Work System Design
Dr. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology – Roorkee

Lecture - 09
Numerical Problems on Productivity

Namaskar friends welcome to session 9 in our course on work system design. We are currently in the second week of our discussion and the topic of the discussion is productivity. In the week #1 and week #2 we are discussing various aspects of productivity, how productivity is different from the commonly used terms such as efficiency and performance.

We have tried to understand what are the factors that influence the productivity of an organization, also we have seen the causes for low productivity. In the last session if you remember we have seen the target areas or how to improve the productivity of an organization and we have seen the various facets, various factors that must be taken into account if we want to improve the productivity of an organization.

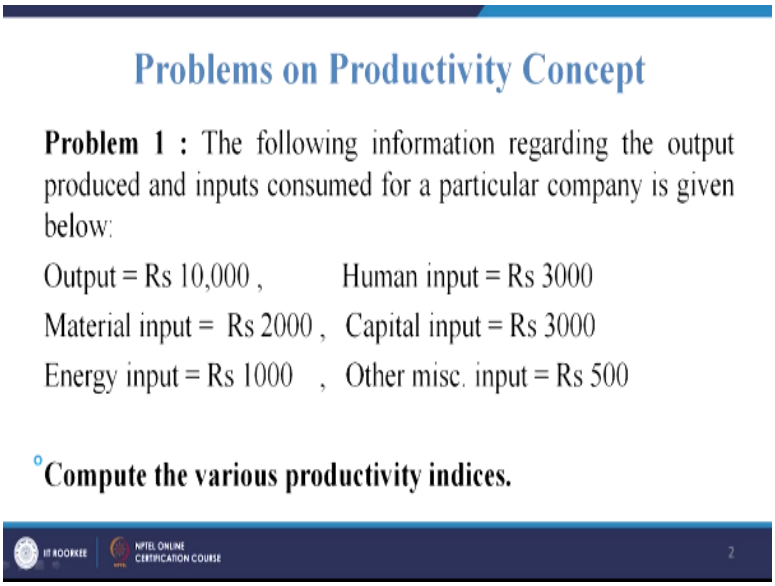
Some of the examples are that we must focus on technology, we must focus on the employees, we must focus on the management procedures, we must focus on materials. So we have seen that what are the various important salient points which must be taken into account if we want to improve the productivity. Now it is easier said than done when we have to increase the productivity, first we have to calculate what is our current productivity.

When by changing certain inputs or by improving our output we have to again recalculate the productivity and then compare the two that we were producing this much output with maybe x amount of input, now we have changed our input to y, how it is affecting my productivity. So first we have to calculate the current productivity and then we have to calculate the modified productivity by changing the input and then compare the two.

So in today's class our focus will be to see that how mathematically we can calculate productivity. We will try to take different examples and understand that how mathematically we can calculate productivity and how we can do decision making based on the various changes in productivity that have taken place by changing the inputs or the outputs. So today's session will more likely be on mathematics.

The mathematics is not very complex it is just basic 10th class mathematics in which we have to do add, multiply, subtract or divide. So no difficult mathematical equations or knowledge is required in order to solve these simple problems, only thing we need to understand is that what has to be taken as an output and what has to be taken as a input.

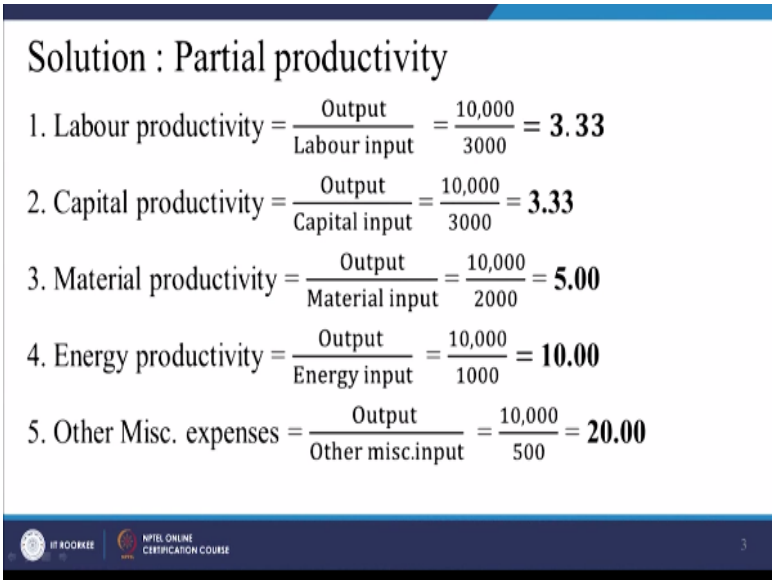
(Refer Slide Time: 03:14)



So let us see the first problem on your screen. The following information regarding the output produced and inputs consumed for a particular company is given below. So the most simple problem, output is itself specified as in terms of money that is rupees 10,000. So we know our numerator is rupees 10,000. What are the inputs are also clearly specified? human input is rupees 3,000.

Capital input is again rupees 3,000, material input is 2,000, energy input is rupees 1,000 and other miscellaneous inputs are rupees 500. So inputs are specified directly, output is also specified now we have to compute the various productivity indices.

(Refer Slide Time: 04:02)



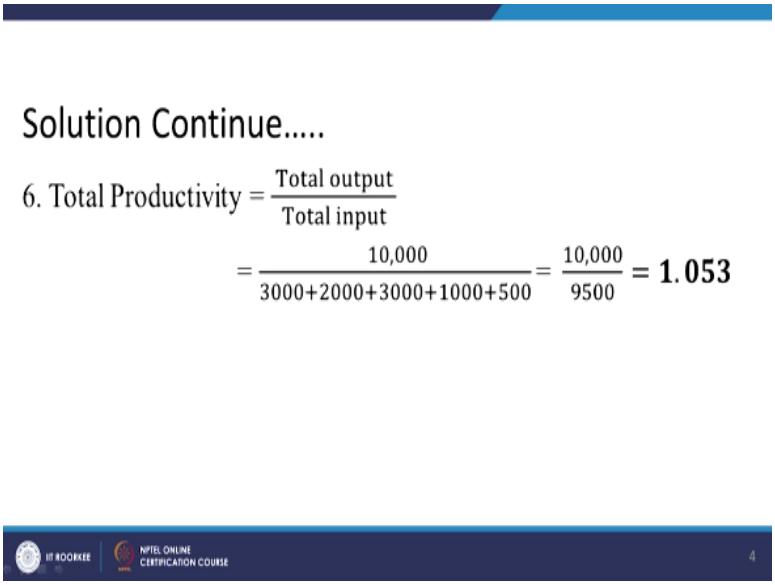
So we can see here the various productivity indices. You can have labour productivity as we have seen a different productivity measures are there. We can have partial productivity measures, we can have total productivity measures, we can have total factor productivity measures, we can have multifactor productivity measures. So today in the first problem we will try to see the partial productivity.

So partial productivity is when the output is divided by an individual input. Now individual input can be in terms of material, it can be in terms of energy, it can be in terms of human resource. So depending upon the input we will have a partial productivity measure. So labour productivity is output divided by the labour input, which is already quantified in terms of rupees, so our output is 10,000 rupees and the input is 3,000 rupees.

So the partial measure of productivity that is labour productivity is calculated as 3.33. Similarly, capital productivity rupees 10,000 divided by the capital input that is also quantified rupees 3,000, again the capital productivity is 3.33 and similarly by dividing the output we can calculate the partial productivity measures in terms of material productivity, in terms of energy productivity as well as in terms of other miscellaneous expenses.

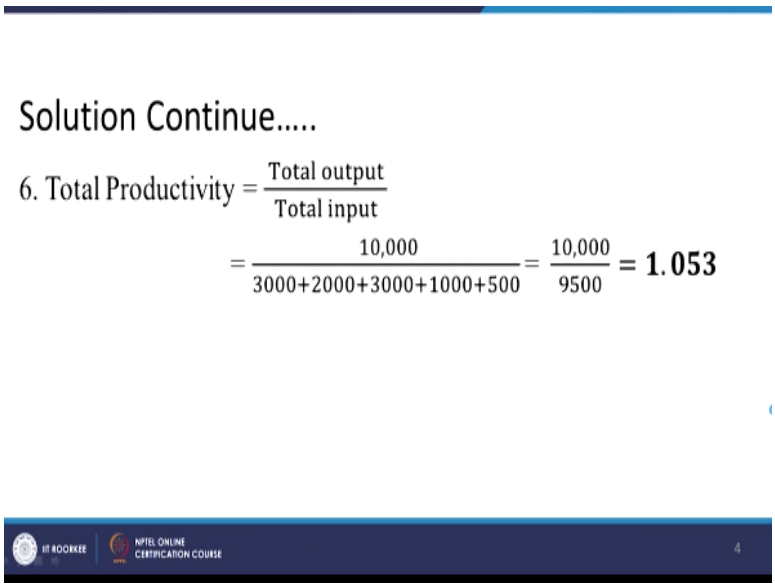
So this is a measure of individual input going as a input and the output is the total output that has been produced. So this is the first way of calculation then if we have to calculate the total productivity, so we have to take into account the total output divided by the total input.

(Refer Slide Time: 05:45)



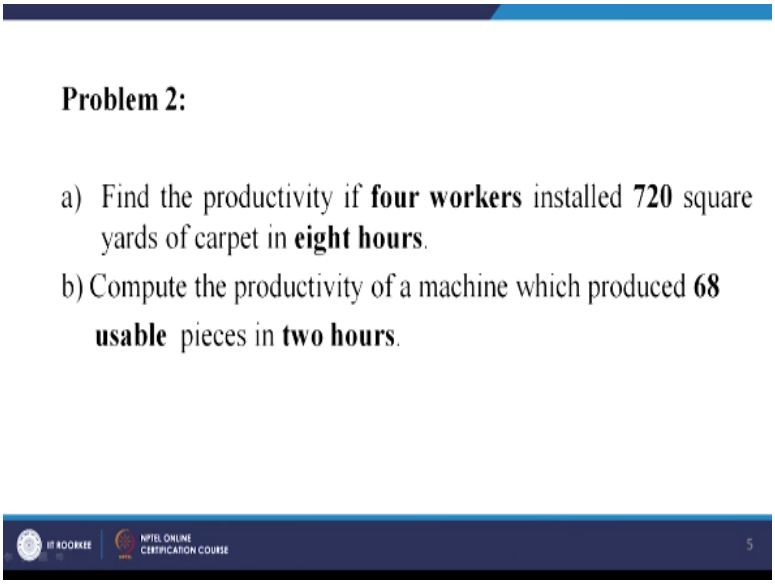
In the previous cases labour productivity, material productivity, energy productivity we were taking an individual input as the input and the total output as the output, but here we are taking total output and total input. Total input will be made up of addition of the individual inputs, so the material input plus labour input plus energy input all inputs will be added and then it will be taken as a total input then it will be taken in the denominator and in the numerator we will take the total output and this will give us the total productivity.

(Refer Slide Time: 06:29)



So we can see here 10,000 is our total output it is divided by the summation of all the inputs which is coming out to be rupees 9,500 so the total productivity comes out to be 1.053. This is our first problem just try to differentiate between the partial productivity measure and the total productivity measure. Let us try to take another problem.

(Refer Slide Time: 06:52)



Here the input and outputs are not specifically outlined. So it is not given in the problem that this is the output and this is the input as was the first case where the output and input was specifically given. Here we have a problem statement, these are 2 problem statements and we will try to see that what is the output and what is the input and then try to calculate the productivity.

I am reading the first statement for you. Find the productivity if 4 workers installed 720 square yards of carpet in 8 hours. Now you can see it will give us a partial productivity because we are having the labour input so we can have the labour productivity here because the input is in terms of 4 workers who are working for 8 hours each. Then 720 square yards of carpet they are laying or they are installing.

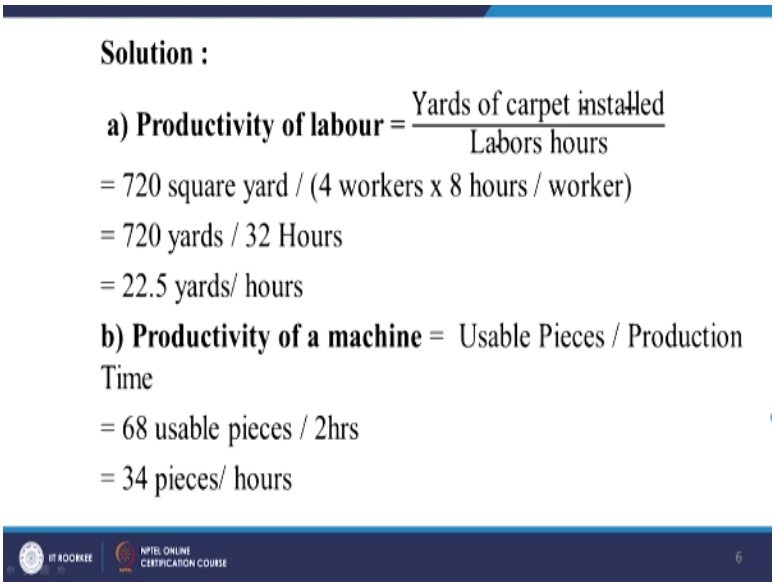
So the output we have to now see that what is the output of this activity? So the activity is being done by a specific number of workers, now they are doing activities, the output is the output of the activity and the output is the installed 720 square yards of carpet so that is our output and the input is the work done by the worker. Similarly, in the second problem statement you can see; compute the productivity of a machine which produced 68 usable pieces in 2 hours.

So here time is the input, so 2 hours have been spent to produce 68 usable pieces. So the output here is 68 pieces and the input is 2 hours so the time is the input. Number of pieces produced is the output, so let us see now how we can calculate the productivity. Now in first

case as I have told you that it is a case of partial productivity, labour hours we are taking as the input so the first thing is the output.

Now the output is the yards of carpet installed and the input is the labour hours that are going into the process of carpeting or in the process of laying the carpet.

(Refer Slide Time: 09:04)



Now 720 square yard has been installed that is the output and the input is 4 workers are working for 8 hours per worker per day. So we can see that 32 hours is the input, 720 yards is the output. So 22.5 yards per hour is the total productivity of this 4 workers working for 8 hours' duration. So we can calculate the number of yards that a person can lay per hour or what 4 persons can lay in 8 hours, each one of them working for 8 hours.

So we can say this is per hour. So if we can say that if we have 2 persons working for 16 hours again we can see that the number of yards that we are laying must remain same. So that is you can say one example of labour productivity. The second problem the output is 68 pieces are produced so that is the output and the input is that for 2 hours we are working. So the machine is working for 2 hours for usable pieces divided by the production time that is the input.

So 68 usable pieces divided by 2 hours so we can very easily say 34 pieces per hour is the productivity for this operation. So first problem was that we are given the direct output and input that output of the process is this, in terms of money and the various inputs are this. This we have tried to understand that what we have to take as the output and what we have to take

as the input. Although it is simple but we are just trying to understand sometimes it may become slightly complicated also.

So in the problems where the input and output is not clearly specified we have to see that what is the output here and what is the input. Now let us see problem number #3.

(Refer Slide Time: 11:16)

Problem 3:

A wrapping paper company produced 2,000 rolls of paper in a day. Standard price is $1/roll. Labor cost was $ 160, material cost was $ 50, and overhead cost was $ 320.

Determine the multi factor productivity.

A wrapping paper company produced 2000 rolls of paper in a day. So we have seen 2000 rolls of paper per day. Standard price is $1 per roll, labour cost was $160, material cost was $50 and overhead cost was $320, determine the multifactor productivity. Now you can see here nowhere it is mentioned what it the output what is the input, now we have to see that what has to be taken as the output.

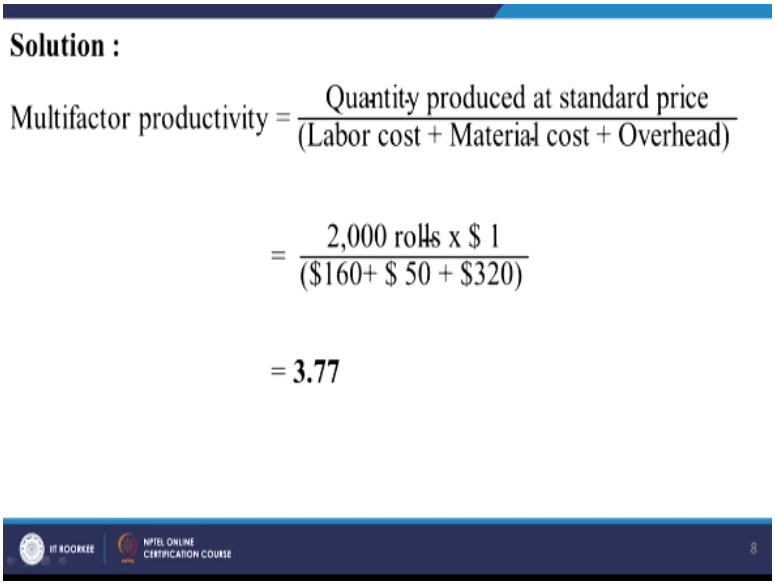
Now whatever is produced what is the output, what is the product produced has to be taken as the output. So in this case we see 2000 rolls of paper in a day is the output and what is the input. The input is $160 as labour cost, $50 as the material cost and $320 as the overhead cost. So we have the inputs, we have the outputs, but if you see the inputs are in terms of that also we have to understand.

The inputs are in terms of currency; the output is in terms of numbers. So we can say that this much number per dollar that can also give us productivity, but what we can do we can also convert it into money that what is the total output because the standard prices is also given. So the standard price is $1 per roll. So we can convert our output in terms of the money that is being generated in the output or the revenue.

And the denominator can be what is the input that is going into the system for producing that revenue, so 2000 pieces or 2000 rolls standard price per roll is $1, so we can say that 2000-dollar revenue is being generated that is the output and then we can see what is the input going into the system and then the output divided by input will give us the total productivity. So we have to calculate here the multifactor productivity.

So in multifactor productivity we can see the multifactor productivity is given by quantity produced at standard price divided by the input.

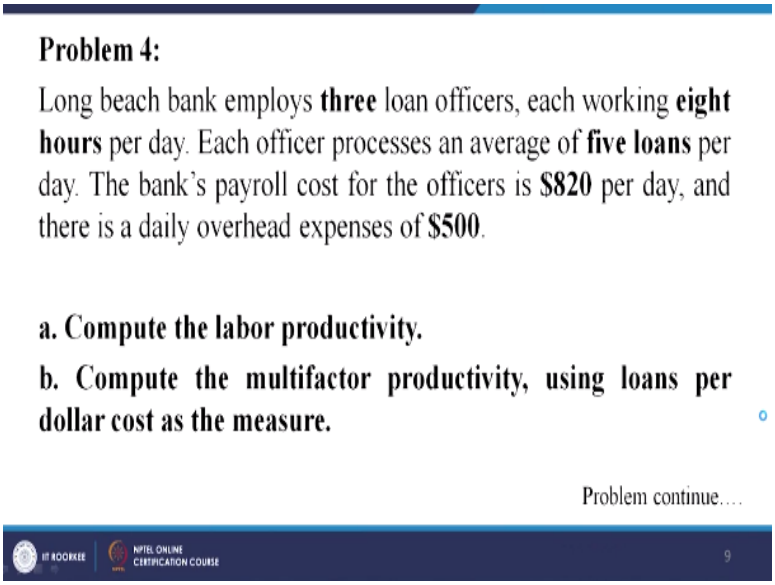
(Refer Slide Time: 13:38)



Now inputs here are labour cost plus material cost plus overhead cost. So 2000 rolls is our output, standard price is $1 divided by the total input 160$ + $50 + the overheads that is $320, so this comes out to be 3.77. So here we have seen that we can always convert our output in terms of money if the price of the component is known and the number of components that are produced as output is known.

So that is we can say another way of representing the data and calculating the productivity this is an example of multifactor productivity. Now let us take another problem which is slightly maybe more involved let us take, read the statement first.

(Refer Slide Time: 14:31)



Long beach bank employs 3 loan officers, now this is the case study or a problem of a bank, which is employing 3 loan officers each working 8 hours per day. So the number of workers is given or the loan officers is given and 8 hour shift per day is also given. Each officer processes an average of 5 loans per day. The bank's payroll cost for the officers is $820 per day and there is a daily overhead expenses of $500.

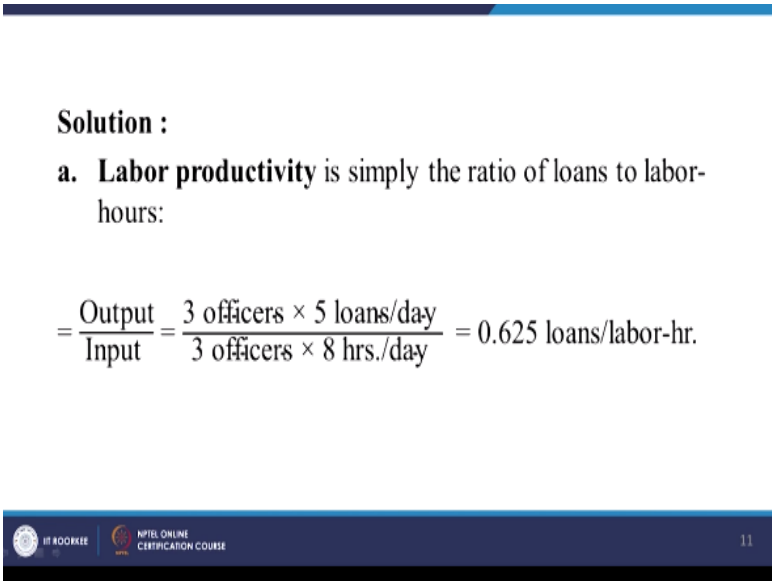
Now we have to compute the labour productivity, compute the multifactor productivity using loans per dollar cost as the measure. So the measure also is given so we can easily from the second statement we can easily see that what has to be taken as the output and what has to be taken as the input. So loans per dollar that means that in the denominator the dollars will come so we have to add whatever is given in terms of dollar.

Little bit of hint is given in the problem only and the first problem statement is compute the labour productivity. So the labour productivity how it can be calculated, what is the input of the labour. The labour gives time for processing the loans so time is the input of the labour. How many people are working? 3 loan officers are working. How much time they are spending? 8 hours per day they are spending.

How much loan application they are processing? I think 5 it is given in the statement 5 loans per day. So each officer, so which means 3 officers are there, so 5 loans per day they are processing, so 15 loan applications they are processing each day. How much time is going into the system that also you can calculate, 3 workers for 8 hours each. So we can easily calculate the labour productivity.

Now let us try to understand the calculation, but prior to that we have to first see the other part of the statement also. So let me first go regarding the calculation of our labour productivity.

(Refer Slide Time: 16:55)



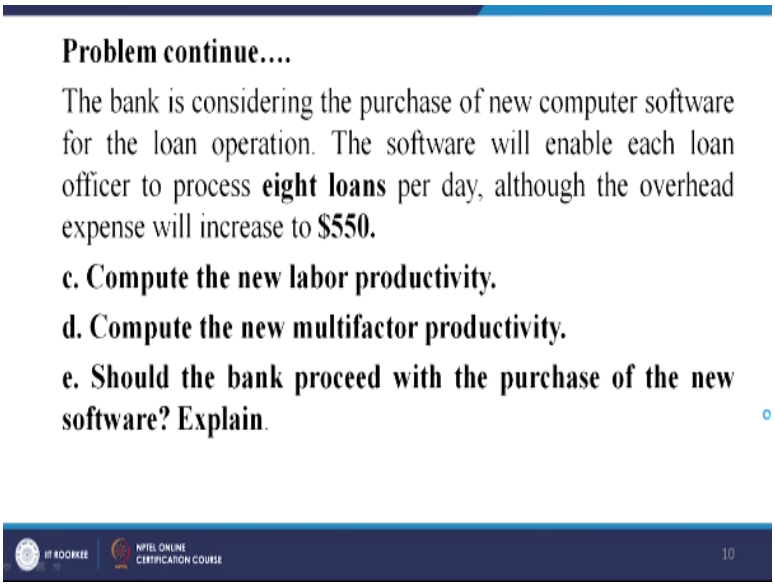
Now labour productivity is simply the ratio of the number of loans processed to the labour hours, which I have already explained. So the output is 3 officers each one processing 5 loan application divided by 3 officers putting 8 hours per day, so we can say that 0.625 loans per labour hour is the productivity for labour that is the productivity per person that whosoever is doing the job of sanctioning of loans.

So this is 0.625 loans per labour hour have to be issued must be issued that is you can say the labour productivity currently. Certainly we can try to improve this value 0.625 by certain methods that we have seen in our previous presentation that how we can improve our productivity so this is the current productivity status.

Now how the company wants to improve this productivity, we have got the current productivity, 3 loan officers, 5 loans per day, they are processing, each officer is processing 5 loans per day. So total loans processed per day are 15/3 officers for 8 hours each total input is 24 hours going into the system so 0.625 loans per hour they are processing, very simple. Now the bank is considering the purchase of a new computer software for the loan operation.

So now they want to upgrade the technology that can be helping them or that can help them to increase this productivity.

(Refer Slide Time: 18:35)



The software will enable each loan officer to process 8 loans per day. So it will definity lead to improvement in the labour productivity because now each person or each loan officer will be able to process 8 loans per day. Although the overhead expense will increase to $550, so initially we had a value which we can see what was the value for overhead expense, earlier it was $500, after the use of this new software the value of overhead will increase to $550.

Now we can calculate the new labour productivity, what will change? the numerator will change, because now each officer is processing 8 loans per day, so our numerator will become 18 and our denominator will remain same because the loan officers are 3 only and they are putting 8 hours each. So if the denominator input remains same in case of I am talking only of the labour productivity.

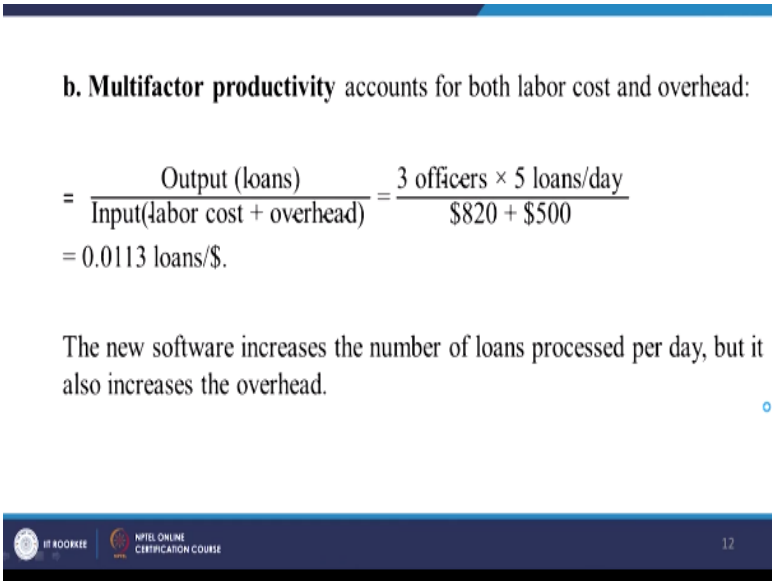
If we talk of the multifactor or total productivity the denominator is also going to change, why, because now our overhead expenses are increasing from $500 to 550, but in case of labour productivity the denominator is 3 workers working for 8 hours per day, so that remains the same. Now we can calculate the multifactor productivity also which will also change, why, because our output is changing, our input is also changing.

Input is changing, why, because the overhead expenses are changing, then we can take a decision must the bank proceed with the purchase of the new software. So we will see the

change in productivity, now inputs are changing outputs are changing, how it is going to affect the productivity. So if the productivity is improving definitely we will say why we should not use this software.

And if our productivity is coming down we will say no, no, we must now go for this software thing, our worker is doing a very good manual job so let them continue. So that decision has to be taken by the organization. Now let us see what is the influence. This we have already seen the labour productivity in the current scenario. Now the multifactor productivity in the current scenario is as we know that 3 officers are processing 5 loans per day, this is the current scenario.

(Refer Slide Time: 21:06)



Input is the labour cost plus the overhead, so the labour cost is $820 plus the overhead cost in the current scenario when we are not using the software is $500. So the productivity is 0.0113 loans per dollar spent. So that is we can see the number of loans per dollar spent and this is the unit which is already given to us in the problem statement that we have to calculate the multifactor productivity in terms of loans per dollar.

So we have calculated in the same units only. So the new software increases the number of loans processed per day which means the output is changing, but it also increases the overhead which means the input is also changing. So now in the changed scenario, the new labour productivity then becomes output is number of persons remain same, but with the use of the software now they are able to process 8 loans per day.

(Refer Slide Time: 22:12)

c. New labor productivity:

$$= \frac{\text{Output}}{\text{Input}} = \frac{3 \text{ officers} \times 8 \text{ loans/day}}{3 \text{ officers} \times 8 \text{ hrs./day}} = 1.0 \text{ loans/labor-hr.}$$

So the total output is now 24 loans per day and they are putting 24 hours into the action why because 3 workers each putting 8 hours per day so 24 hours is the input, 24 loans processed per day so we can say 1 loan per labour hour is the modified labour productivity with the use of the software. Now what is the new multifactor productivity. So output is same, 3 workers each processing 8 loan application, 8*3=24.

So 3 officers 8 loans per day, input is labour cost remains the same dollar rate 20, but the overhead cost has now changed to $550 so in terms of loans per dollar our productivity now is 0.0175.

(Refer Slide Time: 23:00)

d. New multifactor productivity:

$$= \frac{\text{Output (loans)}}{\text{Input(labor cost + overhead)}} = \frac{3 \text{ officers} \times 8 \text{ loans/day}}{\$820 + \$550}$$

$$= 0.0175 \text{ loans/\$.}$$

And we can see what was the previous productivity, multifactor 0.0113. So now we have 0.0175, so the productivity in terms of loans per dollar has also increased. So with this we can

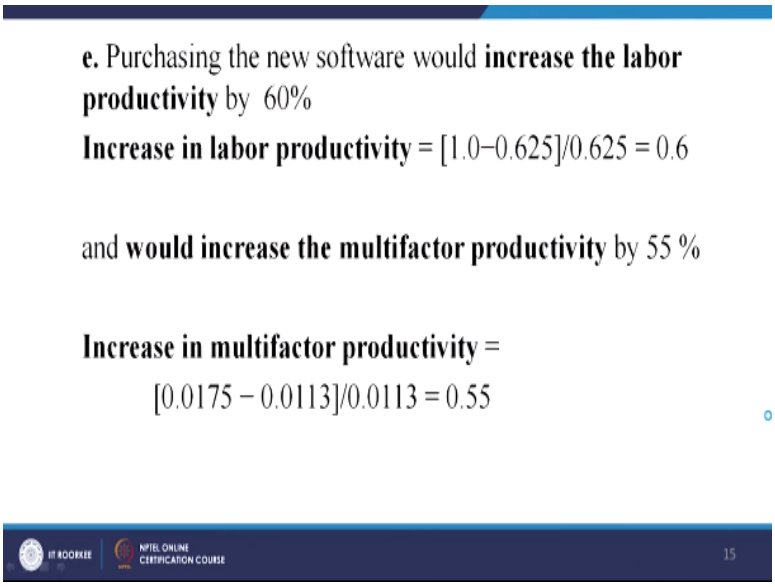
say that whatever changes we are doing we are using a new software so that new software is helping each of our loan officer to process 8 loans per day, so that is definitely improving the labour productivity also and it is also improving the multifactor productivity also.

We will suggest the company that they must go for this particular software so that it is able to improve the productivity of labour as well as the number of loans processed per dollar. So now friends we have seen that we have a current scenario in which our loan officers are processing 5 loans per day and we have certain inputs in terms of labour input that is $820 and we have overhead that is $500.

Now in the proposed scenario or changed scenario where we are using a new software for helping our employees, we are able to process 8 loans per worker, or per loan officer and the only change in the input is the labour cost remains the same, but the overhead expense is changed from 500 to $500. So we have now 2 scenarios, we can check that what is the percentage change with the use of the new technology, what is the overall percentage change.

So we have calculated the labour productivity and the multifactor productivity in case of the current scenario. We have calculated the labour productivity and the multifactor productivity in the changed scenario where we are using a software. Now we can see that what is the overall percentage change in the labour productivity as well as the percentage change in the multifactor productivity. So in the next slide this is the last slide for today.

(Refer Slide Time: 25:17)



Now purchasing the new software would increase the labour productivity by 60%. You can see increase in labour productivity it was in the proposed scenario. It was 24/24 that is 1-0.625 so it is approximately divided by 0.625 which is approximately coming out to be 0.6 and would increase the multifactor productivity by 55%.

You can see increase in multifactor productivity we have under the proposed scenario using the software our productivity is coming out to be 0.0175 loans per dollar – 0.0113 loans per dollar which was in the existing scenario and divided by the existing scenario value is 0.55. So there is we can see that there is a substantial increase in the labour productivity as well as in the multifactor productivity if we switch from the current method of doing the job to the advanced method using the software.

So in this way we can compare the various options and see that whether our productivity is increasing or it is decreasing or there is no effect on the productivity. So with this I think we have tried to understand that how mathematically we can see what are the inputs, what are the outputs and then calculate the productivity and in many cases we have to read the statement and try to understand that what has to be taken as output, what has to be taken as input and then do the division and calculate the productivity.

In our next session our focus primarily will be to understand certain case studies where changes have led to improvement of productivity or in some cases the changes may even lead to decrease in the productivity also. So we will try to find out some case studies which further explain the concept of productivity.

So the second week discussion we will be concluding and our focus on productivity will help us to understand that why do we need to change the processes, why do we need to change the style of working, why do we need to change the steps of working, why do we need in general to change the way we work, because once we change the change has to be for the better and why it has to be for the better because it will make us more productive.

So we will focus on the method study, time study, ergonomics and try to understand that how we must design our work system so that we are more productive, our time is utilized in a best cost efficient and most effective manner. So with this I conclude today's session, in the next session our focus will be on the case studies related to productivity. Thank you.