Manufacturing Systems Management
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Lecture - 05
Production Flow Analysis

In this lecture, we discuss Production Flow Analysis in detail. We introduced production flow analysis in the previous lecture and we explain production flow analysis using this matrix.

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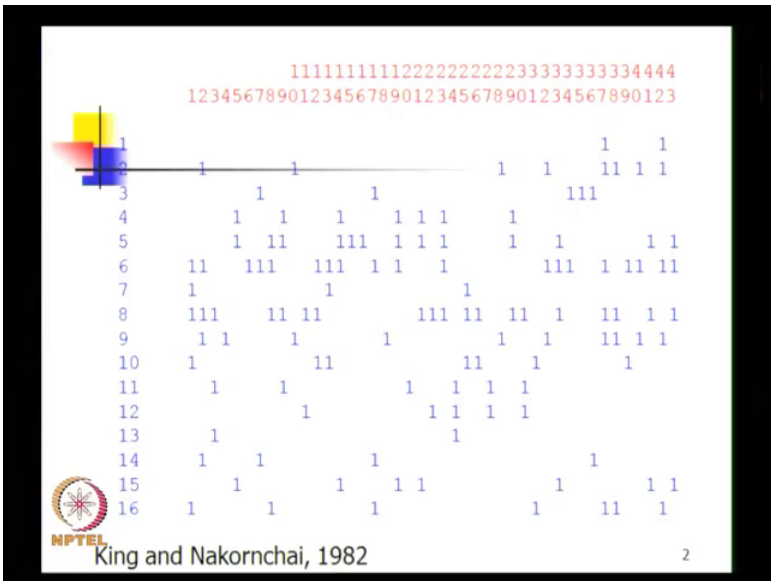

We have already seen this machine component incident matrix which is a 16 by 43 matrix, where 16 machine types 43 parts or components and the incidence data is captured in the form of a binary or 0 1 matrix. This matrix was originally introduced by (Refer Time: 00:50) early in one of his papers.

Now, this matrix is also used by King and Nakornchai in their paper or rank order clustering. So, we have adapted this matrix from King and Nakornchai and one could see the reference in the bottom of the slide. Now we have 16 machine types and 43 parts or components. From this incidence matrix we first create a frequency table.

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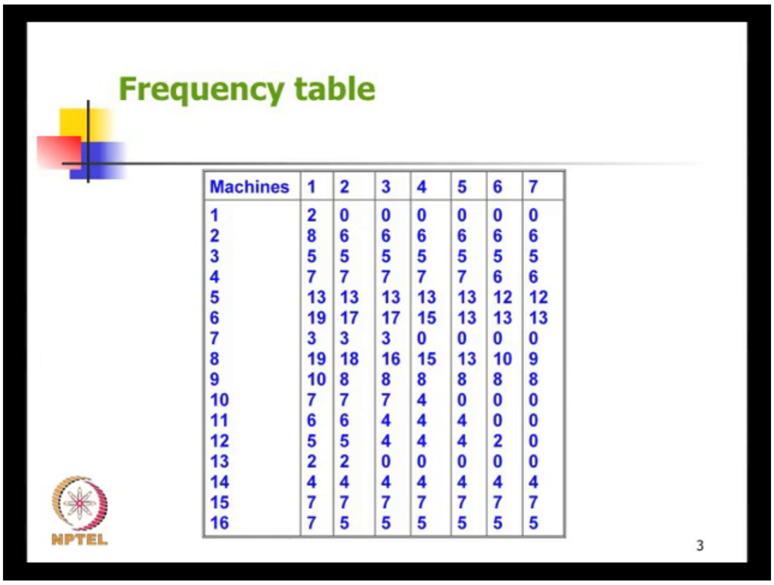
Frequency table

Machines	1	2	3	4	5	6	7
1	2	0	0	0	0	0	0
2	8	6	6	6	6	6	6
3	5	5	5	5	5	5	5
4	7	7	7	7	7	6	6
5	13	13	13	13	13	12	12
6	19	17	17	15	13	13	13
7	3	3	3	0	0	0	0
8	19	18	16	15	13	10	9
9	10	8	8	8	8	8	8
10	7	7	7	4	0	0	0
11	6	6	4	4	4	0	0
12	5	5	4	4	4	2	0
13	2	2	0	0	0	0	0
14	4	4	4	4	4	4	4
15	7	7	7	7	7	7	7
16	7	5	5	5	5	5	5

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This frequency table shows machines 1 to 16 listed here the first column of the frequency table shows the number of parts or components which visit each machine.

So, going back to the incidence matrix, we observe that row 1 which corresponds to machine number 1 has 2 components; 37 and 42 visiting. So, the frequency is 2; row 2 which represents machine number 2 has 1, 2, 3, 4; 8 components visiting. So, the frequency is 8. So, this way we filled this 16 numbers representing the frequency of visit or the number of components that visit each of the machine.

Now, from this column number one we pick the machine which has the lowest frequency as a nucleus machine and create a module using the nucleus machine. We saw how to create that in the previous lecture, we once again show for the sake of continuity. So, we take machine number one as the first machine which has the lowest frequency. So, this is called a nucleus machine around which this module is created.

Now, machine 1 is written first, and then we go back to the original matrix to see that 37 and 42 are the 2 component numbers which stands for a frequency of 2.

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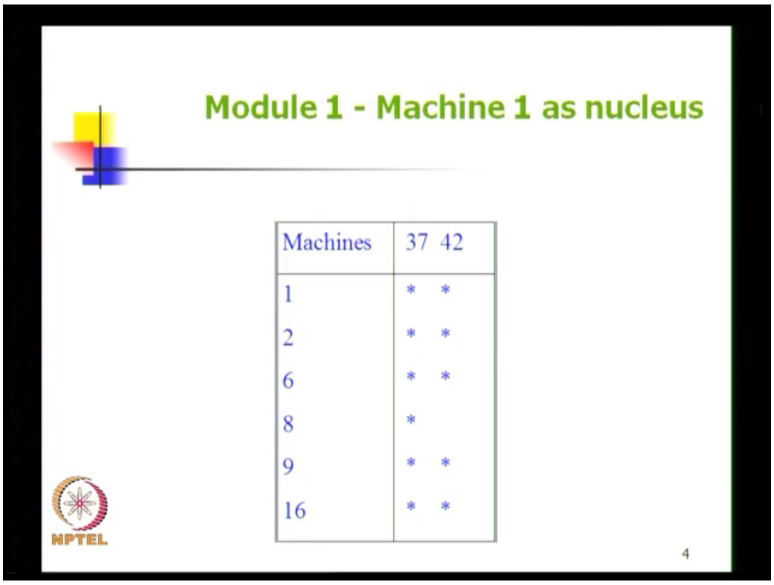

So, we write component numbers 37 and 42 here, then we go back to this original matrix and look at column numbers 37 and 42 to find out; what are all the other machines that 37 and 42 visit.

So, 37 visits 1, 2, 6, 8, 9 and 16. So, we write 1, 2, 6, 8, 9 and 16 here and then we indicate with a star mark or a tick mark that 37 visits; all of these machines we once again go back to this look at column number 42 and understand that component number 42 visits machine number 1, 2, 6, 9 and 16.

So, we put a star mark under 1, 2, 6, 9 and 16 there is no star mark under 8; Now we realize that one has a frequency of 2; 2 has a frequency of 2; 8 has a frequency of 1 and so on.

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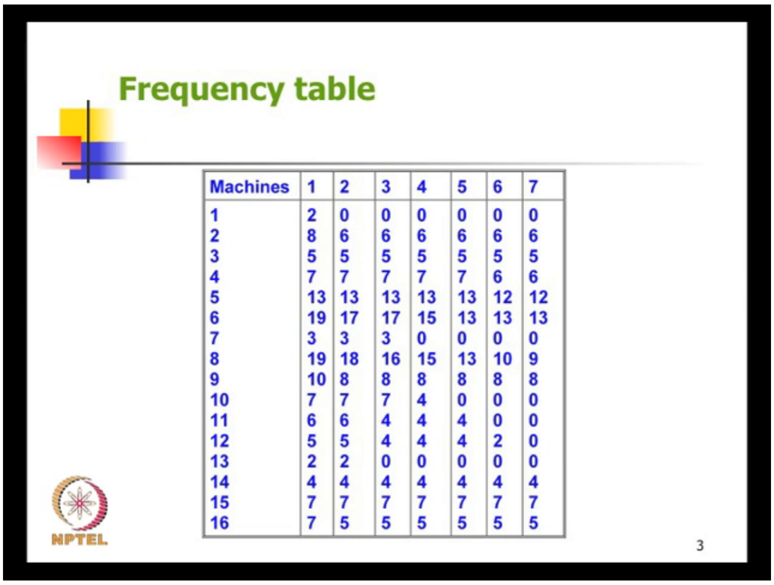
Frequency table

Machines	1	2	3	4	5	6	7
1	2	0	0	0	0	0	0
2	8	6	6	6	6	6	6
3	5	5	5	5	5	5	5
4	7	7	7	7	7	6	6
5	13	13	13	13	13	12	12
6	19	17	17	15	13	13	13
7	3	3	3	0	0	0	0
8	19	18	16	15	13	10	9
9	10	8	8	8	8	8	8
10	7	7	7	4	0	0	0
11	6	6	4	4	4	0	0
12	5	5	4	4	4	2	0
13	2	2	0	0	0	0	0
14	4	4	4	4	4	4	4
15	7	7	7	7	7	7	7
16	7	5	5	5	5	5	5

Now, using this module or this table; we update the frequency table by creating column number 2. Now for machine one a previous column had 2 components. Now from this table there is a frequency of 2. So, the 2 becomes 0 for machine number 2; the previous number was 8. Now the both the components visit machine number 2. Therefore, 8 become 6.

As far as machine number 3 is concerned the original number is 5; machine number 3 does not figure in this table. So, the frequency remains as 5 for machine number 8 the frequency is 1 here. Now 19 becomes 18; so, for machines 1, 2, 6, 8, 9 and 16, the frequency is reduced for the remaining machines frequency is remain the same and for machine number 1; the frequency become 0.

The nucleus machine will always have frequency 0 at the end of the module because based on the nucleus machines frequency of 2, we created this table we listed both these component. So, both these components will have a star mark on this. Therefore, 2 will become 0 in the next iteration or in the next column. Now we look at column number 2 here and find out the machine which has the lowest frequency now we understand that machine one has a frequency 0, but machine one has already been considered. So, we look at the machine with the smallest non-zero frequency.

So, machine number 13 has smallest non-zero frequency of 2. In fact, from column, we could have picked either 1 or 13; both had 2 we picked machine number 1. Now we pick machine number 13 and create the next module.

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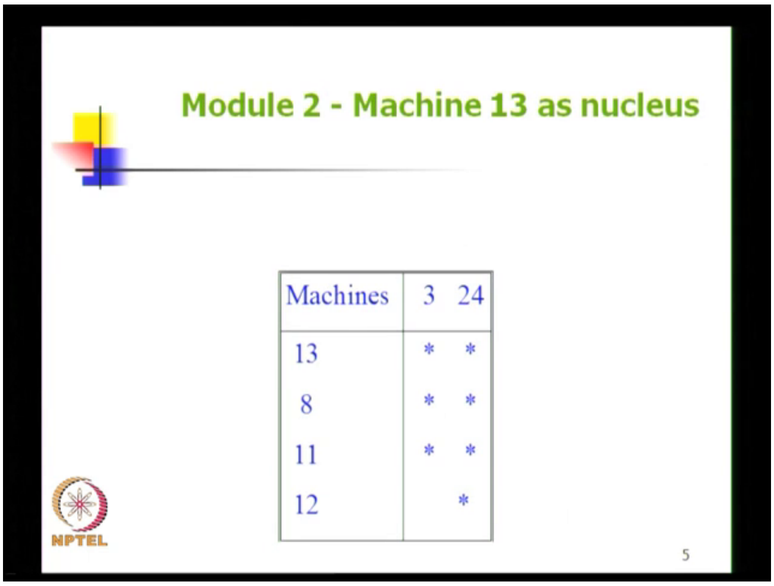

So, the next module is created with machine number 13 as the nucleus machine the frequency of 2 comes from component numbers 3 and 24.

From this we go back and see for machine number 13; here the frequency comes from 3 and 24 which are here component number 3 and component number 24. So, we create this with component number 3 and 24 and put a tick mark on both. Now look at component number 3 from the main matrix. So, component number 3 has 8; it has 8, 11 and 13. So, we come back. So, 13 is already written here. So, we write 8 and 11 and put star marks under 8 and 11.

Now, we go back to component number 24 and observe that under component number 24 this component visits machines 8, 11, 12 and 13. So, we come here. So, under 24, 13, we have already written. So, we write 8, 13, 8 and 11 are already here. So, we add 12 to this list and then we mark a star under 13, 8, 11 and 12.

So, now we have completed this module, but as we complete this module we also have to understand something in the previous module; we had a situation where the machines visited by component number 42 where a subset of those visited by component number

37. So, we had either 2 or 1 as a frequency; now here 24 visits' an extra machine. So, we can have situation where extra machines are added as we move and follow the requirements of these components. So, we could have a blank here as well as a star here.

So, this module has something like that where the component number 24 visits machines other machines other than what component number 3 is visiting. So, we again go back and update the frequency table. So, we update this frequency table and we realize that the machines that we have here are 13, 8, 11 and 12. So 8 has a frequency of 2. So, 18 becomes 16 13 has a frequency of 2. So, 2 becomes 0, 11 has a frequency of 2 again from here 11 has a frequency of 2. So, for 11, 6 become 4.

Now, 12 has a frequency of 1. So, 5 becomes 4, rest of the machines the frequency remains the same as in column number 2. So, now, column number 3 has been generated. So, we have to now create a third module with the nucleus machine which is the machine which has the smallest non-zero frequency from here.

So, now we realize from here that machine number 7 with 3 is the one that has the smallest non-zero frequency and in the same manner we will go on and create different modules with different nucleus machines. Now the other thing, we need to look at is for example, when if you observe here see the fourth module, we would be creating with machine number 10 as the nucleus machine because from here it becomes 0.

So, when we create the fourth module we have to go back to this and see that machine number 10 has 7 components which are here, but right now the frequency is 4 which means 3 out of this 7 components have already been taken into earlier modules and therefore, this module with machine number 10 as a nucleus machine will have only 4 out of this 7 which have not been taken earlier.

So, we have to keep that in mind as we create these modules. So, we continue to create these modules and as we create these modules we observe something interesting now at the end of with every column here we create a module with the nucleus machine as the machine with the smallest non-zero frequency.

So, between columns one and 2 the nucleus machine in column 2 will get a frequency of 0 in column 3 another machine which was the nucleus earlier will now have a frequency of 0 in column 4 some other machine will have a frequency of 0. So, every column now has one machine having a one additional machine having a frequency of 0 therefore, it is possible to have a maximum of 16 modules that we can have because each module should have a nucleus machine and once it becomes a nucleus machine its frequency will become 0 therefore, it can become a nucleus machine only once and since there are 16 machines in this example we can create a maximum of 16 modules sometimes we may create fewer than 16 modules also.

Finally, we will encounter a situation where all the frequencies will become 0 at which point, we will not be able to create or find a nucleus machine and the process of creating this modules stops. So, let us assume that we have continued creating all possible modules.

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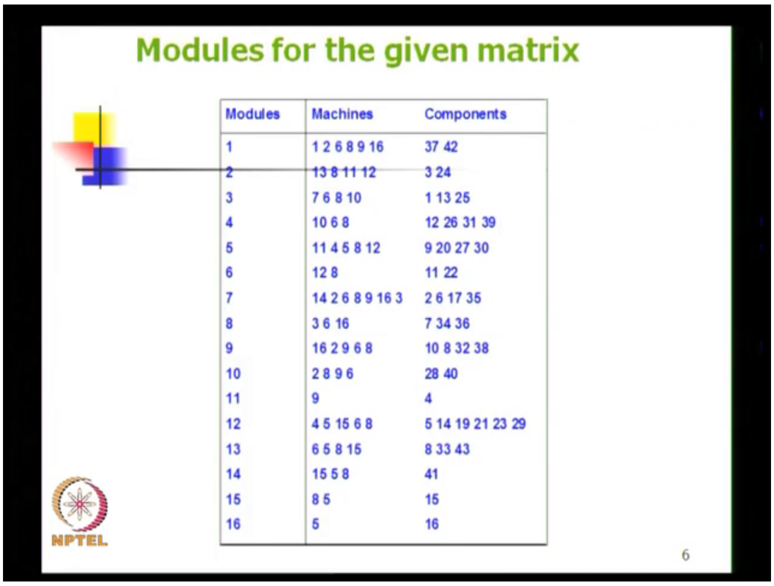

Modules	Machines	Components
1	1 2 6 8 9 16	37 42
2	13 8 11 12	3 24
3	7 6 8 10	1 13 25
4	10 6 8	12 26 31 39
5	11 4 5 8 12	9 20 27 30
6	12 8	11 22
7	14 2 6 8 9 16 3	2 6 17 35
8	3 6 16	7 34 36
9	16 2 9 6 8	10 8 32 38
10	2 8 9 6	28 40
11	9	4
12	4 5 15 6 8	5 14 19 21 23 29
13	6 5 8 15	8 33 43
14	15 5 8	41
15	8 5	15
16	5	16

And we will get a table like this. So, in this example we are able to create 16 modules and these are our 16 modules we can show some of these here module one had machines 1, 2, 6, 8, 9 and 16 and it has components 37 and 42 you see this, it has 1, 2, 6, 8, 9 and 16 and has components 37 and 42.

Look at module number 2 has machines 13, 8, 11 and 12 with 3 and 24. So, 13, 8, 11 and 12 with 3 and 24 module 3 we said 7 is the nucleus machine with the frequency of 3. So, go back and see module 3; 7 is the nucleus machine first machine written here with a frequency of 3 components one 13 and 25.

Now, we also observe from here that the fourth one is machine number 10 with a frequency of 4. So, once again machine number 10 as a nucleus machine with a frequency of 4 and you also realize that some of the components for example, 1, 12, 13, 24, 25. So, like this you realize that for this; 12, 26, 13 and 1 have already gone earlier with ten. So, like that we have 10 has figured here. So, 13 25 have come here. So, the frequency has come down. So, with 4 components we have created this. So, like this all these 16 components have been or 16 modules have been created.

Now, we look at this matrix which has the module number machines in the module and components in the module in a little more detail. So, the first thing we observe is that every component will appear only in one module whereas, a machine can appear in multiple modules for example, you see 6 appearing here, 6 appearing here, 6 appearing here, 6 appearing here and so on.

You also realize that after it becomes a nucleus machine, it cannot figure later which means one appears only here and one will not appear in any subsequent module if you take for example, something like 12, you see 12 has appeared here, it is not a nucleus 12 has appeared here, it is not a nucleus. Now 12 has appeared here as a nucleus after which 12 will not come therefore, it is necessary when we write we write this exactly as we created it is not it conveys better meaning when we write this module as having machines 13, 8, 11 and 12 rather than saying 8, 11, 12 and 13.

So, when you say 13, 8, 11 and 12 you know 13 is the nucleus and 8, 11 and 12 have been added after the nucleus was created. So, the first machine should be the nucleus and after that this machine will not appear in any subsequent modules; now each of these modules represents in principle it represents a machine cell for example, if we are able to create a machine cell with machines 1, 2, 6, 8, 9 and 16; now we will be able to make component 37 and 42 because these 2 components do not require any additional machine other than 1, 2, 6, 8, 9 and 16.

So, if we were able to create 16 modules with each module having these set of machines and these components then we have created 16 manufacturing cells to make these 43 components or parts, but we also understand that we will not be able to do that because the number of machines that are required is very very large if we have to create 16 manufacturing cells to make these 43 components. So, what we do now is, let us look at some part of this table and let us look at modules 12, 13, 14, 15 and 16. Now module number 12 has machines 4, 5, 15, 6, 8 and it makes a certain number of components.

This module has 6, 5, 8, 15 this has 15, 5, 8, 8, 5 and 5. Now you realize that actually speaking this module can not only make these entirely can also make this can also make this, this and this. So, we can actually merge all these 5 modules into a single module which can make all these components.

So, we follow a rule by which you merge 2 modules when the machines in a particular module are a subset of the machines in another module, then you merge them. So, the bigger one takes over because this is a subset the components get added to the bigger module.

So, we can use this idea to merge modules and we can merge 2 modules when the machine set of one of them is a subset of the other and we add all the components also. So, if we do this for these 16 modules; we now get a more comfortable number, we have 6 modules after the merger and these 6 modules are like this.

So, module one has 1, 2, 6, 8, 9 and 16 with all these components module 2 has 8, 11, 13, 12, and so on.

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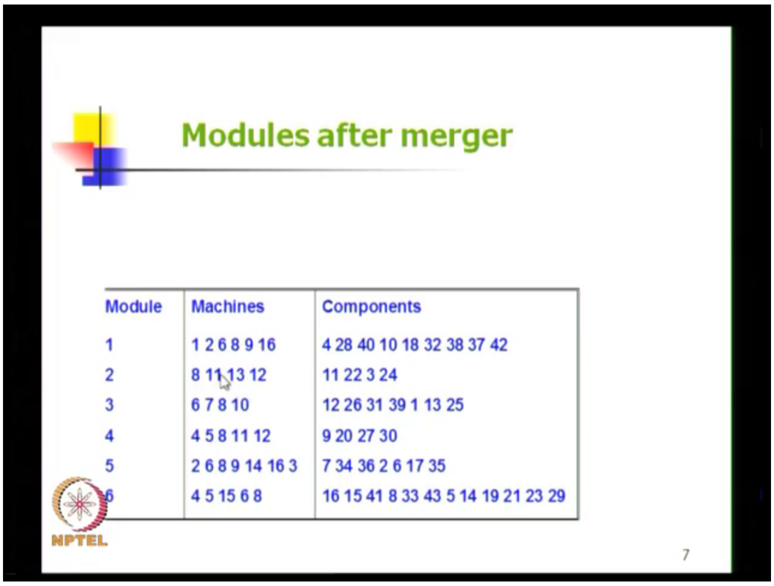

Module	Machines	Components
1	1 2 6 8 9 16	4 28 40 10 18 32 38 37 42
2	8 11 13 12	11 22 3 24
3	6 7 8 10	12 26 31 39 1 13 25
4	4 5 8 11 12	9 20 27 30
5	2 6 8 9 14 16 3	7 34 36 2 6 17 35
6	4 5 15 6 8	16 15 41 8 33 43 5 14 19 21 23 29

So, now this table tells us that if we have sufficient number of machines we can create 6 manufacturing cells to make these 43 parts and components and first manufacturing cells will make all these components and it will contain these machines. So, we now ask ourselves a question do we have enough number or enough copies of all these machines.

Let us quickly look at it and say we need 6 machines here 6 plus 4, 10, 14 plus 5, 19 plus 7, 26 plus 5, 31 machines we require to make this and we have 16 machine types now we have to go back and see whether we actually have since each machine type can have multiple copies do we have enough machines to create this.

Now, let us assume for a moment that we do not have enough machines to create this and let us also assume that we it is difficult for us buy extra machines to create this. Now can we do a few more things to bring down the machine requirement here? Now let us look at 2 aspects of it; now what we do now is even though we created this table from the previous table this table also has this nice property that if I am able to create a machine cell with 1, 2, 6, 8, 9 and 16. Then I will be able to make all these components entirely within this cell and there is no need for me to visit any machine other than the machines that are there in the cells.

So, in some sense these 6 modules are also independent and independently can produce these components which are listed against them. So, in some sense we have taken a very large matrix of 16 by 43 and we have now divided that into 6 modules each of which is self contained and there is no requirement for example, for a component here to go to any of these machines.

Now, let us look at each one of these modules in a little bit of detail to see whether we can do some more things in this now let us look at this particular module there is a module here.

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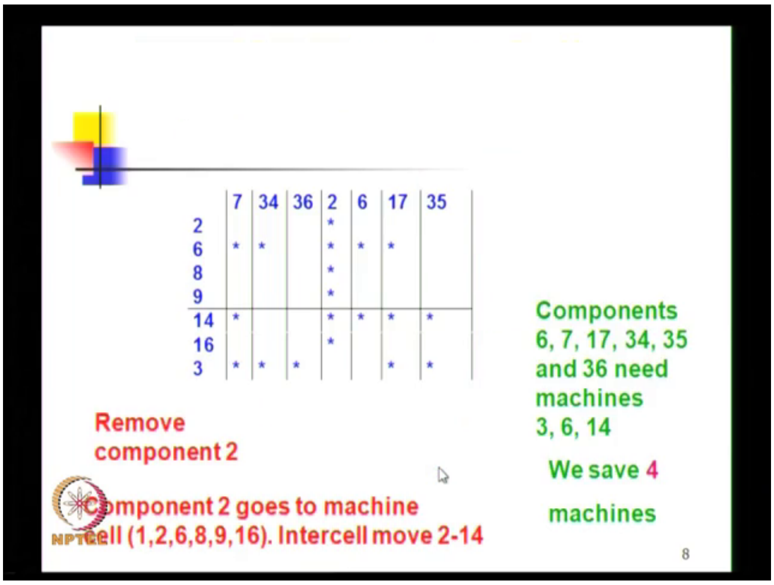

With 2, 6, 8, 9, 14, 16, 3 which makes 7, 34, 36, 2, 6, etcetera. So, this is the module that we have. So, we have written these machines here we have written these components here and we go back to the main matrix and capture wherever there is a one in that subset we capture and we have captured this in the form of a star.

So, that can be taken from the main matrix and we can do this now when we look at this matrix we can observe certain things now what we can observe by looking at this smaller module we will not be able to observe when we see this large matrix. So, the advantage of keeping it small and simple we are able to exploit. So, we look at this module now and we quickly understand a few things.

Now, what happens is several of these machines which are there in this module have come into this module because one component in this which is component number 2 requires a lot of these machines. So, in some sense component number 2 is the culprit which has resulted in unnecessary perhaps unnecessary or unnecessary may not be the word perhaps it has resulted in machine numbers 8, 2, 8 and 9 as well as 16 into this cell because of the presence of component number 2.

So, if we pull out component number 2 we have rest of these components which are 6, 7, 17, 34 and 35 and 6; 6, 7, 17, 34, 35 and 36. So, these 6 components other than component number 2 if we pull out component number 2 then we can produce 7, 34, 36, 6, 17, 35 in this module and if we take all these components it is enough to have machines 3, 14 and 6; we do not need machines 2, 8, 9 and 16 all these 4 machines have come into this module because component number 2 requires this.

So, if we pull out component number 2 from this module, we can save 4 machines from this module, but we have to do something for component number 2 we cannot leave it. So, we go back to this table and see which are the things that the component number 2 visits now component number 2 visits its which also here we do not have to go that far it is also here component number 2 visits 2, 6, 8, 9, 14, 16, 2, 6, 8, 9, 14, 16; there is a module with 1, 2, 6, 8, 9 and 16. So, 2, 6, 8, 9, 16; they are all here, but 14 is not here which has made this happen.

So, now take component number 2 from this module from this module and put it into the machine cell 1, 2, 6, 8, 9 and 16 if we do that if we add that we put take this 2 from here and put it here; now 2 can be made in all of these, but 2 requires machine number 14 extra. So, either we can put one machine number 14 here extra even, then we save 4 machines or at present we assume that component number 2 which is attached to this cell this cell does not have machine number 14, but component number 2 requires machine number 14.

So, only for machine number 14 component number 2 will come to this cell and visit machine number 14. Now this is called an inter cell move because component number 2 is attached to module number one or cell number one, but it has to visit cell number 5 to access machine number 14. So, we create one inter cell move at the same time we save 4 machines from this cell we relocate one component from here to here.

So, that is what we do when we take a close look at this module number 5 which has this. So, now, module number 5 will have only 3 machines which are 3, 6 and 14, 6, 14 and 3 it will have only 14, 6 and 3, 14, 6, 14 and 3. So, we have reduced the size of one of the modules we have relocated one of the components and we have created one inter cell move to save 4 machines from this module.

Now, let us look at another module there is a module with 4, 5, 8, 11, 12, and has 9, 20, 27 and 30. So, there is a 4, 5, 8, 11 and 12 which has 9, 20, 27 and 30.

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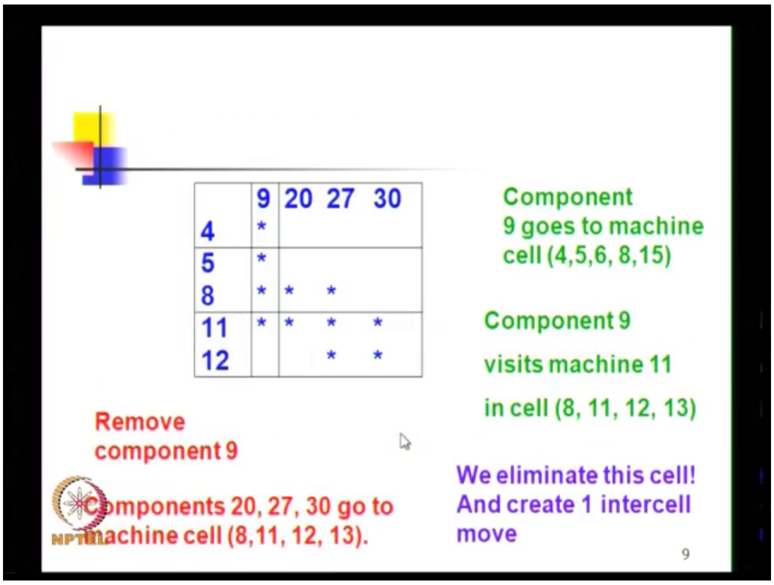

So, we once again create this small module incident from the main matrix and when we look at this module we realize that component number 9 is the reason for the presence of machines 4 and 5.

So, if we remove component number 9 from this it is enough to have 8, 11 and 12 alone in this and we can save 2 machines the most interesting part is if we remove component number 9; we can also remove machines 4, 5 we require only 8, 11 and 12 to make 20, 27 and 30, but then when we go back there is another module with 8, 11 and 12. Therefore, 20, 27 and 30 can be merged with this module following the earlier rule that the machine set is a subset.

So, in some way we can actually eliminate this entire module by removing component number 9 putting it elsewhere and by understanding that I need to make only 20, 27 and 30 with 8, 11 and 12 and therefore, 20, 27 and 30 can go to some other module which has 8, 11 and 12.

So, you can eliminate this one cell, but then we have to keep component 9 somewhere. So, component 9 requires 4, 5, 8 and 11. So, we go back. So, 8 there is 4, 5, 8 and 11 now there is this module which has 4, 5, 6, 8 and 15. So, it has 4, 5 and 8, 11 is the only thing that needed. So, create 1 Intercell move with remove component 9 create 1 Intercell move push component 9 to this module push it to this module and create 1 Intercell.

So, in this way we have eliminated a cell and we have created 1 Intercell. So, when we do these 2 things.

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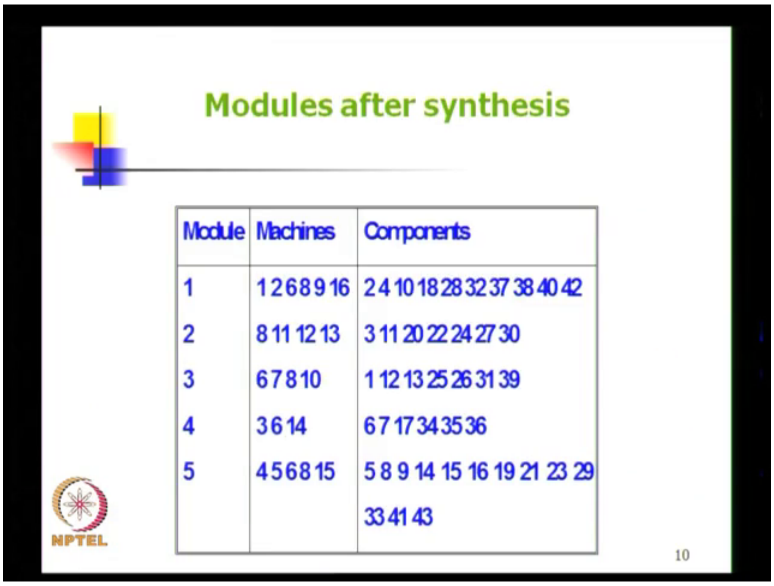

Module	Machines	Components
1	1 2 6 8 9 16	2 4 10 18 28 32 37 38 40 42
2	8 11 12 13	3 11 20 22 24 27 30
3	6 7 8 10	1 12 13 25 26 31 39
4	3 6 14	6 7 17 34 35 36
5	4 5 6 8 15	5 8 9 14 15 16 19 21 23 29 33 41 43

Then we get a solution like this which has 5 modules; it has it requires all these machines it can make these; now you can see 9 has come here 2 has gone here it has 2 Intercell moves.

This aspect what we have done is called module synthesis. So, initially there was module creation and then there is module synthesis by which the number of modules can come down or the number of machines within a module can come down. So, 2 things are possible in module synthesis.

So, now we go back and see is this solution acceptable to us; now there are 5 modules to make these 43 components there seems to be a reasonable distribution of components to this modules you still find 1 or 2 modules having a large number of components while one or 2 are small number of components 43 components to be put in 5 modules you expect between 8 and 9 where as you have only 6 component here you have only 7 components here, but then you have a large number here 3, 6, 9, 10, 13 components here.

So, the component ranges between 6 and 13 and not for example, between 8 and 10 it is assumed that it is acceptable to us; now we go back to the number of machines and when we look at this table carefully we realize that other than machines 6 and 8 all other machine appear in only one module if you see one appears here 2, 3, 4, 5 like that other than 6 and 8 all other machines appear only in one module.

Since the original matrix has 16 machine types; we assume that there is at least one machine of each type therefore, all the other machines other than 6 and 8 we have enough number of machines. So, they can be allocated to each of these modules.

Now, let us look at 6 and 8; now 6 is required in 1, 2, 3, 4 out of the 5 modules and 8 is also required in 1, 2, 3, 4 out of 5 modules. So, if we have 4 copies of 6 and 4 copies of 8 we can start creating it by assigning putting one copy of 6 in each of the 4 required modules and similarly one copy of 8 in each of the required modules.

If we do not have; then we could go back and check whether we can buy additional machines of 6 and 8 to try and put it into these cells. Now let us ask another question ordinarily do we expect to have more than one copy of 6 and 8 or will we have exactly one copy of 6 and 8. Now to answer that question; let us go back to the main matrix when we go back to the main matrix you see that 6 and 8 have a large number of ones in their rows corresponding or compared to every other machines.

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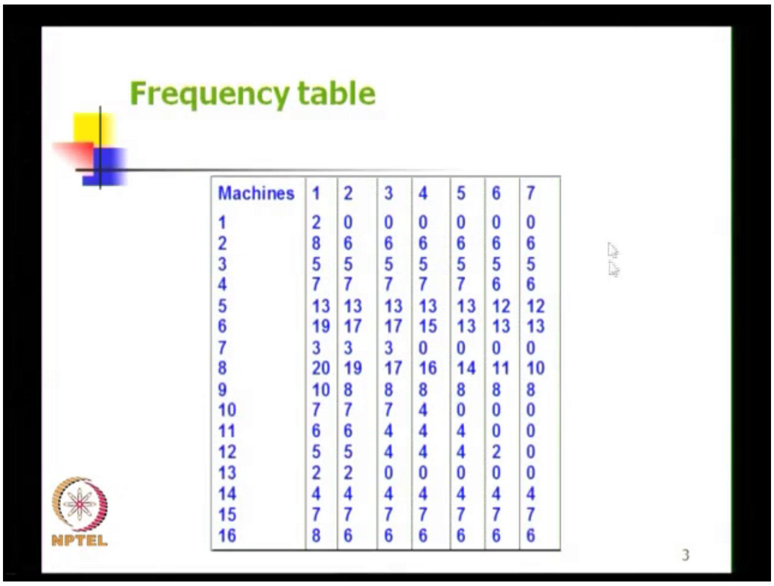

Machines	1	2	3	4	5	6	7
1	2	0	0	0	0	0	0
2	8	6	6	6	6	6	6
3	5	5	5	5	5	5	5
4	7	7	7	7	7	6	6
5	13	13	13	13	13	12	12
6	19	17	17	15	13	13	13
7	3	3	3	0	0	0	0
8	20	19	17	16	14	11	10
9	10	8	8	8	8	8	8
10	7	7	7	4	0	0	0
11	6	6	4	4	4	0	0
12	5	5	4	4	4	2	0
13	2	2	0	0	0	0	0
14	4	4	4	4	4	4	4
15	7	7	7	7	7	7	7
16	8	6	6	6	6	6	6

So, you realize that 6 has large number of ones 8 has large number of ones. In fact, the frequency table column number 1 shows highest frequency of 19 and 20 components for 6 and 8 whereas, 5 has only 13 components and so on. So, when in the functional layout itself a very large number of components are visiting 6 and 8; it is only likely that we have multiple copies of 6 and 8 already existing.

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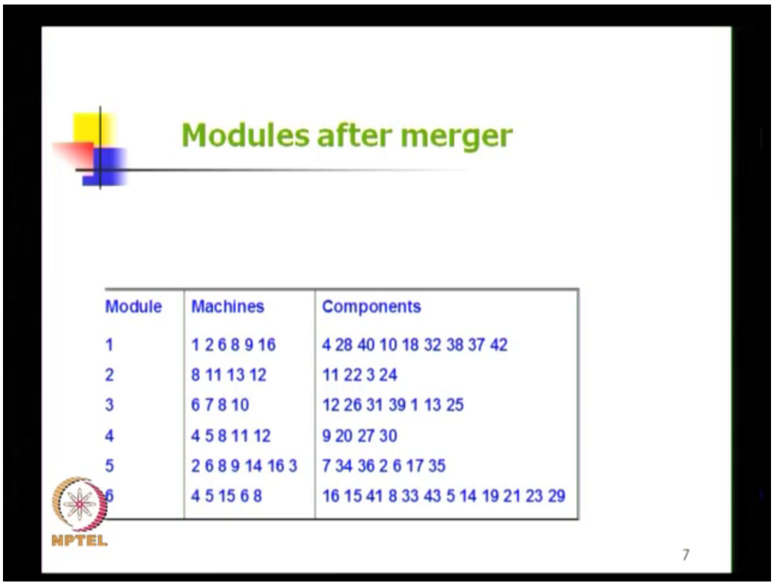

Therefore if we have 4 copies of 6 and 8; it is possible to implement this system if we have a little shortage say we have only 3 copies of 6, then we may have to buy one copy of 6 and put it in one of the machine or one more machine of type 6 and put it in one of the cells. Similarly we can create this.

So, this solution is reasonable and seems to be acceptable with 5 modules; this is the solution with 5 modules and making these machines and making these components when we again show this in this schematic manner.

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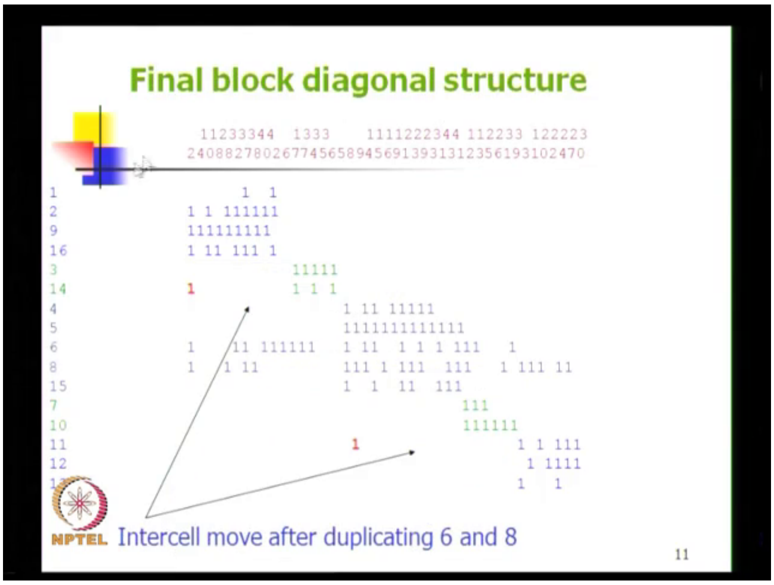

Now, we realize that this is the rearranged matrix you see carefully this is the rearranged matrix also realize that. So, this is the rearranged matrix; now you see that the row rearrangement is not 1 to 16; it is rearranged according to the modules the components or columns are also rearranged according to the modules, but 6 and 8 are shown only once in this not in each one of the modules, but they are shown only in one.

So, there are 2 ways of interpreting this if 6 and 8 are adequately duplicated to figure in each of the modules then we have only 2 Intercell modes that we have created which is component number 2 on machine number 14 and component number 9 on machine number 11. So, these 2 Intercell moves are shown by the arrow after duplicating 6 and 8 sufficiently. So, that if we add another 6 and 8 into this you will see that this part will go and merge with this one.

So, this will not appear as Intercell moves it also helps us in understanding that if we have only one copy of 6 and 8 then the number of Intercell moves is large and all these will have to be taken into account as intercept modes now this structure is called a block diagonal structure what we have essentially tried to do is if we duplicate 6 and 8 you now realize that you have made it into diagonal blocks.

For example this is a diagonal block this is a diagonal block this is a diagonal block here is diagonal block and here is a diagonal block. Now all these will go and merge within these diagonal blocks if 6 and 8 are duplicated. So, the diagonal blocks there will be 5 diagonal blocks and this rearranged structure is called a block diagonal structure.

So, this process is also called block diagonlising a given 0 1 matrix by identifying or finding out a new permutations of the rows and columns such that ones are converged only in the diagonal blocks with a very small number of exceptions in this case 2 exceptions and these 2 are called either exceptional elements in the context of block diagonlisation or they are called Intercell moves in the context of application of cellular manufacturing and group technology.

So, this is how production flow analysis helps us in creating machine cells and part forming. Now, starting with this matrix which has 16 machine types and 43 parts that are made we have now created 5 modules or 5 cells cell number one has machines 1, 2, 6, 8, 9 and 16 makes components 2, 4, 10, 18 and so on.

So, each cell now this word module can be replaced by a cell there are 5 machine cells each component is made exactly in one cell or is assigned to one cell the ownership of this component is on that cell machine 6 and 8 alone have to be duplicated there are 2 Intercell moves and in some sense the 2 Intercell moves are not very desirable because they take away the control; now how do they take away the control; now we look at the 2 Intercell moves now component number 2 is attached to Mach cell number one and only to visit 14, it comes to cell number 2. So, component number 2 visits both cell number one and cell number 2 there is a Intercell move, but the ownership of component number 2 is with cell number one it visits cell number 2.

So, to that extent the control over component number 2 is lost cell number 2 does not own component number 2. And therefore, even though cell number 2 will try to help by allowing component number 2 to visit machine number 14; 1 can understand that the importance given to component number 2 in this cell will definitely be less. So, to that extent we lose what we started to aim at which is complete independence now there is dependence.

So, to that extent Intercell moves are not very desirable. So, the next step one has to look at is how do I eliminate Intercell moves ideally I should have a solution with no Intercell moves if I have Intercell moves; I first minimize them while creating them or making them and then try to eliminate them a very similar argument can be told for component number 9 which is visiting machine number 11. So, component number 9 is assigned to cell number 3, but it is going to cell number 5 to meet to visit machine number 11. So, the same thing can be told.

So, next step is how do I minimize the Intercell moves.

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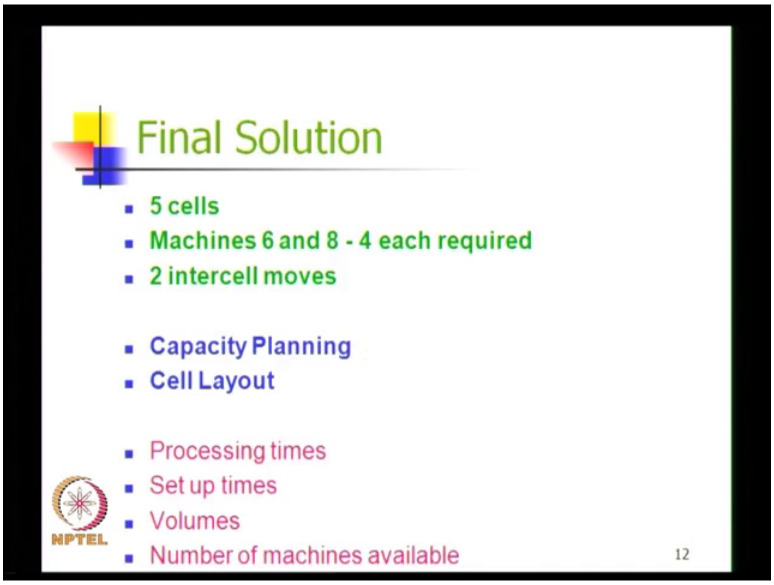

Now, let us look at this solution which is the last slide here a final solution has 5 cells that we have seen it has machine 6 and 8 with 4 numbers of each required and it has 2 Intercell moves.

Now, as I mention we now have created these 2 Intercell moves, but we should make effort to minimize or reduce this Intercell move. Now there are few other things that need to be done; now when we started production flow analysis we said there are 3 parts to it factory flow analysis group analysis and line analysis now we have come up to group analysis and we have said; we can create a cell like this we have said we can create 5 cells which are like this with 1, 2, 6, 8, 9 16 making 2, 14, 2, 4, 10, etcetera; now we need to do capacity planning within the cell.

Now, even though we have said that this cell will have 1, 2, 6, 8, 9 and 16 and it will make all these components. Now we need to check whether there is enough capacity in the cell to make these components now what is capacity in the cell how do we measure that now suppose we create this cell with 1, 2, 6, 8, 9 and 16. Now we go back and realize that out of all these components only 37 and 42 require 1, whereas a large number could require 6 or 8 or 9.

So, for every machine we have to go back and see what are the components that are visiting this machine how much of time is required on this machine or what is the demand of time on this machine how do we compute the demand to compute the demand we need all of these the first 3 things we need what is the expected volume of production of these components what are the processing times and what are the set up times.

So, what we have to do is for every one of this visit first we take machine number one now we realize only 2 components are needed what is the volume of production within a certain time period say annual or monthly. So, we have to find out the volume of production and then multiply it with the processing times to know what is the processing time alone required on this machine.

Let us say we take monthly requirement let us assume that V 37 and V 42 are the volumes. So, V 37 into processing time plus V 42 into processing time on m one will tell us what is the time required only for processing. Now we are not going to make all the volume in a single batch they will be need in multiple batches.

So, every time it is made in a batch or these components are going to be made one after another. So, there will be a production run in the cell which will be. So, the volume required of 37 will be made in several production runs and each production run would also involve a set up time. So, we have to find out in some sense what is the production run divided to find out number of setups and then we have set up times to be multiplied.

So, what is the total set up time component what is the total processing time component add these 2 to find out the demand now what is the supply or availability suppose we take 1; 1. Now this machine for the sake of illustration if this cell is going to work 6 days a week and it is going to work 2 shifts which is 16 hours a day; so this will work 96 hours in a week and multiplied by 4 would give us 384 hours in a month 96 into 4 is 384 hours in a month.

That is the time available now time required will be the volume of production the processing time the number of runs and the setup time would give us the demand now it is only common or fair to assume that it will not be available for all the 384 hours for production, because of several uncertainties there could be uncertainties due to machine availability and breakdowns which we have to try and minimize there would be uncertainties due to material not coming there could be uncertainties due to operators not available or correct operators not being available there could be other uncertainties.

Now, all these uncertainties have to be reduced there could also be some scheduling delays there could be maintenance time required. So, all of these have to be reduced if we want to get the best out of this cell and utilize this cell for all the 384 hours in a month now we would have a realistic estimate on availability which could be eighty percent or it could be 75 percent or it could be 85 percent and then multiply it the availability factor with 384 to find out the amount of time that is available on one machine, then we have requirement on the other.

So, divide the requirement by availability to get a number if that number happens to be 0.75 for machine number one in this cell, then we are anyway going to put one machine there. Therefore, we have enough capacity, but if we do it for let us say machine number 2 within this cell then we have to find out what are all the components that require machine number 2 and do this calculation and suppose we get a number like 1.3 machines of machine number 2 required.

Then we realize that it is not enough to have one machine of machine number two, but we need to have 2 machines of machine number 2. Therefore, when we actually implemented these 6 machines in the cell may even result in 8 machines with more than one required at some point. So, this aspect is called capacity planning.

So, capacity planning has to be done which is here the second thing is also to ensure that there is unidirectional flow within the cell. Now the machines have to be laid out in the cell 1, 2, 6, 8, 9 and 16 usually is laid out in a u shape, so that there is unidirectional flow of components within the cell.

Sometimes with 1, 2, 6, 8, 9 and 16 arranged in a u shape we may not be able to get a unidirectional form. However, small the possibilities are there could also be revisit of component within the machines in the cell. So, revisit always takes us away from a unidirectional flow. Now this would necessitate some other analysis and some other change which could be even inclusion of a small inexpensive machine which can carry out some of the operations.

So, all these things also have to be done: capacity planning and cell layout have to be done considering processing times setup times and volumes to determine the number of machines required based on the number of machines available. Now this aspect is called line lay out. Now we will see more of cellular manufacturing in the next lecture.