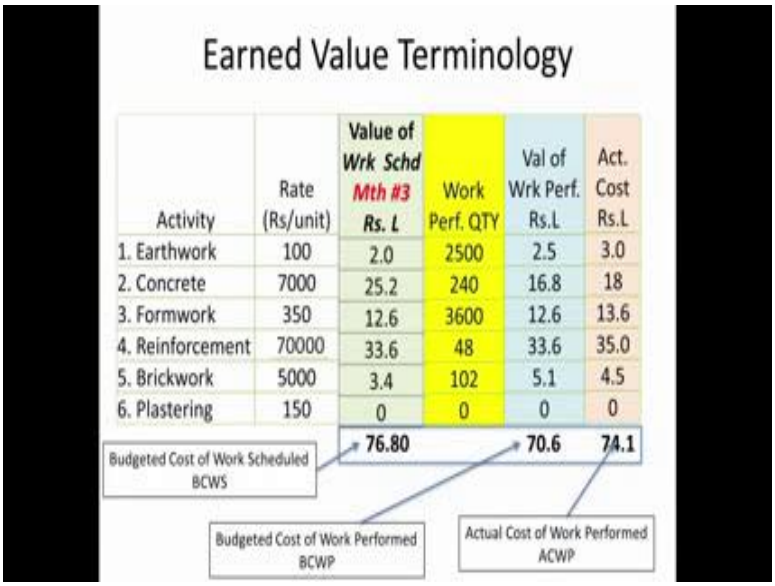

Now, we now move into formalizing this in a way when we use the earned value terminology. So, what the column here, what we calculated in terms of the planned value, our original S-curve- that is called budgeted cost of work scheduled or BCWS. And, what we calculated in terms of the value, the value of the work performed based on calculating the quantity of work and multiplying it by the unit rate, and summing it up- that is called the budgeted cost of work performed or BCWP. And this is the earned value of the project at that update period; this is the earned value; the earned value of the activities and summing up to get the earned value of the project and this, as we have discussed is the actual cost of work performed. This is the actual amount of money you paid for it. So, this is our original estimate of what we had planned for month three; this is what we actually spent and this is the value earned based on the work actually done. So these three from the basis of your earned value, terminology and concept, and these values are then used for further calculations.

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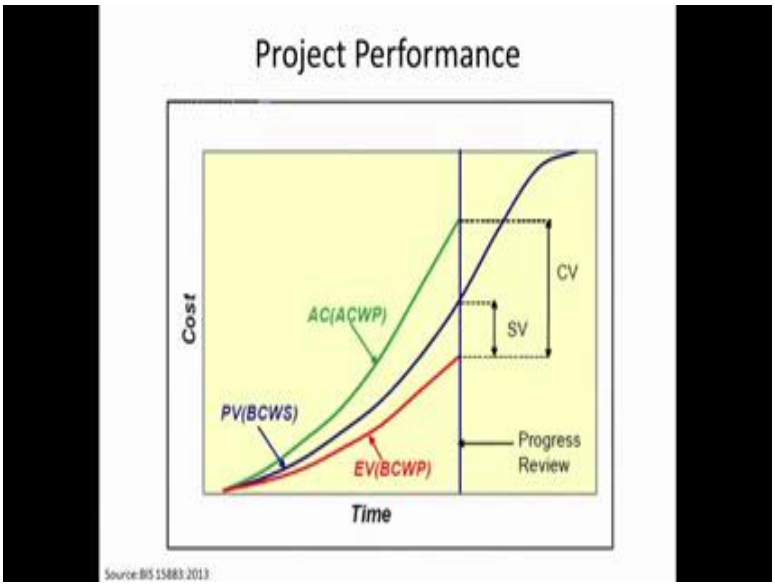

So, a typical way of looking a project performance here is a graph. So, we have the budgeted cost of work scheduled, this is the blue line- budgeted cost of work scheduled. Like we said, this is our S-curve as per plan and then we have, the other curve, which is the green one is the actual cost of work performed. So, this is the cash you are measuring through your account is a money or actually spending. And then, the earned value is the budgeted cost of work performed which is the red line here, and this is like we see, obtained based on the actual quantity- measured quantity of work done and the original rate estimate. So, this is one way of estimating BCWP, this is one way of estimating it. You might want to analysis how is percentage complete related to this, there is a strong relationship you can see between percentage complete of the activities and BCWP.

I leave that you all to kind of, find that relationship, it is intuitive and it is not very complicated. But, now coming back to this, what we had now.. what we call the scheduled variance which is so at a particular review period at a particular review period here we did it exactly this, we calculated the cost of work scheduled. We calculate, that we had got from the plan for the particular month, we looked at the budget cost of work, we calculated the earned value of budgeted cost of work performed and then we looked at the actual cost of work performed. And the difference between this is the scheduled variance, and the difference between these two values is the cost variance as we had discussed in the example.