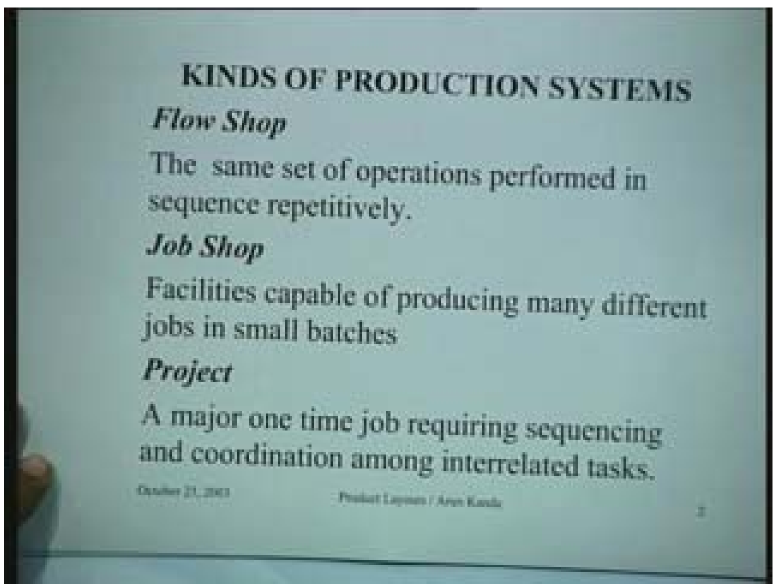
Project and Production Management
Prof. Arun Kanda
Department of Mechanical Engineering
Indian Institute of Technology, Delhi

Lecture - 33
Product Layouts and Assembly Line Balancing

Last time we were talking about computerized layout planning and the focus of the last two lectures has been on the development of process layouts. In today's class we are going to talk about the design of product layouts or assembly lines and the features that we have there in product layouts. If you recall, we had talked about the PQ chart and in that we are identify the range in which product layouts and process layouts are used. Let us briefly recall the features of these different kinds of production systems and see which kind of layout is relevant under what circumstances.

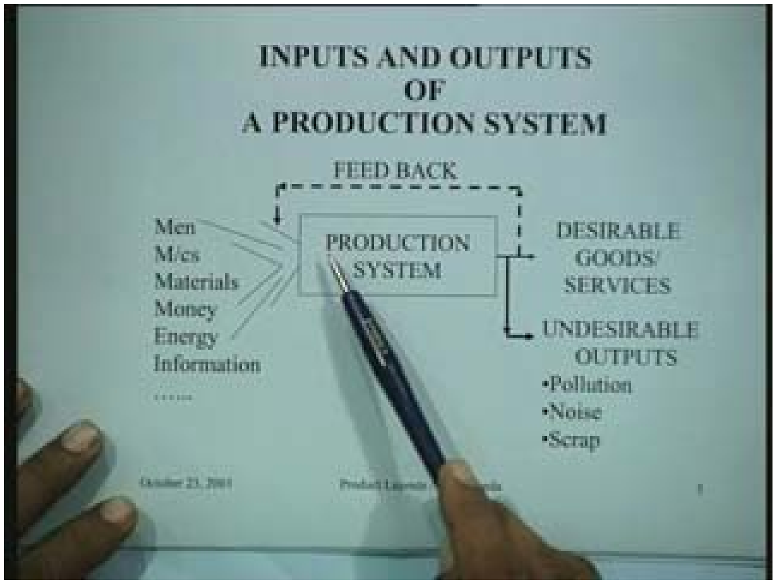
(Refer Slide Time: 01:53)



For instance when you talk about kinds of production systems, we can talk about a flow shop. A flow shop is essentially a production system in which the same sets of operations are performed in sequence repetitively. So what we have is essentially when the operations are going to be repeated so that the pattern of flow of the raw materials through the plant is constant more or less. That particular configuration is called a flow shop and in fact such systems even in assembly line could be used as a flow shop in that sense. On the other extreme we can talk about a job shop. Job shop is something with facilities, capable of producing many different jobs in small batches. So the difference between a job shop and a flow shop is essentially in terms of the variety of products that we are handling. In a job shop you can handle a variety of products and because each product might require different kinds of processing depending upon its requirements. You have actually general purpose machines laid out in the job shop and each product can go to the respective machine, get the operations done and then you to the next particular machine for the new operations. So what really happens in the job shop is that the flow pattern is quite complicated and material handling costs are pretty high. Basically when you are designing layouts for such job shops you are basically talking about the design of process layouts. What we are talking about is designing a process layout which can accommodate a variety of products that you make. That is what we saw when we were dealing with both the systematic layout planning procedure of Muether and also the computerized layout planning packages which are there for handling such types of systems.

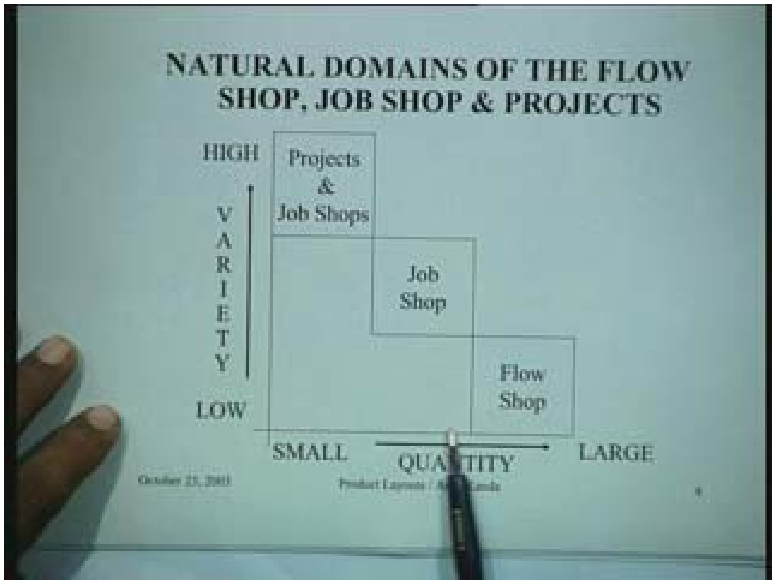
Of course one can have a production system which is totally distinct and which is a project that should be a major one time job requiring sequencing and coordination among interrelated tasks. Now in a project therefore things are done once and for all and there is no need for repeating whatever you are doing. Generally a project is a one time activity and therefore whatever layout emerges is actually a layout dictated by the particular circumstances. Therefore there are no formal methods of designing a layout for a project it is actually dictated by the various activities which have to be performed in the project, the kind of equipment that is to be laid and the kind of terrain in which the project is to be done. So we are not really talking about layouts when you are talking about a project for these reasons. Now it is important to note that all these different kinds of production systems that we have talked about essentially require resources. Let us recall these resources could be man power machines, materials, money, energy, information etc.

(Refer Slide Time: 05:39)



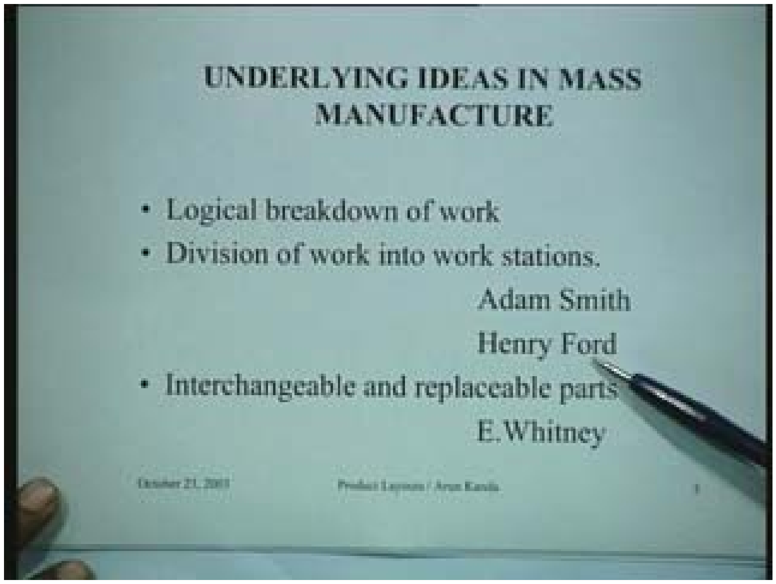
They have to be provided to the production system and the production system will generate to you the desirable goods and services and also some undesirable goods and services in the form of pollutions noise scrap etc. The purpose of a layout is actually to facilitate this operation which goes on within the black box. So we should look at a layout as something which facilitates the production process and at the same time tries to improve the productivity of the production system by enlarged. So it has to be viewed in that integrated concepts and not a problem nearly in isolation. This particular diagram which shows a plot of the product variety versus the quantity in fact brings out very beautifully the natural domains of the flow shop, the job shop and the projects. For instance if your quantities are small but the variety is large then this particular domain is the domain of the project and the job shops primarily on the other hand when you increase the quantity and also relatively reduce the variety in fact, what happens here is that we are talking here about predictable variety ion a job shop.

(Refer Slide Time: 07:12)



The medium level variety and medium level quantity is actually the domain of the job shop and when you are talking about the job shop, you are primarily talking about the design of process layouts. Whatever we studied in layout planning was actually applicable to the job shops that this particular ends up the spectrum here. On the other hand if you have a situation where the quantities are large and the variety of the product is relatively low, we come to a domain that is naturally suited for a flow shop or in assembly line or in mass production in that sense where we are basically performing the same set of operations repetitively without much change. So in such a case you tend to use a layout which is generally called the product layout or we will see how assemble lines are designed for this. So I think this point needs to be kept in mind and depending upon the natural requirements of variety and quantity you choose the type of layout and it could be a process layout or it could be a product layout as things are there. We are all familiar with the concept of mass manufacture, these things and mass production. However there are a couple of ideas in mass production or mass manufacture which are worthy of note. So we will talk about some of the key ideas which led to mass manufacture as a viable entity. You probably know that the first assembly line was set up be Henry ford for making cars in the United States.

(Refer Slide Time: 09:28)



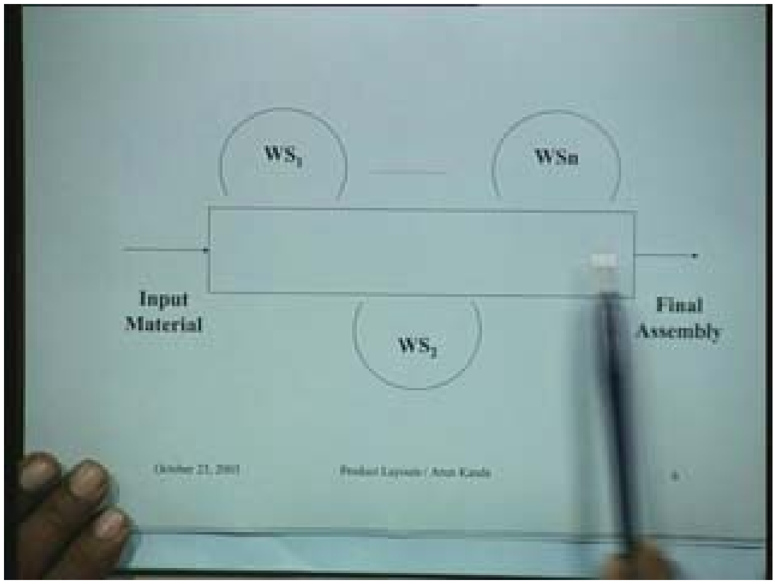
But this could not have been possible unless you have number one a logical breakdown of work which means the entire task is to be performed is broken down into smaller and smaller tasks and some group of tasks are assigned to one particular individual or a machine. This breakdown of tasks into smaller task helps in the division of labor to a very large extent. As a consequence of that suppose you could know what is the basic advantage of the division of labor rather than one person doing all the jobs involved in an assembly, if there are ten people doing fractions of those jobs, what is the specific advantage that you get by engaging a large number of people? That is one thing you get. Specialization of labor that means individual people will now be focusing on individual tasks and as a consequence they could become more and more skilled and learning times will tend to draw depending on the operation time. The real advantage of the concept of division of labor depends on what the assembly line is based. What is that specific concept?

The major advantage of the division of labor is the fact that it is much more economical to produce parts when different people do the jobs. Why is this so? It is because different tasks involve different degrees of skill. So what could happen is that there could be many tasks that can be performed by an unskilled operator. Other tasks requires skilled operators and you can buy along skilled operator at a much cheaper rate as compared to a skilled operator for whom you will have to pay that much. However if you have one skilled operator doing the whole job then even for the unskilled job which is done you are actually paying in at a higher rate. That is what it is. So you are really underutilizing these capabilities. If you are employing only one person for doing all the jobs, this particular fact is in fact responsible for much of the economic advantage that you get through the division of layout. Apart from this of course there are other factors like development of a skill and these kinds of things. But I think this must not pay last site off. The second underlying idea in mass manufacture is that it is possible to divide the work into workstations. What is the work station? Work station will be a set of tasks; you have now broken down the original work into smaller tasks. Some of the tasks are grouped together and assigned to one particular work station. So at one particular work station maybe the operator will take part and will be inspected. It will be a fixed up component on it and then clean it and compressed and send it to the next operation. So here we performed a number of different tasks. So this grouping of what task set to be performed by the operator defines the content of workstation. Basically Adam Smith was responsible for the basic idea of the division of labor. He wrote a book called the wealth of nations in 1776 which was basically concerned with the advantages of the division of labor. Henry Ford was credited with the first person who actually put this ideas together and develop the first circular and of course assembly lines could not have been possible but for this very important contribution by E Whitney. E Whitney is the person who actually talked about the concept of tolerances and fits in meeting parts.

So he in fact showed that if you maintain the tolerances with the certain range you could have parts which are interchangeable and replaceable. This is something very fundamental to the assembly language. For instance if you look at the assembly of let us say Maruti cars, the person has to fit the four tyres on to the on the wheels of this particular car. He can pick up one particular wheel, put it on, put the second wheel, put it on third wheel, and put it on. We can take any one of the wheels from the bilor wheels which are lying within. Why is this possible? Because of the processes standardization that has taken place which means essentially the dimensions confirmed to a certain range. Now in fact in all assembly lines this happens. The automobiles are being assembled. We will pick up any carburetor and fit up the carburetor of the car and followed by fitting up the next carburetor and so on. So it does not really make a difference which carburetor was fitted on to the whole thing, whereas this kind of thing could not be possible if standardization was not there.

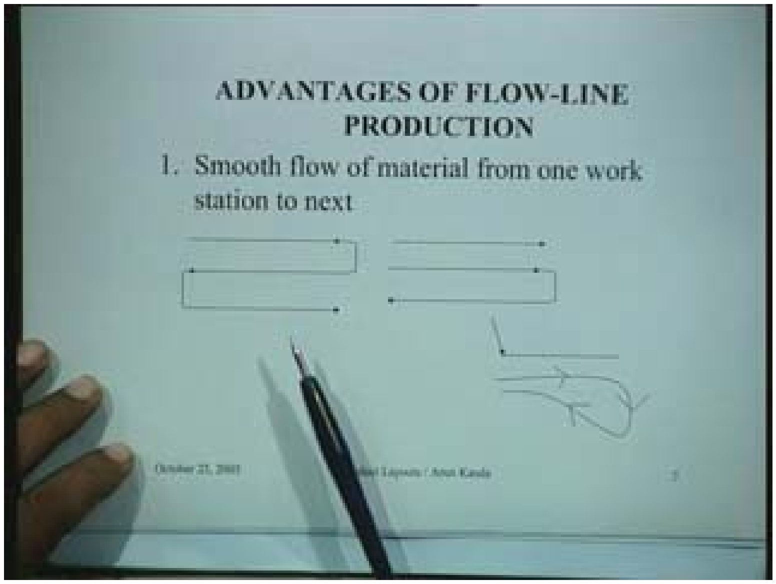
You know jocularly we can say you are all seen in the Mahabharata and you know during the war the chariot of particular prince was broken. The edges couldn’t replace the wheel by any standard wheel. It has to go to a specific carpenter. We have to make wheels specifically designed for that and then put it on. This is because that, it was not a standardized kind of operation, each thing was there. So unless standardization is done you will not be able to go for this assembly. So these are three fundamental concepts which are at the back of mass manufacture. What is an assembly line? Assembly line is actually a very sequential progression of the input material that comes with one particular point and one edge. Then it goes to the first workstation. This person it could be a person, it could be a machine, anything. This workstation performs certain operation on it. Sense it to the next operator who performs those operations which are required and so on. So at the end of the whole thing, the final assembled product comes out of the line. What are the specific features you see in the assembly line? I think one of the immediate things which come to mind is that this production is going to be much faster.

(Refer Slide Time: 16:57)



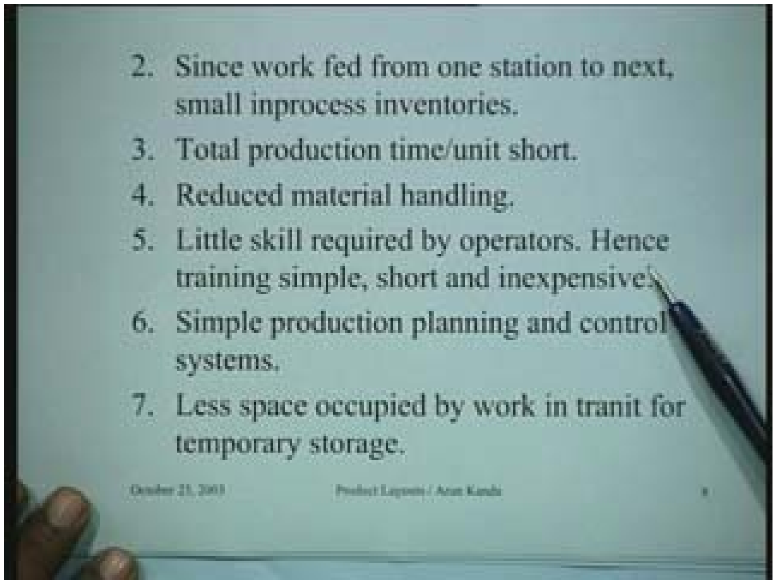
As compared to a process layout, why not, because these machines are more official. The same machines could as well be used in the process layout. So the total processing time for producing a part could be the same. The only difference comes because in a process layout it has to go from one department to another department. So there are waiting times then there is cost of transfer and then it is waiting at the new workstation and then so on. Once after the pieces finish, it has to gain rate of the department. So all these loading, waiting, traveling is involved in the process layout. But here the part is some operation is performed in this part, immediately it goes to the next machine which is waiting for the path with open arms. It welcomes to the part and starts performing the operation. So the element of material handling time involved has considerably reduced this system. That is the reason why these systems are much more efficient in terms of production time. This is what it is. Here as some of the advantages of flow line production system which we are talking about today. The first advantage is the smooth flow of material from one work station to the next.

(Refer Slide Time: 18:38)



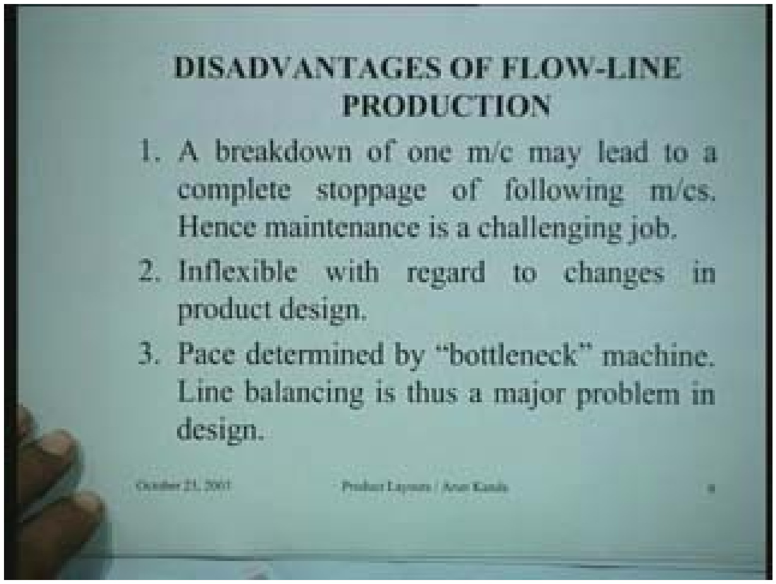
I just like to point out that this flow need not only be linear. You could have material flowing like this and then coming back like this and then going in this direction and then coming here. So it is like a serpentine flow especially when there are constraints on space you will find that this kind of flow takes place. If you see for instance any television assembly unit probably go to LG or some other place, you will find that the operators are set like this and then set like this and then set like this. So they accommodate many more people and this is also an assembly line. Moreover the flow could be a straight line. It could be U shape flow, it could be this kind of a flow or it could be even be circular flow. The idea is that depending upon the space but the crucial thing is that smooth flow of material from one workstation to the next takes place. So this is one of the features. Since work is fed from one station to the next small in process inventories result. This is another major advantage because directly the piece is going from one workstation to the other. So there is a much need for having in process inventories between the two stations.

(Refer Slide Time: 20:26)



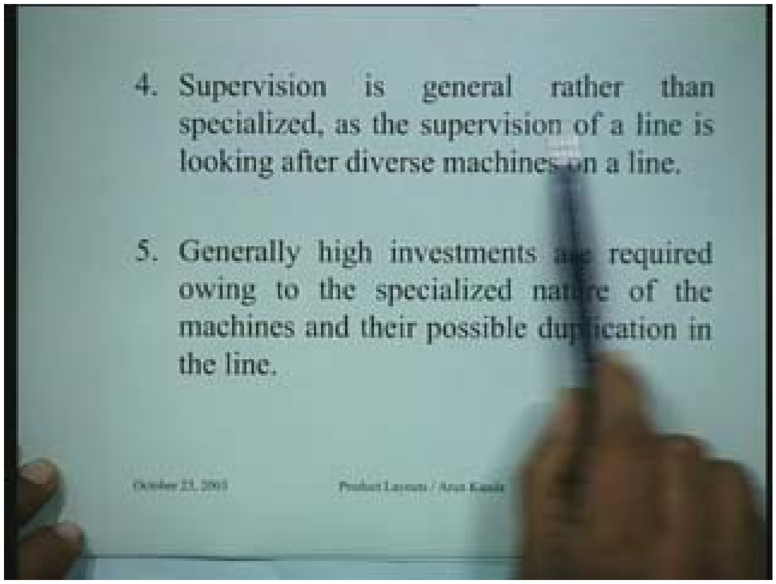
Though of course there could be some times some inventories between the stations in the form of buffer stops for some reasons. The total production time per unit is quite short for reason that we just mentioned. There is reduced material handling, little skill required by the operators. Hence training is simple short and inexpensive. Why because the operator is doing very simple kind of things. This job might be to pick up the piece from here, operate a foot pedal where it is held and then take the compressed here. Then probably release it and send it the next operation. So he has to do a couple of things which can probably be landed in half a day. So training is quite simple and inexpensive unlike the training for a process layout. In a process layout you might have a lathe operator. Lathe operator must have proper training. You should be able to read the vernier calipers. You should know how to operate a lathe. You should be at least an ITI trained person and so on. Greater problems are there. In the product layout production planning and control systems are simple. Less space is occupied by work in transit for temporary storage, obviously because we have less. So transit storage so that kind of space is not really used to appear. Whereas if you happen to work flow process layout, work through for instance what you find is typically pasting are storm all over the place. So you probably might not have space to work through the whole thing. You have to mind your step as you step from one costing to the other and you know because of the storage, there is something like this. It could not happen at least in a product layout. It could happen only at the end. The process layout of course, you will have a where house. All the cars are stopped and therefore that is a different thing.

(Refer Slide Time: 23:02)



Some of the disadvantages of flow line production are that a breakdown of one machine may lead to a complete stoppage of the following machines. Hence maintenance is a challenging job here. This is a very significant thing because if you happen to be in charge of an assembly line, you got to make sure that the line is running all the time which means that is, if there is a request, if there is a breakdown then maintenance staff has to be on the job constantly doing this job. This is relatively in flexible with regard to changes in product design. We cannot keep on changing the product design here. The pace of the line is determined by the bottle neck machine line. Balancing is thus a major problem in design. Obviously different operations workstations take different amounts of time to process the part. The overall phase of the line will be determined by the source machine. Therefore you would like to have as far as possible fairly constant times for all the sections, all the workstations. This may not be possible for various reasons but at least that is the intention.

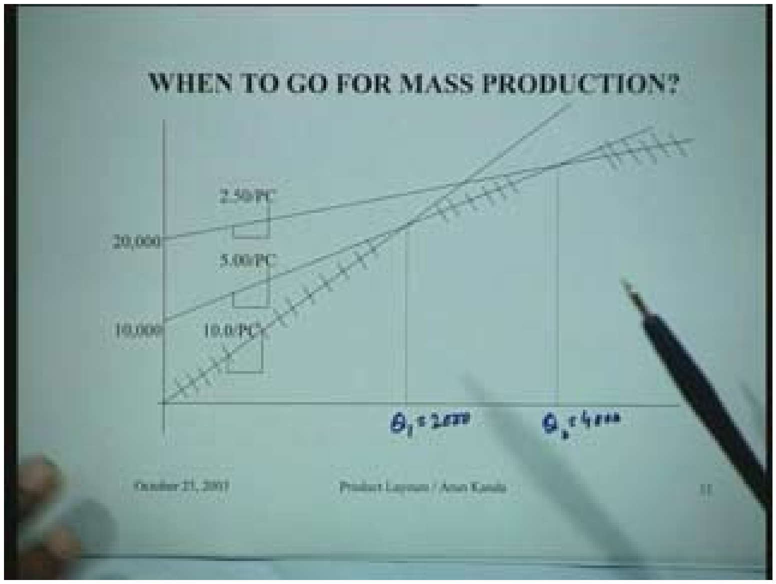
(Refer Slide Time: 23:52)



.

Supervision is general rather than specialized as the supervision of a line is looking after diverse machines on a line. Compare this with supervisor for a process layout. If you have a supervisor, let us say in the lathe section that person could probably have spent ten years in the lathe section and could be familiar with all the machines. We can probably open out each machine and assemble it, that kind of thing because all are lathes and he has considerable experience. But this could not happen because you have one lathe, one milling machine, one some special kind of machine and so on. So all machines are distinct in the line and you don't expect any person to be specialized of all of them. Generally high investments are required owing to the specialized nature of the machines and their possible duplication in the line. So this is also possible here. Now having understood the features of an assembly line, let us see for instance we want to go for mass production. Indecently you must understand that this decision is primarily economic decision. So just for the sake of argument you might say for instance, suppose we have three options, we can either purchase the path that we are interested in making for ten rupees a piece and just keep buying it that is it or we can invest 10,000 rupees and set up some general purpose machines are individual stations as the case maybe. Then we will be able to make a path on our own for 5 rupees a piece and the total cost will then be the fixed cost and the variable cost could be of this nature. You might say that I can spend and make a heavier investment of 20,000 rupees or whatever it is it is.

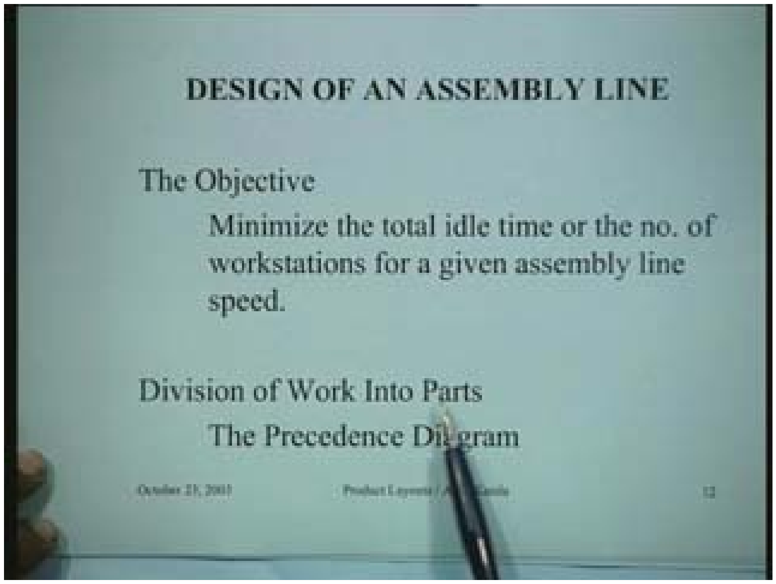
(Refer Slide Time: 27:54)



Then maybe we can produce the part for 2 rupees 50 paisa per piece and it will be like this. Now through a simple break even and analysis, for instance you can find out these two quantities quantity Q_1 and quantity Q_2 here. This is very simple for instance in this particular case what could be the break even quantity here for this particular situation?
I mean what we are saying is what could be the break even quantity here this is like trying to say 10X is = 2000. So what we can therefore say is that we can directly determine this quantity. Let us call this quantity as Q_1 and which is that is say 2000 here. Then you find out the tradeoff between the other two options that is between the option of buying at individual stations and the options of setting of a full assembly line. So what could be this value 4000 mean?

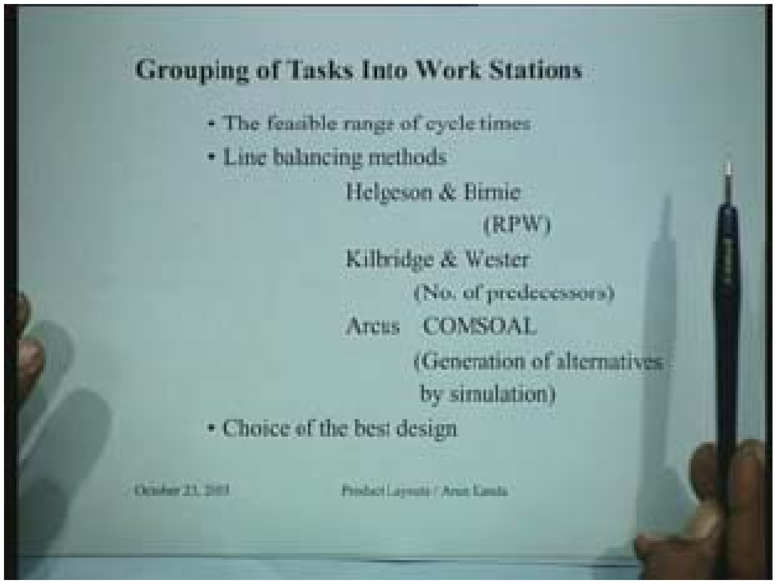
This Q_2 is 4000 of this simple analysis tells you something very interesting or it says is that the least cost option is the one which is shown here. Therefore if you have demand that happens in the range of up to 2000 rupees, it is better to be just by the part from outside, that is the cheapest option here. If you happen to be in the rage of 2000, your demand happens to be in the range of 2000 – 4000. The best thing could be to goal for this intermediate option because it will be cheaper in this case and it will be worth wise to set up an assembly line only if your quantity of production demand happens to exceed 4000 rupees that is all. So you can get quantitative answers to the questions of finding out what could be the best thing to do under various circumstances. So in this particular situation we could go in for assembly line only if it is 4000. What might happen in real life is suppose your current demand is 3500 somewhere here whatever it is, and then obviously you can think of the feature. You are expecting a growth in the next year; it might be worth while to set up an assembly line considering the fact that you are going to cross this barrier of 4000 in the next year and so on. So these kinds of decisions actually have to be taken before you make this decision of trying to find out whether you should go for mass production and when you should go for mass production. So it is essential. Let us now talk about the design of the assembly line.

(Refer Slide Time: 29:11)



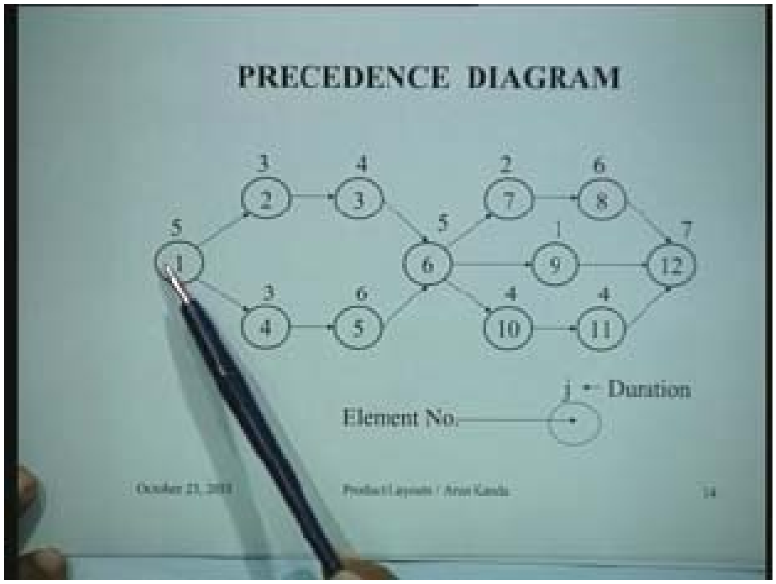
What is the objective in the design of an assembly line? It is basically to minimize the total idle time or the number of workstations for a given assembly lines speed. The basic information that we have at disposing such a situation is that we are dividing the work into parts and this division is known as the precedence diagram. So the precedence diagram is basically projection of what other parts have to be, the components of the parts that have to be done in overall products and in what particular sequence. Once we have done this development of tasks, the basic design of the assembly line is actually done by grouping the tasks into work stations. Before we do this exercise we have to know what the feasible range of cycle times is.

(Refer Slide Time: 29:56)



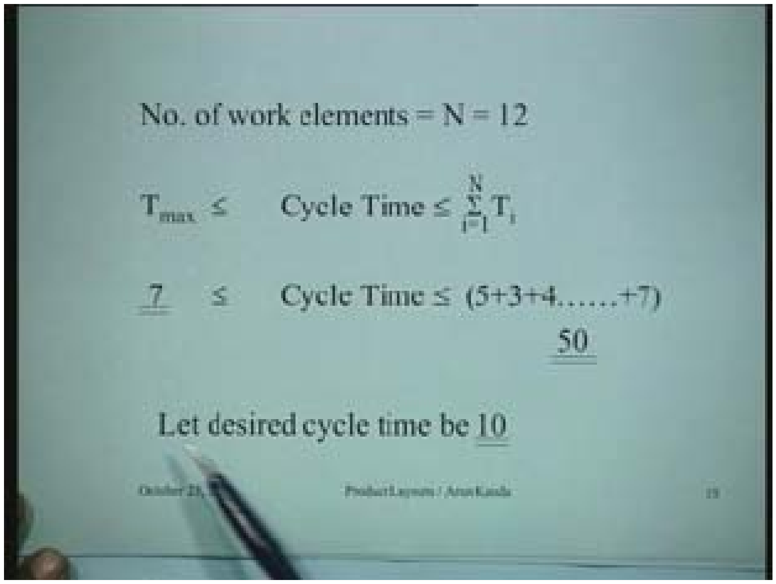
We will see the feasible range of cycle times through an example. It can be determined very easily as something which lies between the maximum time for an operation and some of the times for all the operations. Then there are many algorithms available for the line balancing process. We have a procedure due to Helgeson and Birnie which is quite commonly known as the rank positional weight method. We also have a procedure due to Kilbridge and Wester which is based on the number of predecessors that means priorities are decided based on the number of predecessors. There is a procedure due to Arcus called COMSOAL which is a computerized method for sequencing operations on assembly lines. The basic philosophy in this procedure is the generation of alternatives by simulation and once you generate a large number of alternatives, you evaluate them and take the one which have you think is best. Once we have generated a large number of options, the next stage is choosing the best design. Choice of the best design obviously depends upon things like balance delay and ideal time for the operation should be minimum. So this is a broad set of picture of assembly line design procedure. Let us now take an example. What we have here is a precedence diagram and the precedence diagram shows that 1, 2, 3 and so on up to 12 are the individual operations or tasks.

(Refer Slide Time: 31:58)



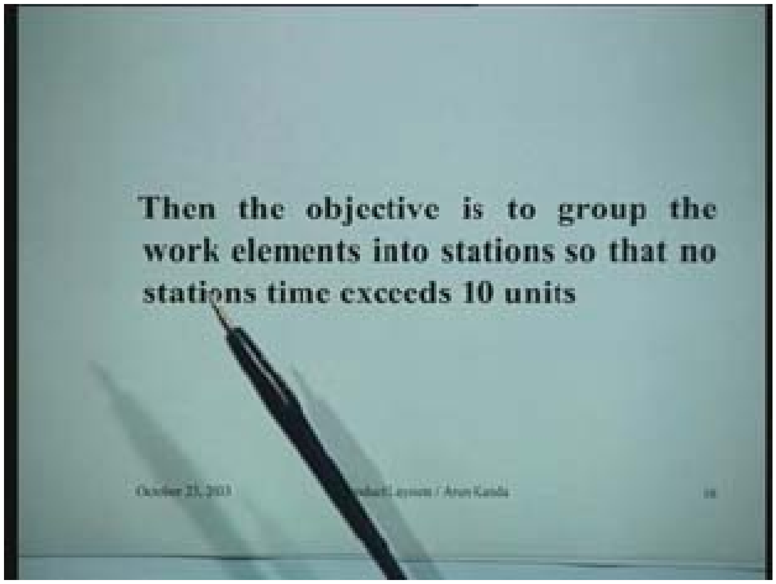
We are assuming these tasks cannot be further divided. This could be like drilling a hole. So obviously drilling a hole cannot be divided into drilling one quarter of the hole and then draw in the next quarter of the hole. So this is that one particular operation which is indivisible. So we have divided the entire tasks in to the twelve operations and this network diagram shows the precedence requirements that are operation one has to be performed first. Then two and four can be performed, similarly six can be performed only when three and five are over in that sense. The figures here refer to the duration of each task. So the duration of the tasks could be determined by a time study or whatever other procedures you have. You know the time required to do this individual task. From this we would like to possibly design an assembly line. Let us see how we can design an assembly line manually for this operation and then we will compare it by using the rank positional weight technique. Now clearly in this particular case we are going to group these operations. So one thing is clear, the maximum time that is required for any operation is seven and the minimum what is the total time required for all the operations could be some of the times of all the operations which is fifty. This clearly means that any assembly line for this precedence diagram will have a cycle time which will range between seven and fifty. This defines the limit on the cycle time for any design. In this particular example, the number of work elements is 12, the cycle time will live between T max and summation Ti is = 1 to N so seven is the bottle neck operation.

(Refer Slide Time: 33:59)



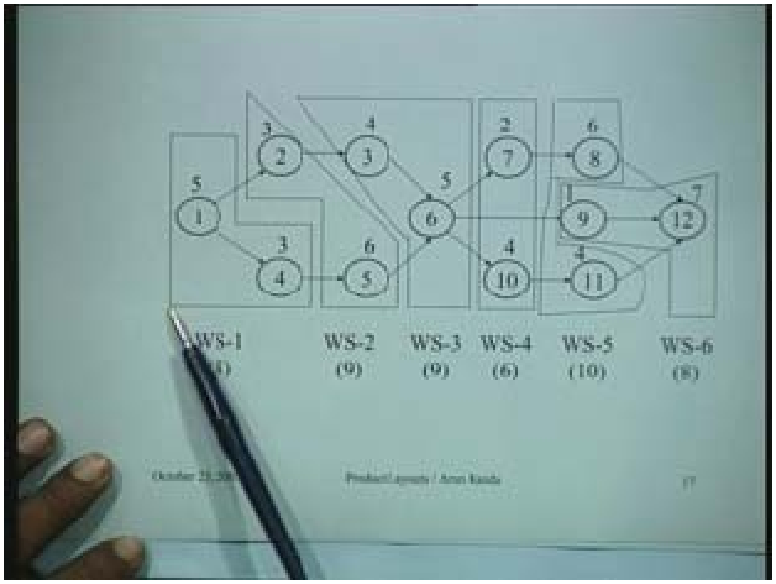
The operation which takes the longest time in the cycle time will therefore live between fifty. Now you talk about the desired cycle time. A desired cycle time must be somewhere between these two operations between these two limits. So let us say about desired cycle time is ten. How does the desired cycle time come about? It is based on the market demand. It depends upon how many you want to produce per day so cycle time is determined accordingly. This is something the marketing people would be actually telling you if there is a demand for so many cars per day therefore your cycle time should be search. So we say that the desired cycle time is ten and we have this, so this cycle time should be within this range. Obviously if the cycle time happens to be more than fifty, what is going to be the implication? The implication is that you don't require an assembly line. Your cycle time happens to be more than fifty itreally means that you require a piece that is 60 minutes. What you can do is you can gain one percent, he will do all the tasks in 50 minutes and still have ten minutes free with him. You do not really heed to set up an assembly line if you are in this particular range. You can use that person for ten minutes and you can do something else. You don't need here and on the other hand if your cycle time is less than seven what are you going to do? Suppose my demand is search there I need a cycle time of five or three. On this side you need multiple lines on this side, you have one line and beyond this you don't need any assembly line. So this gives your clear idea as to when you need and how many lines.
So let us take for this example a situation that the desired cycle time is ten. This is now feasible and it should be between seven and fifty. Let us now try to find out or design the line for us.

(Refer Slide Time: 36:26)



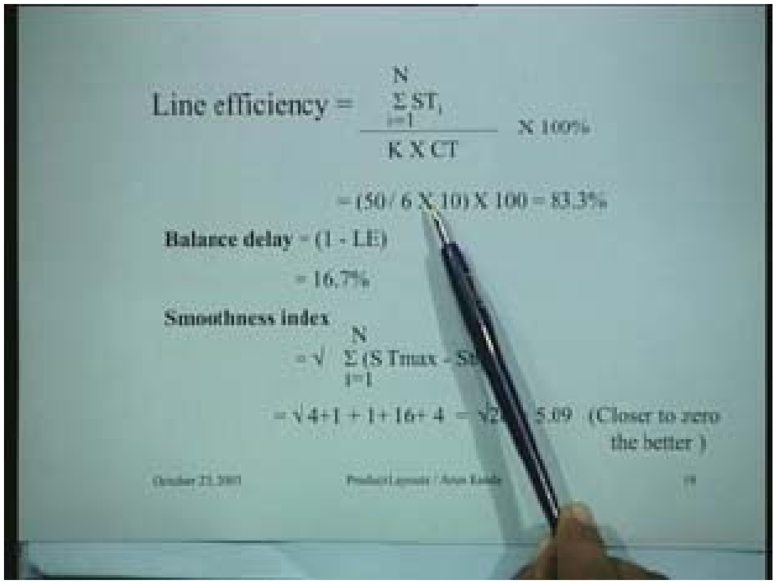
What we are basically trying to do is our objective is to group the work elements into stations so that no stations time exceeds ten units. That is what we trying to say because if it exceeds ten units, our cycle time will be more than ten and we are designing the line for a cycle time of ten units. How do we attain this? We could do it by inspection and no algorithm. Just look at the precedence diagram and this is the feasible solution what we can say is I can club these two operations one and two and this takes five minutes, five seconds or minutes whatever with the unit of time five + three, so the workstation one will take eight units of time.

(Refer Slide Time: 37:06)



I should not exceed ten. This is now three and six, so this takes a time of nine. This one takes four + five which is nine. This takes two + four which is six, this takes six + four which is ten and this takes seven + one which is eight. What we are able to do is by simply grouping parts, now what is the objective in grouping? In grouping, some of the time must not exceed ten. So I have six workstations. What is the workstations I have exactly defined? What is to be done at this workstation? I t means the persons going to sit at workstation one will first do a operation one and take five minutes and then do operation four which will take three minutes thereby taking a total of eight minutes here and so on for the next operator in the next operand. So I have a design of an assembly line which as six operators and we exactly know what each operator has to do. This is basically the idea of an assembly line which we just date by simple common sense logic which we can do this one. However to evaluate how good this design is you could need some performance measures. You can have for instance if this is the bottle neck operation you can have two machines here in parallel and each machine will have a in mean effective time of only 3.5,in that point of view and then your bottle neck will be maybe six this will be six which will be the bottle six as you can work that way also. Are you can look for a superior machine which instead of taking seven minutes we will take etcetera and whatever is your requirement. So for this particular example that we just worked out we can calculate something called the line efficiency. What is the efficiency of this line and this is nothing but the summation of all the station times.

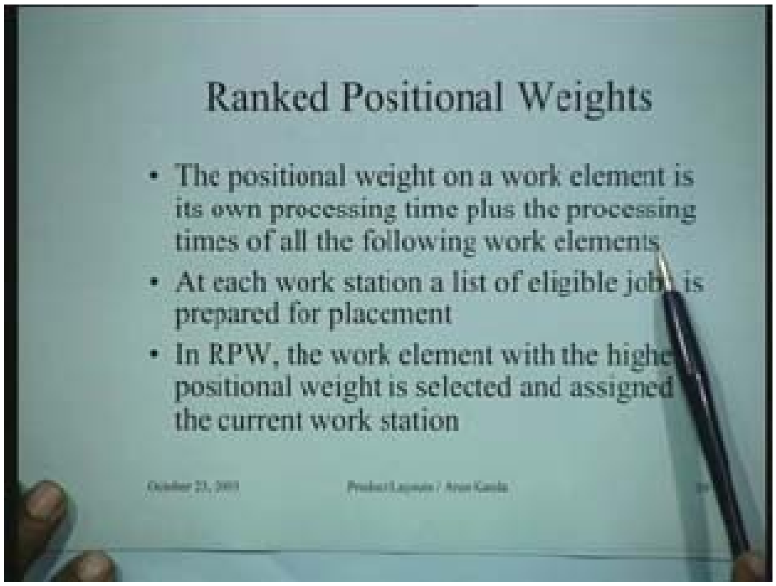
(Refer Slide Time: 40:04)



Summation of the station times will be nothing but the total time for all the jobs so you have fifty divided by K. K is the number of workstations the number of workstations that we have got a six into the cycle time of the line is ten. Notice that the cycle time need not be always ten because when you are doing this grouping you are constrained by saying that it should be less than ten. So just we have got lesser than here. Suppose this value and then only eight then our cycle time could have been nine although we started to design a line for a cycle time of ten. So we have here ten and then of course the line efficiency works out to 83.3 percent. One minus the line efficiency is called balance delay. It is a nature of the inefficiency of the operation really. So it is a nature of the idleness of the different stations. When we talk about idleness, what you see out of a total of ten minutes, this value is idle for two minutes. This is idle for one minute, one minute, four minutes. This is not idle at all and this is idle for two minutes. So we would like this idle time to be as small as possible and ideal situation could be, the line is perfectly balanced that everyone is doing the same amount of tasks. That is generally not possible. Why? Because the times are integral number one and then you have a constraint and precedence. We cannot group everything into everything else.

You are not way for instance raise that you can put something here and make it exactly two hundred and fifty grams. It is not possible to do that because you are dealing with these individual entities which have to be grouped together. So the balance delay is 16.7 percent and the smoothness index for this is a is a term for an assembly line which is nothing but the this is the idle time ST max, maximum station time that mean that is the cycle time minus Sti, which is the station time of the ith operation and whole square. So it will be for each operation. So what we have to look at is this example, idle time here is two. So two square is four and here it is nine, so this idle is 14 + 1 + 1 and this is sixteen because the idle time here is four. Four four sixteen no idle time here and then four. So root of twenty six which is 5.09 and closer to zero the better if a line is perfectly balanced this smoothness index will be zero. So we try to minimize these smoothness index so we have got measures of the efficiency of this design, you got a line which has an efficiency of 83.3 percent. Balance delay of 60.7 percent and a smoothness index of 5.09, this is what we have. Now let us see how we can use one of the standard procedures available. We will discuss the so called ranked positional weight method for developing the line.

(Refer Slide Time: 43:29)

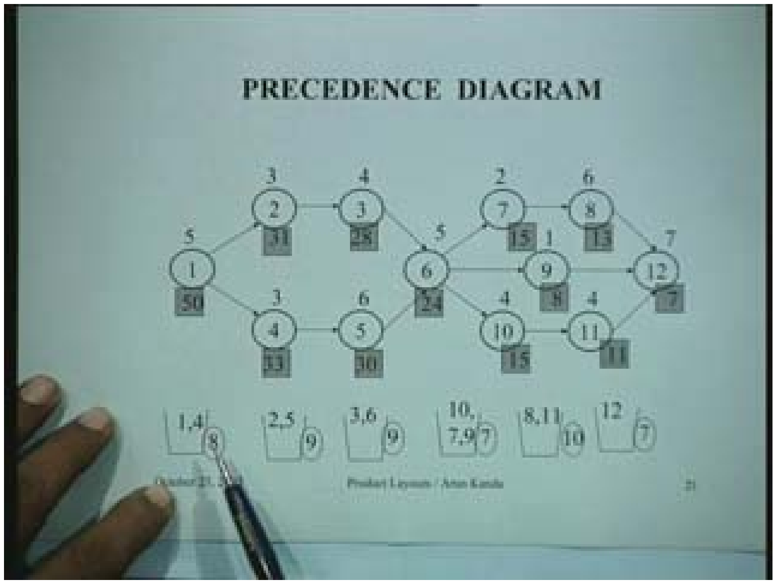


We will compare the design with the design that we had obtained by induction as it is possible. So the positional weight of a work element is its own processing time plus the processing time of all the following work elements. We define a positional weight for each element in the precedence diagram by same, that this is the time of that operation plus times of all operations which follow it. The basic idea could be that the total positional weight will give you an idea, how much time it will take, at least to go to the end from that operation that happens to be the idea. This is used subsequently in defining your priority for assigning jobs to workstations that is the only thing. At each workstation a list of an eligible job is prepared for the placement. In the rank positional weight technique, the work element with the highest positional weight is selected and that is why it is called ranked positional weight is selected and is assigned to the current workstation. So that is the basic logic of the RPW technique. Let us try to apply this technique to the example that we are considering earlier. What you notice in this precedence diagram is the same precedence diagram that we have. The times are shown on top of each operation but the figures are available in the squares at the bottom or the positional weights. Let us look at them. You start calculating the positional weight from the back. So what do you see is for operation number twelve the positional weight is seven because this will take only seven units of time?

You come to eleven then from eleven, this is the operation and this is the following operation for this. So seven plus four eleven will be the positional weights for this elements. Similarly thirteen is the positional weight for this element which is six plus seven; similarly for nine the positional weight will be what follows it which is seven plus one which is eight. When you come to job number six for instance what happens is it is not necessarily fifteen plus eight plus fifteen that will be the positional weight for this, that the point that you have to get. It is all that these jobs are successors of this job. So the time required two plus six plus seven plus one plus four plus four, the total time required for all these jobs is twenty four if you add the five also and therefore this becomes the positional weight for this particular job. For job number three, the positional weight will be simply whatever follows this plus so twenty four is the positional weight here twenty four plus four which is twenty eight. Similarly here is going to be twenty four plus six which is thirty. Thirty plus three thirty three thirty one twenty eight plus three is thirty one. When you come here obviously it is going to be some of the all the jobs which come to plus five. So the total positional weight is fifty here. So the numbers that we have computed here can be computed in one run starting from the back and coming to the front and getting these particular numbers. Now these numbers will define and will actually tell us how to determine then try how to go about designing the assembly line.

See designing an assembly line is now based on these numbers and this is how we proceed. For instance you start with a first basket which is the first workstation. You open the first workstation and at the first workstation this is the only job which is eligible because it has no precedence relationships. So one will be put there and the moment you put one, we have consumed five units of time and two and four are again candidates for placement. But out of two and four we will take four because it is a higher positional weight. So we will put four here and once we put four here, one and four will consume a total time of 8 and we can go up to a maximum time of ten. There is no other job available at this junction which can be accommodated within this. So we close this particular workstation with work time of 8 units and proceed to the next station.

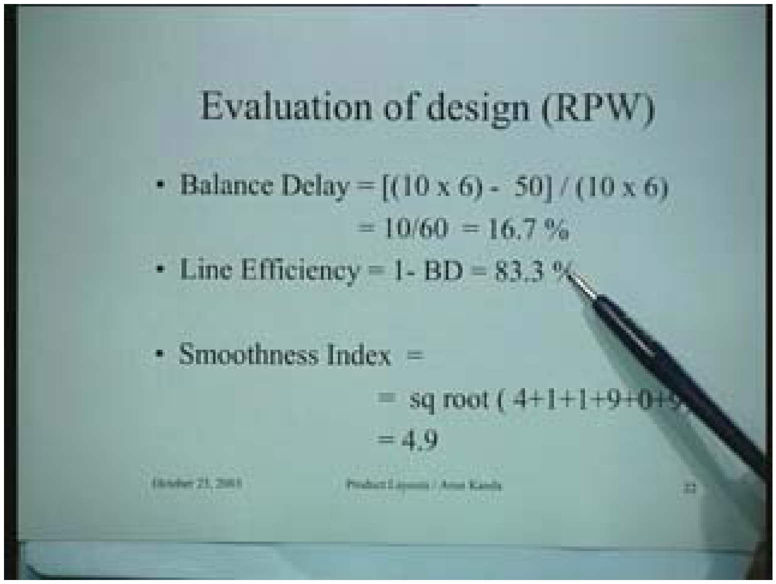
(Refer Slide Time: 48:03)



When you proceed to the next station, this has been placed. There are two jobs completing for placement in this particular work station. This 1, 2 and 5 and out of these, this one has a higher positional weight so we take two and place it first. When you place two, three can be placed too and five can be placed but out of the two this will get a priority. So it can be accommodated because the total time is going to be only nine, so you can put this. You keep proceeding in this particular fashion and you will keep on filling these buckets. The movement you cannot enter anything more into this bucket you open the next bucket. So we are now at the first workstation, the second one, the third one, the fourth one, and fifth one and sixth one. So in this design two we have been able to determine the six workstations and also the operations which are to be done at these individual work stations and these are the cycle times. Since this has the highest cycle time which is ten that means this particular line will now operate for a cycle time of ten, as we have decided earlier.

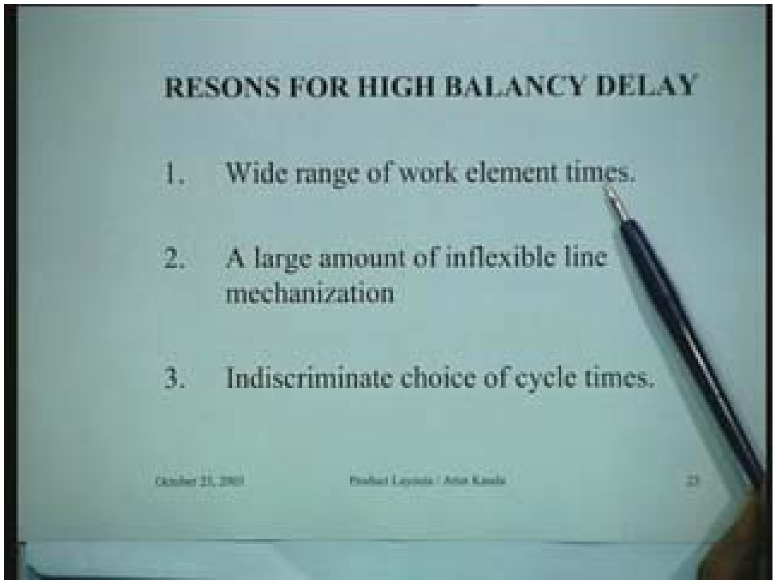
So what we can do is we can look up and can try to evaluate this particular design. We can see for instance that the evaluation of the design by the RPW method. Again the balanced delay in the line efficiency of the same is because the balance delay and the line efficiency are determined by the number of workstations. In this design also you have six workstations in the previous design and you get six workstations. So practically what is the minimum number of workstations? How will you calculate this? You have fifty which is your total work content and your cycle time is ten, fifty by ten which five is.

(Refer Slide Time: 49:54)



Ideally you can work with the theoretical minimum number of workstations are five but in the two procedures that you have just adopted, we could not we could have these individual operations into five workstations. So the balance delay is 16.7 percent. The line efficiency is 83.3 percent and this particular case. However if you look at the smoothness index, there is an improvement in the smoothness. The smoothness index is found for this design. Look at the ideal times here, 2 2 square which is 4 1 square which is 1 1 square which is 1 3 square which is 9 0 and 3 and 3 squares which is 9. The square root of this is 4.9 is an improvement on the earlier smoothness index that we have. It means this is slightly better balanced line as compare to the previous one. So we can therefore look at the precedence diagram and from the precedence diagram depending upon the RPWs, depending upon the positional weights, we can determine how to fill up these individual workstations and come up with design. Subsequently we can evaluate the design in terms of the three major parameters, balance, delay, line efficiency and the smoothness index for these particular situations. The question now is what are the possible reasons for high balance delay? Balance delay measures the inefficiency line; inefficiency means the degree of idle time which is there for the various operators.

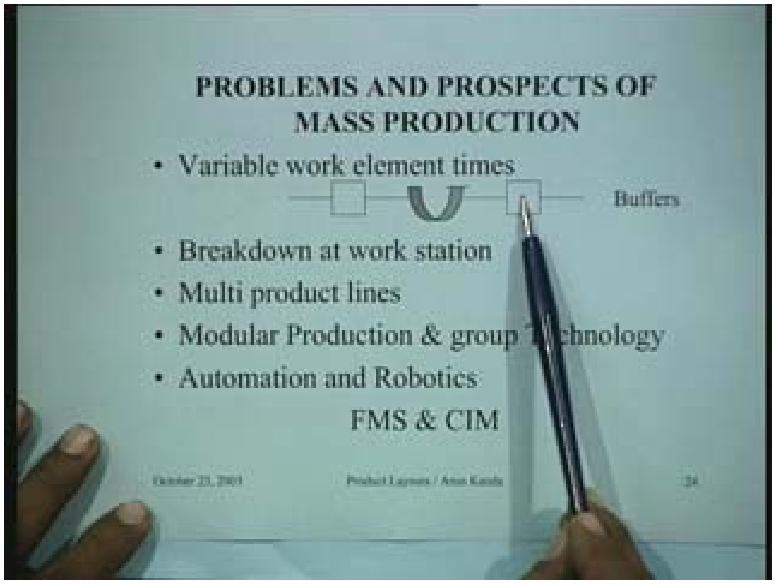
(Refer Slide Time: 52:11)



Some of the reasons for this are:

1. The wide range of work element times. What can happen is for instance in your example the work element times will not be constant for all the operations. If all the work element time references in one each or even smaller than this one, then you could combine them into getting any operation time. But this does not happen. Some work element time maybe only one unit second, work element time might be 12 units and you have to take it as it is because the operations are not further divisible.
2. Another possibility could be a large amount of inflexible line mechanization. What might happen in the practical design situation is that you already have a line and you already have a great degree of mechanization. So when you have placed some machines at certain stations which already perform a certain number of operations, you are actually constrained by putting in those operations and that particular point although might not result in the best balance delay. This could be another reason.
3. Then indiscriminate choice of cycle times could also lead to high balance device. What it means is if you know that in our example we consider the feasible range of cycle times was from 7 units to 50 units, a wide range is in it. So you could attempt to do a line of cycle time of let us say seven or a cycle time of ten or a cycle time of fifteen or cycle time of whatever it is. If you do that then for different cycle times, you will probably not get the right time. You might get a high balance delay. These are at least some of the reasons why you have high balance delay. Let us now look at some of the problems and prospects of mass production. You see for instance that one of the major problems of mass production is that the variable work element times. We have designed the line based on deterministic times but if an operator is doing a manual task then it is quite likely that the task time is normally distributed with certain mean and certain variance. So sometimes you operator will take less some times the operator will take more. Then you will probably find that there could be starvation for these subsequent machines in that sense of the term.

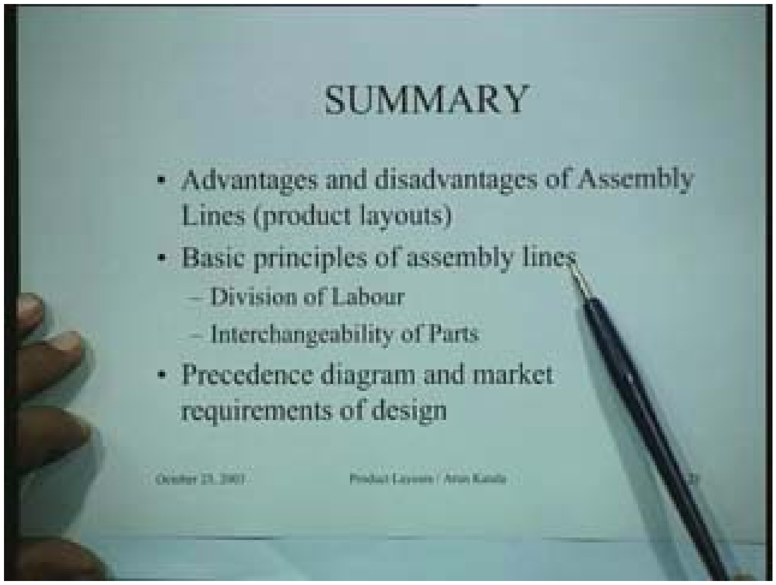
(Refer Slide Time: 54:58)



What is done is in order to deal with this problem sometimes buffers are provided in between the tasks. What can happen is even if this fellow is slow, or this machine is slow, this particular person can keep on operating from these buffers. So this is the variable effect of the variable work element time. In fact this problem of finding out the optimum buffer is an optimization problem. A problem which can be determined and then there could be a breakdown at a workstation. If there is a breakdown at workstation what will happen? Since the line is all connected, where there is a breakdown they will be flooding of parts and beyond that there will be starving of parts. All the other machines will be start. So that is why you have to get back into operation as early as possible and we said the maintenance stop has to be very quick.

There could be multi product lines that mean the same line can produce multiple products this can happen. For instance in Maruti udyog the same line can produce a Maruti 800, you can also produce a Zen because what we do is we change some operations and something can be done. So designing multi product lines means that you can handle the same thing. We can also talk about modular production and group technology which is an alternative to assembly lines. This means that you can talk about grouping parts in a certain fashion. So that you can achieve modular production and cellular manufacturing which will try to capture the advantages of both product and process layouts and that is the basic feature of cellular manufacture and of course automation and robotics have their role to play. When you are talking about assembly lines, many operations can be automated. You can have robots performing many of the operations. Typically for instance in automobile manufacturing you find that robots perform this operation of spot welding of various sheets and components and we can also use FMS and CIM systems to perform and automate and programs and some of the operations that have to be done. Finally let us try to summarize what we have tried, what we have done in this particular class. We will try to look at the advantages and disadvantages of assembly lines or products layouts. We have seen the basic principles involved in the design of assembly lines.

(Refer Slide Time: 57:44)



We found that the basic principles involve things like division of labor and interchangeability of parts. Contributions by Adam Smith and by E Whitney help us operate the assembly line and then we saw that the assembly the precedence diagram and market requirements of the design are the two major inputs you need for designing an assembly line. So you need the precedence diagram and the desired cycle time, the rate you would like to produce the part at. We could like to do the grouping of elements in a product layout. This could be done by various algorithms. We mention some of them and we actually looked at the RPW procedure in some detail. We found that they were measures and efficiency like balance delay line efficiency and smoothness index for a line and finally we talked about some of the emerging concepts which could be in the nature of multi product lines. The provision for a buffer automation and worker empowerment is a very important concept, originally given by the Japanese which allows the operator to run the line at his will. That means you can stop the line when there is a problem. All the workers get together and they repair the line and then they go back to the respective places in from the line. So these are some of the concepts which are there for productiveness. I think with this we have been talking mainly about the strategic aspects of design of a production system in this course. Now we will go over to the operational decisions which are relevant in a production system. We talk about the problem of forecasting aviate production planning and planning production system.

Thank you!