**Project and Production Management**
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Lecture - 32
Computerized Layout Planning

Today we shall be talking about computerized layout planning. If you recall, last time we had talked about the layout planning problem in general. See how process layouts could be designed. In this particular lecture we are going to look at some computerized packages which are available for solving this problem of layout planning. We will see how exactly they help us in developing layout. Brightly speaking layout planning packages that are available could be classified into two broad categories. We could talk about a call construction programs and we could talk of a call improvement programs.

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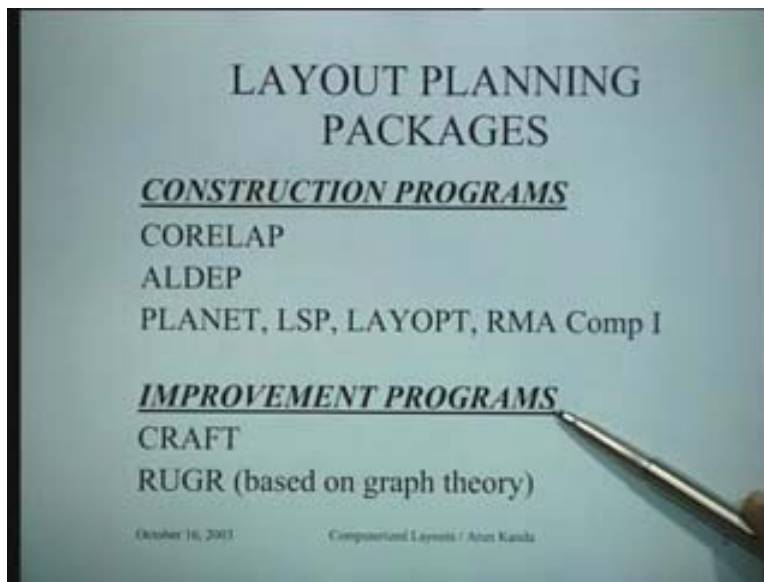
Construction programs are those programs which try to generate the layout plan from a scratch, that is you don't need any initial layout as an input, that depend by utilizing the information that is available about the layout. You can generate a layout from a scratch and the important programs in this category are CORELAP, ALDEP, PLANET, LSP, LAYOPT, RMA and COMP 1. These are all commercial names and we will look at one particular type of construction program in detail that is ALDEP which was one of the early programs that came on the scene. It summarizes the mechanism by which the layout plans can be generated. On the other hand when we talk about improvement programs we require an initial layout of the system as an input. What really these packages do is that is that they tend to improve upon the layout and some of the packages that are popularly used or CRAFT and RUGR. This particular package is based on graph theory. So we will try to look at one of these packages, the more popular one namely CRAFT in some detail

in today's lecture. You get a flavor of one of each of the programs in the category of construction and improvement programs. Let us look at ALDEP.

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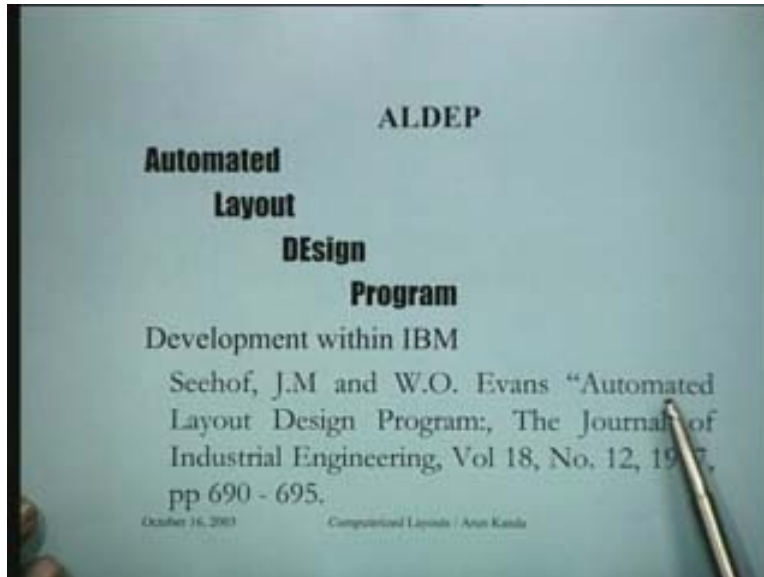
ALDEP incidentally stands for automated layout design program and it was developed within the IBM. This is the original reference of the particular package. It was a paper by Seehof and Evans, the two people working with IBM, who developed this program. The title of the paper is an automated layout design program. The journal of industrial engineering volume 18, number 12, 1967, pages 690-695. The basic idea behind ALDEP was that it is based on the activity relationship chart. If you recall the discussion that we had in the last lecture about systematic layout planning and the procedure for systematic layout planning, we saw that after computing the material handling relationships you assigned certain activity relationships between all pairs of departments. These activity relationships are called A for absolutely essential, E for essential, I for important, O for ordinary closeness is okay, U for unimportant and X undesirable.

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ALDEP based on closeness Ratings

A	4^3	=	64
E	4^3	=	16
I	4^1	=	4
O	4^0	=	1
U	0	=	0
X	-4^5	=	-1,024

Can handle 63 departments on 3 floors

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So ALDEP is based on this scheme and this very scheme is subsequently used for purposes of scoring different kinds of layouts. These are the values numerical values given to these numbers. So it is 4 to the power 1, 4 to the power 2, 4 to the power 3, so this should be 4 to the power 2 here and 4 to the power 3. The X which is highly undesirable requirement between two departments is given in negative score of –4 raise to power 5 in that sense. So these are the numerical ratings that come. Essentially this is rated in a logarithmic scale in that sensibility. ALDEP has a capability of handling 63 departments on three floors, when the package is operated. Let us see the scoring pattern of ALDEP. What is being done when you are scoring a particular layout? For purposes of scoring the layout, you develop; you set up, divide the entire area into equal size squares.

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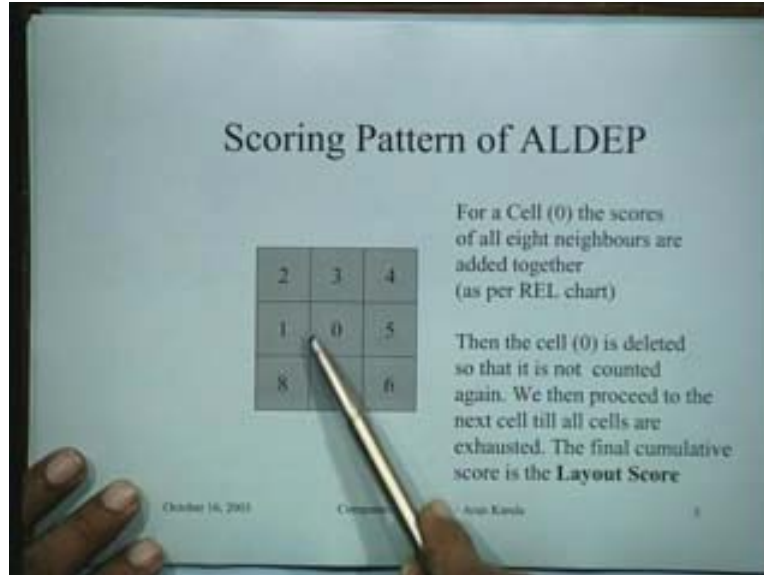
What could happen is that if you looking at one particular square, let us say we are focusing on cell 0. Each cell will have 8 neighbors which are shown here. So for cell 0, the squares of all the eight neighbors are added together as per the REL chart, which means if cell 0 belongs to a certain department, and this belongs to the same department, then there is a low contribution to the score. But if this particular thing belongs to another department which has an A rating with this, then depending upon the value for the A rating, you will have that much score coming out of this interaction. Then similarly for 5 and 0, similarly for 0 and 6 and all these values 0 1, 0 2, 0 3, 0 4, 0 5, 0 6, that means all the neighbors of this particular cell could be evaluated and could be given marks. Then after having done that cell zero is deleted so that it is not counted again. So you can put a cross on cell 0 and go to the evaluation of the next cell in the whole scheme of things.

I evaluate all the neighbors for that particular cell and keep on adding the values there, so we then proceed to the next cell till all cells are exhausted in the entire space and the final cumulative score is the layout score. So this is the basic procedure by which ALDEP assigns a score to a layout. I would like to mention here that ALDEP is based on a lot of random features and the basic advantage of having these random features is that you run the program and a second time you will probably get a different layout and a different score. So if you run the program in number of times, each time you will get a different layout with the different score because of the randomness which is built into the program. So obviously if you run it, let us say hundred times you can always select the layout which is the highest score. So that is basically the idea in using ALDEP. Here at the input requirements for ALDEP, what is the input needed? You need the length, width, and area requirement for each floor on which you are going to do the layout and as I indicated to you ALDEP has a provision for handling layout problems on three floors.

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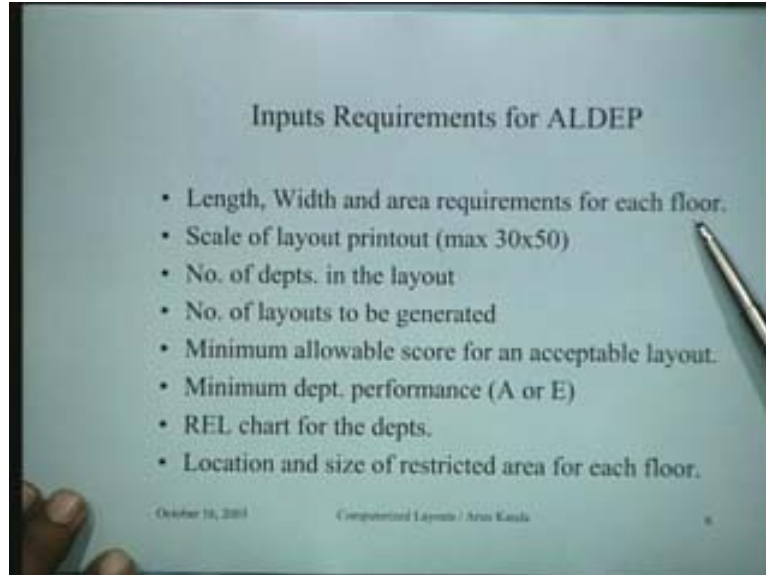
You have to specify the information; you need to specify the scale of layout, printout, which is generally maximum of 30/50. You have to specify the number of departments in the layout, you have to talk about the number of layouts to be generated. I indicated to you that large number of layouts can because generated and each time you generate a layout you can get a different layout and you can get a different score. The purpose of this particular exercise is to try to get a layout with the highest score. So in order to cut down computer time, you specify a priory what is the number of layouts that you like the program to generate whether you want 20 layouts, 50 layouts and so on. Then a minimum allowable score for an acceptable layout can also be fed. In the beginning when you run the program for the first time you have no idea what it is. The program generally runs in that the first time you generate ten layouts and maybe the highest score is 120. So in the second time when you run the program, you can specify the minimum allowable score for the layout as 120 and run the program again and maybe on the second run you generate 20 layouts and the highest score that you generate is maybe 250 and the third time you specify the minimum allowable score as 250.

Suppose you don't get any layout that means the best layout is the one with the score of 250 that you have generated earlier. So that can be the typical stopping criteria for ALDEP, the minimum department preference can be either A or E generally. What it means is that if department is already placed in the layout, the next department which you pick up for placing adjacent to that department should have a high activity relationship with that particular layout. It can be specified as A or E, you need the REL chart for the departments. You need the location and size of any restricted area of each flow. So these are essentially the requirements for running ALDEP in that scene. One other feature of ALDEP is how it places the departments in the layout. What it does is that suppose this is the area in which you want to develop the layout,

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Vertical Scanning Pattern for placing depts. in ALDEP
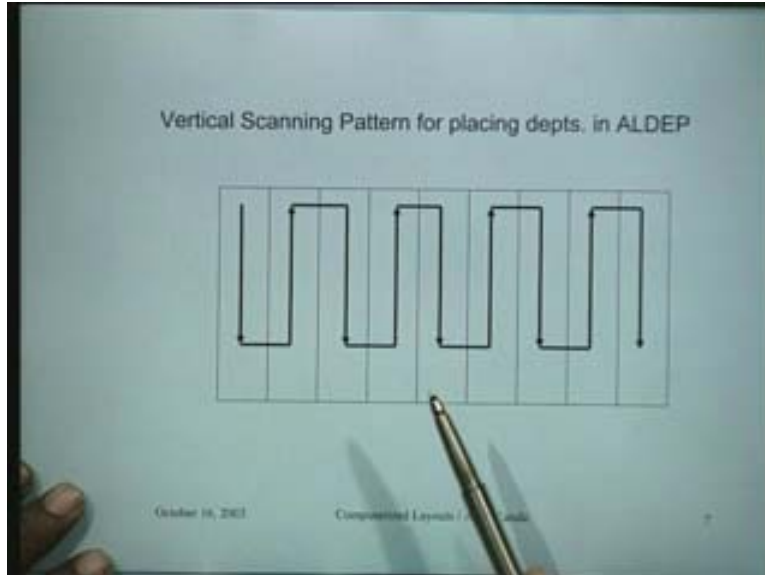
what it essentially assumes is, it assumes that there is a constant width and suppose you want to locate a department, it is like saying this is the width of sellotape. Let us see and you keep on unrolling the sellotape in this direction and you know the area of the departments, so you can find out what length of the tape you need to represent the area.
So you can represent the area in one way and then once you come to the end, you can start putting the tape in this direction and in this direction and in this direction (Refer Slide Time: 13:09) tell you, follow this scheme. So this will you give a manner by which you generate the layouts. This pattern is known as the vertical scanning pattern. So we are vertically scanning the area and taking a strip of the required size and putting it there, and then the next department comes from here and we put it there and then the third department and then the fourth department and so on. This is the mechanism that is adopted in ALDEP for placing with departments on the shop floor.
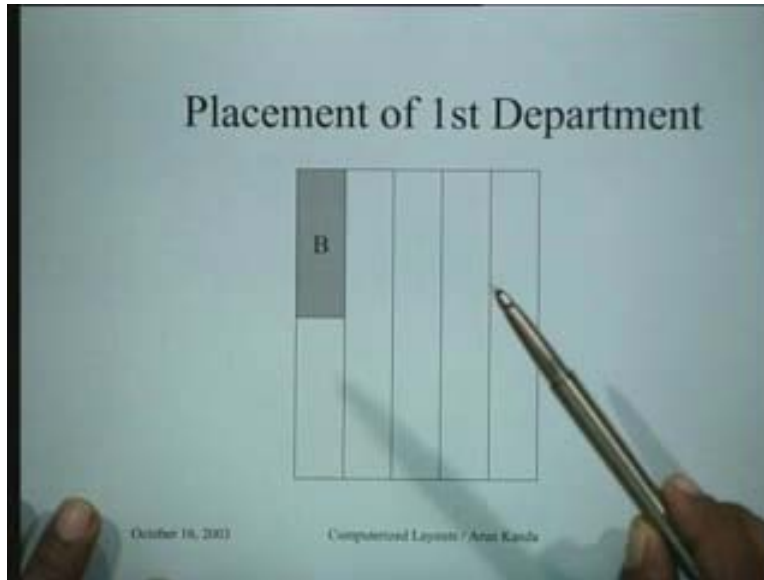
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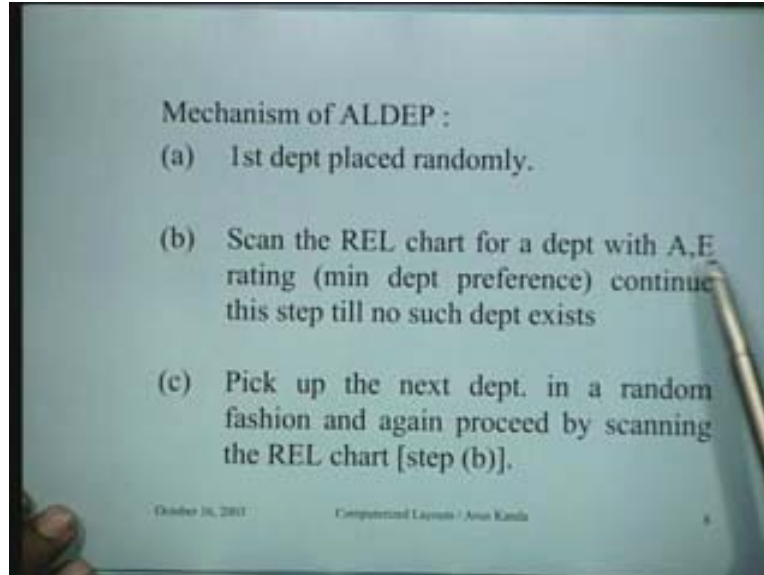
Here is a brief glimpse of the mechanism of ALDEP that is the algorithm that is followed by ALDEP. The first step is, the first department is placed randomly. After having placed the first department, the second step is to scan the REL chart which you have, for a department with A or a E rating, that is the minimum department preference, whatever is specified and continue this step until no such departments exist. So what happens really is that you place the first department at random and then you have to pickup another department which has a close rating. That means when you are trying to locate friends in a hostel, you locate the first person randomly and then you pickup a second person who is very friendly with the first person and place him next. Then again put the next person who is very friendly and the friendliness layout is being determined by the ratings A or E on an REL chart. Once you find that no such departments exist, in the A or E rating in the REL chart, then pick up the next department in a random fashion.

Take the example of locating friends in a hostel, once the friends have been located, we don't find a friend. We took up any random person and put in next and put in next and keep on doing this exercise. So pickup the next department in a random fashion and again to see by scanning the REL chart which is the step D. We can continue with this exercise till we develop a layout. Now let us try to get an idea of what the whole thing looks like if you follow this procedure of ALDEP. We start with the available space, we want to locate let us say, there are four departments, let us called them A, B, C, and D and we want to locate them in this particular space. What is going to happen is we are going to the constraints by this width, we are imagining that each department is cut out on a strip of constant width and we will cut out the length depending upon the area of the department which we know and we will allocate that in this. From this we pick up a department at random. Picking up a department at random can be done very easily by using random number table and we can generate a random number table in the computer. Suppose the random department that we pick up is department B so we place department B here and this length is such that this satisfies the area requirement for department B.

After having place the first department using this vertical scanning pattern, we are now looking for placing departments next to it.
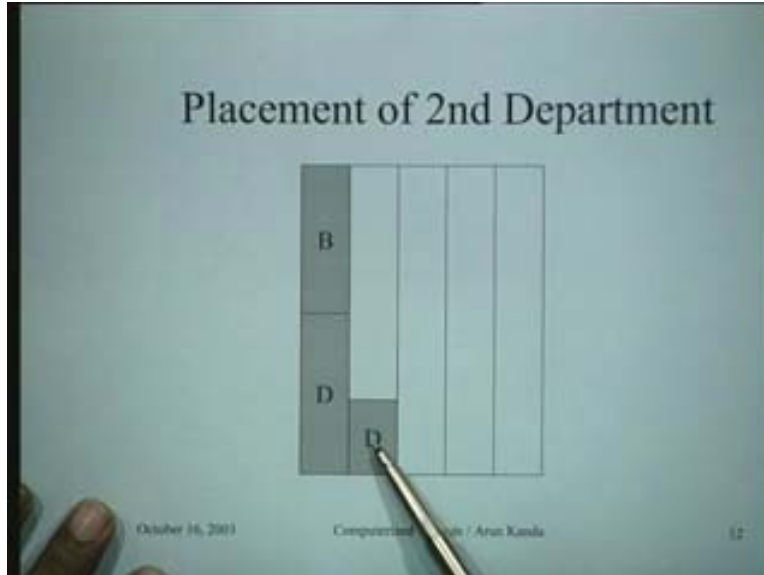
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Placement of 1st Department

What we do is we look for in the REL chart for a department which as at A rating or a E rating with department B. Suppose we find such a department, what we do is suppose the department is D, what we do is we place D like this (Refer Slide Time: 17:28) but then the space is over. So then ALDEP says that you place the department D and you cut the strip like this and finish it off here, then you are accommodated by the entire area of D.
So now at this stage we have placed two departments B and D on this particular thing and we are now looking forward to placing the third department. As for as the third department is concerned what we could do is you could again scan the REL chart and try to find if there is a department which is friendly with D depending upon the minimum department reference.
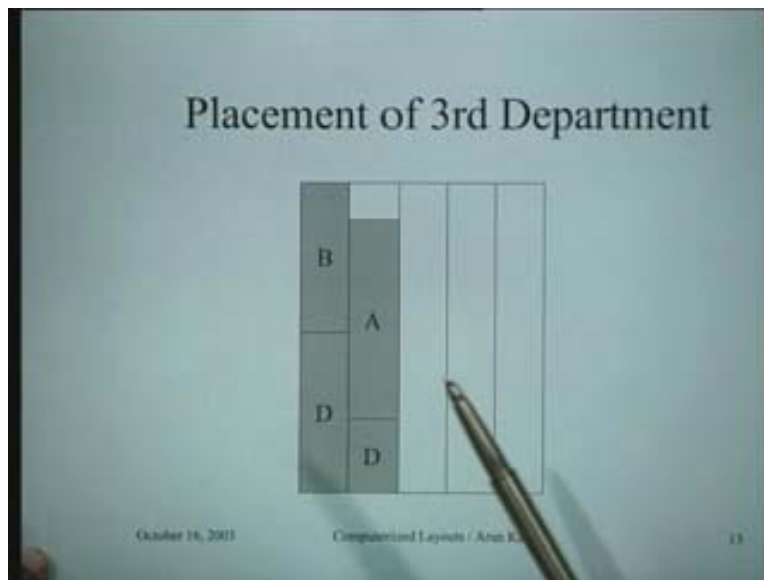
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So based on that information suppose in this particular situation department A is a department which is picked up for placement, we place department A depending upon its requirements here.
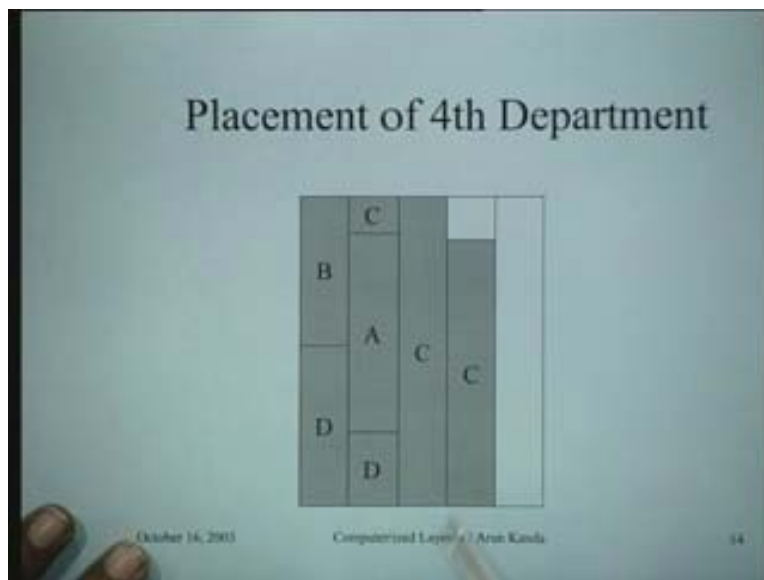
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We are now enable to place three departments in the layout and then the next department is in fact, we are talking here about the fourth department that means there are around four departments and only one department is left. That particular department has to be the one which has to be placed next that is the department. In ALDEP what is being considered is only that A has a friendly rating only with D, which are placed next to D.

Also another possibility that can happen in the process of placement is A and B might not get along well. But that is not taken care of in ALDEP. That is a limitation or a drawback of ALDEP. If you keep on following this vertical scanning pattern it may so happen that you have placed department A next to D. But the neighbor on the size might not get along well or might have a low weighting with this. But the beauty of ALDEP license is simplicity, and there is no idea or there is no attempt in this particular procedure to gain and optimal solution. Moreover since the program can be run again and again at the different random numbers, you are likely to get different layouts and each one can be scored and determined by this. But this could remain a major limitation of ALDEP. If there are two departments with A rating, you take one at random in this step, any one at random. Now finally we talk about the fourth department. The fourth department is C.

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C is placed here (Refer Slide Time: 20:23) and suppose it's a big department it goes on like this and then it goes on like this and finish is here and you will find that the shape of the department is something like this as for as C is concerned as a consequence of 7the vertical scanning pattern. Now this in fact could become if there only four departments to be located our final layout right.

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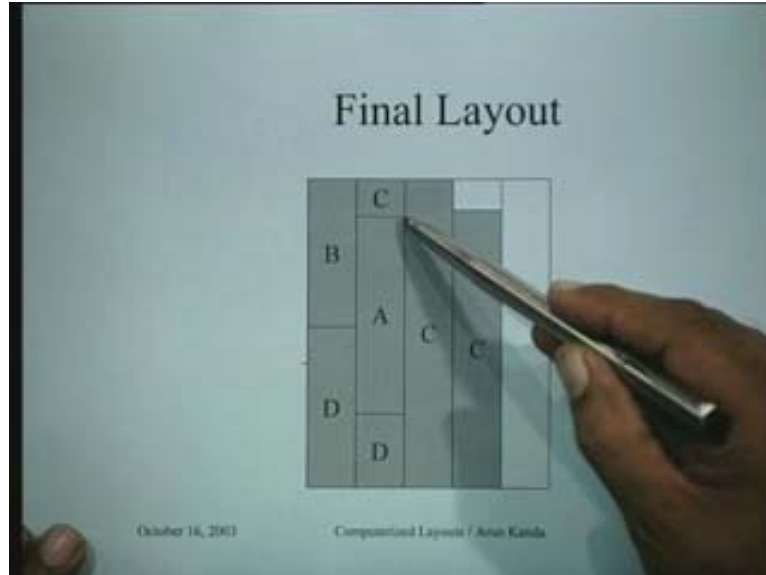
So let us see the final layout and let us try to make some comments on the final layout that you get in ALDEP. You know a few ideas and how it operates. It has elements of randomness built in to it so that the starting department could be different and depending upon the starting department other departments could keep on changing in subsequent runs of the program. You notice that departments need not necessarily have rectangular shapes, functions. Look at department D. D has a very peculiar shape and no company would like to have a department which could have this kind of a shape. I don't know, Similarly, you look at the department C. C has a very peculiar shape which is it is a jetting position here. Then you have something like this. You have C as a funny shape so one of the features or one of the drawbacks of this particular procedure is that you land up with departments and some of the departments maybe non rectangular, of course some are rectangular. B is rectangular, A is rectangular but some of the departments could be rectangular. Another thing which happens is that the final boundary need not necessarily be rectangular. It could be rectangular; it could be rectangular of the total area.

The total area of the departments is equal to the total space that is available. So if you make a provision that you want to locate the department and exactly a certain space and you make sure the total area is the same, and that area you divide into strips, then of course it should happen. But if you just layout something in the area then the final boundary that you get is also very peculiar. Therefore this could give you some insight into how ALDEP actually operates in terms of generating the layouts. It uses a very simple principle of that scratch state or the edge state, you keep cutting the departments according to the size and pasting them there. You keep on and it is basically the simulation of what ALDEP really tries to do. You take different widths but there is no guarantee it is a heritage trial procedure. You do not know exactly what could be the size because what can happen is the department may finish here and the second one might have to end up somewhere else. So there is no guarantee that this could happen. What could happen is that all departments which have an x rating are generally placed

randomly in this case. So they could be coming anywhere, but in this particular case the placement of C is governed by its relationship with A which is you know where you cut of the tape last and then place. So obviously you could always have situations where certain departments could be negatively placed with regard to other departments. This is essentially a serious limitation. But I think the purpose of the exercise of ALDEP is you choose one of the early programs that came on the scene. It shows that by using simple logic and by using the concept of randomness you can generate different types of layouts. Also because of this randomness you could run this program and number of times to get alternative layouts. Then you could pick up the one with highest score and that was the basic idea. So the idea was never to find out an optimal solution.

An optimum is to try to find out the best from amongst the one that you generate. Another feature another program that we talk about which is the construction program is CORELAP which incidentally stands for computerized relationship planning.
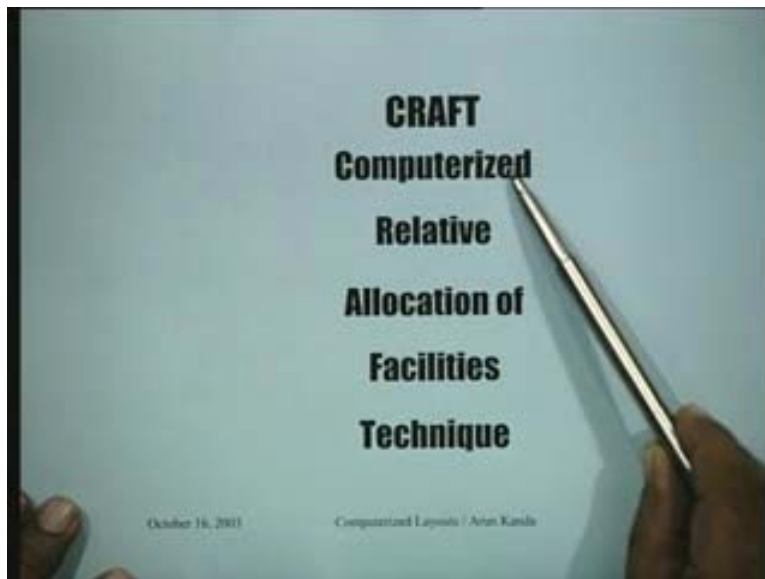
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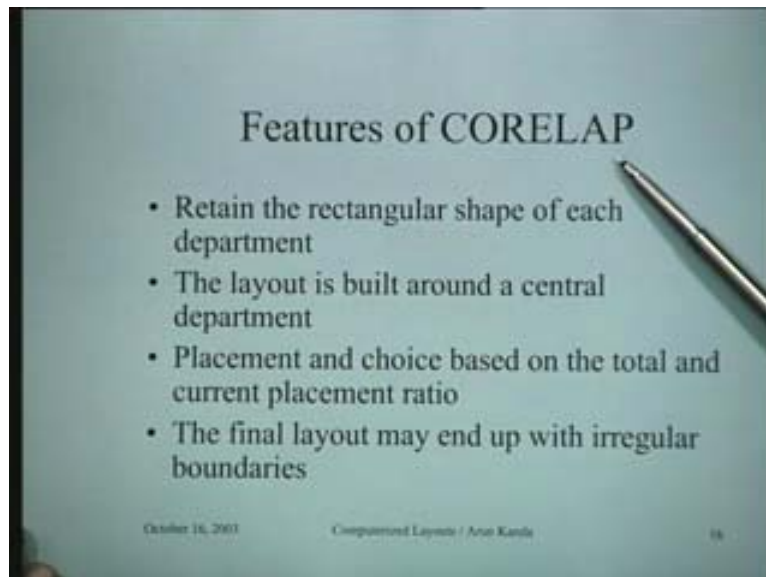
Now you see what happened was that one of the major drawbacks with ALDEP was non rectangular shapes. So in ALDEP what was done was that each department shape was, fixed first. The V_1 department A has to be rectangular, department D has to be rectangular and so on. So you fixed up the shapes like that. Then what was done was you pick up a department at random. It is based on what is called the total closeness rating. If the current, the total placement ratio or the current placement ratio, which means essentially that the department is placed centrally first and then around that you build other departments, if I place a block in the middle and then I take another block which one do I take depending upon the relationship diagram? Some calculations are based on that and you take that block and I can place it anywhere along the boundary, I find out in place it along the boundary. Where should I place it? In that particular point whichever is the best, you place it there. Then you have a block of two departments. One department and then followed by the next department and then it has shown boundary,
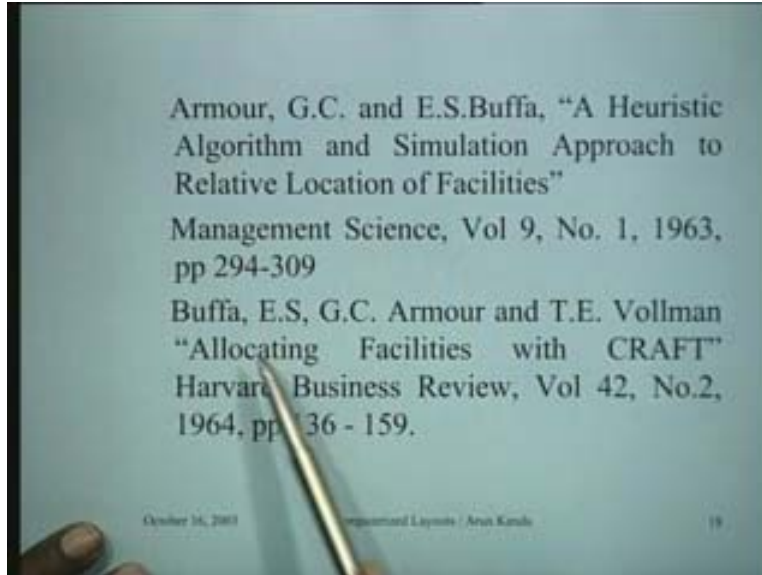
then you pickup a third department and place it along that boundary of the two departments. You place it somewhere and according to the placement you are getting the best value of the objective function and so on and you continue like this. So this was the attempt in CORELAB to experiment with rectangular shapes and the layout is built around this central department. The placement and the choice ratio is based on the total and current placement ratio. We will not go into that because you can always device other objectives or other criteria and matrix to choose that particular department. The final layout in this case also may end up with irregular boundaries. Even if you have different departments, you start with rectangular department. You place another one and ultimately there is no guarantee that the boundary of the whole thing will be rectangular. So at least you have rectangular department, but irregular boundaries could result. So this is the basic feature of CORELAB which is another program for construction program which generates the layout from a scratch. Let us now talk about the other category of programs which are used and we will talk about CRAFT.

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CRAFT is a procedure and stands for computerized relative allocation of facilities technique.

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Armour, G.C. and E.S.Buffa, "A Heuristic
Algorithm and Simulation Approach to
Relative Location of Facilities"
Management Science, Vol 9, No. 1, 1963,
pp 294-309
Buffa, E.S, G.C. Armour and T.E. Vollman
"Allocating Facilities with CRAFT"
Harvard Business Review, Vol 42, No.2,
1964, pp 136 - 159.

CRAFT was actually a procedure that was developed by Vollman Buffa and a Sturet. Buffa was the professor of the University of California at Los Angeles and he had written a book on Modern production management. Most of you have heard about that book. These are the original references for it. So it was basically, he involved Armour and Buffa, a heuristic algorithm and simulation approach to relative location of facilities. It was the first paper which appeared in management science, volume 9, and number 1963, pages 294-309. A second paper based on this was by Armour and Vollman just like saying that Armour was the first person to introduce Betech with him and Vollman in the next batch did that project with him. He heard this paper called allocating facilities with CRAFT; he published the Harvard Business Review volume 42, number 2, 1964, in pages 136-159. These two papers actually give you the details of this particular procedure called CRAFT. Now we look at this procedure. This particular procedure, before we take an example of CRAFT is actually an improvement type algorithm. So an improvement type algorithm means that you have to specify an initial layout for the departments. All that you do is you try to fertile around with that layout and try to find out that better layout exists. The objective function is being chosen and CRAFT is minimization of the material handling effort. You could recall that it is quite often the design of process layouts. The material handling effort is a major problem. The intention in designing this layout is actually to minimize the total material handling effort involved. This is an explicit attempt by the origin of CRAFT. Look at the material handling effort and we try to reduce it in developing layout. Let us look at the major inputs required for this particular package. If you recall the systematic layout planning procedure, it says what the various inputs are? These inputs are pertaining to the product process and schedule. So let us take an example and in this example what we find is that we are dealing with three products.

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Product, Process & Schedule Data

| Product	Processing sequence	Daily production	No of items in Trolley	Trolley loads/ day
1	ABCBCD	100	5	20
2	ACBD	50	5	10
3	ACBCBD	200	40	5

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Let us call them 1, 2 and 3. Suppose a company is interested in making these 3 products, and let us suppose that the processing sequence, that is the process information for these products. It has to first start with starting department A, then go to B, then go to C then go to B again then go to C and then finally come out the department D. So the processing sequence is fixed by the nature of operations required of product 1. Let us say the daily production is 100 units and these are all products which could be of different sizes. But in terms of material handling effort we could like to combine this information in the form of common material handling units. So you can talk in terms of trolley loads per day because the material is moving in the factory in let us say trolleys. So what we are trying to say here is that the number of items that can be accommodated in this trolley for product 1is modified, similarly 5 for product 2.

What it means is that product 1 and product 2 are roughly of the same size. As far as this product is concerned this is much smaller in size. So 40 products of this size can be accommodated in the same trolley and our unit is movement in trolley loads. So this is what it is and this is the daily production. We can determine the number of trolley loads that we will see in moving of these products in the factory. So 100/5 is 20 trolley loads per day and will be moving of product 1 and 50/5 that is 10 trolley loads will be moving of product 2, 200/40 that is 5 trolley loads, only 5 trolley loads will be used to carry these items because these are rated in small items. So these could be very small items and these are relatively bigger items. So you need only 5 trolley loads nutced loads that you need something like that which can be carried in only 5 trolley loads per day. So the information that you need is the input information in that we are making 3 products. This is the sequence of operations of these products and each of these products will require a total movement of 20 trolley loads, 10 trolley loads and 5 trolley loads per day in the plant. So we know the total quantum of movement in the plant. Second thing that we need to specify as an input is the initial layout for the plant for the sake of simplicity. We

are assuming that the four departments A B C and D are initially laid out in equal squares as shown here. So this is the initial layout A is here, B is here, C is here and D is here.

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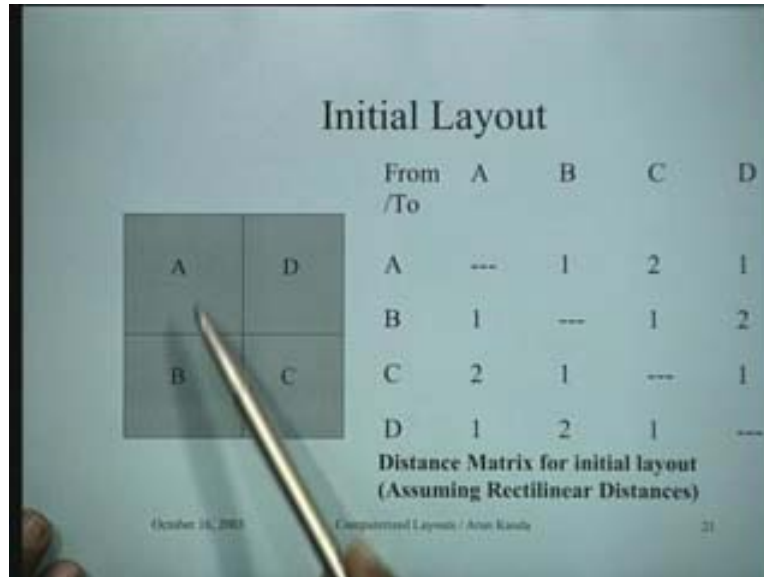
So the four departments are located here in equal squares. For this particular layout you can easily determine the distances between the various pairs of departments. For instance if I go from A to B I have to travel a distance unit of 1, we are measuring distances between the centralized departments. We are assuming for instance that the side of each of these squares is 1 unit. So A to B is 1 unit, A to C is 2 units because I am assuming that you will have to go like this from A to C, so 2 units from A to D is 1 unit. Similarly B to A is the same as A to B. Here we are permitting a 2 way travel, so B to A is 1, B to C is 1 and B to D is again 2 units and similarly here. So this matrix this 4 by 4 matrix is actually nothing but the distance matrix corresponding to this layout. If I change the layout obviously, the distance matrix will change. So this is the distance matrix for the initial layout which is what we are assuming here. A B C D is placed here and we are assuming that rectilinear distances are involved. That means I am going from here and here and not this way. So I am talking about movement using rectilinear distances. So this is the information pertaining to the initial layout. What we can then do is determine a matrix known as the load matrix for this particular information which is the total quantum of trolleys which are moving between all pairs of departments.

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How do I compute this information? This is the load matrix. What is the load moving between all pairs of departments? Take for instance; this particular value which is from A to B. What happens is look at the product process in schedule data. What you find is the only movement from A to B is this one; A to B is here, there is no other way from A to B movement here. So A to B is the total movement which is 20 trolley loads per day. So I enter this 20 trolley loads per day. Similarly I look at A, it to C, what happens in A to C, look at this diagram again, A to C does not occur in the processing sequence of product one. But you have A to C is here and A to C here. So the total movement from A to C is going to be 15 units. So I put 15 units as the movement that takes place from A to C and there is no movement from A to D but you have the first movement from B to C.

Look at the movement from B to C, there is a movement from B to C here and there is another movement from B to C here and there is another movement from B to C here. So it is going to be $20 + 20 = 40$. $40 + 5 = 45$ trolley loads are going to be moving from B to C, that is what you are going to see in the class. From B to D just look at B to D, there is no movement from B to D here. There is B to D here and there is B to D here, the total movement is 15 trolley loads. So this is 15 i.e., the total movement from C to D. Similarly you can see from C to B movement here and from C to B movement here and from C to B movement here and a movement here. C to B is 10 from here, $10 + 10 = 20$ here, 20 and $20 = 40$ here. So that is talks about the movement from C to B. There is another 5 here because C to B occurs 2 times. So it is 45 and the movement from C to D is 20.

So the idea is how to construct the load matrix?
A load matrix is actually summarizing the total movement that takes place between all pairs of departments and you know the number of trolley loads moving, for instance you find that the maximum movement takes place between B to C and C to B. Thus, this gives you the hint, the hint is obvious that these two departments should be close to each

other. If you want to minimize the material handling effort that is what it is. So we construct this load matrix. The next thing we do is that we might have a unit cost matrix. Unit cost is nothing but the cost in card in transporting between different pairs of departments.

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You could be using different methods of material handling between departments. So between A to B, it could be manual and between A to C it could be some kind of motorize to earlier something of that kind. So the cost might be developed. Similarly say B to A is manual, B to C is manual and so on. But C to A could again B motorizes to early something whose cost is double. So you have a matrix which we call the unit cost matrix, this is an input to the problem. Still we are trying to identify the major inputs to the problem. If you have for instance all movements taking place by the same material handling equipment, then this matrix will be all once and you can in fact forget about this matrix. What we do is we construct a matrix by multiplying the load with the unit cost matrix multiplying element to element.

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So what will happen is this was 20, 15. So we have because the cost here was 2, this becomes 30, so 20, 30, 45, 15, 45, 20 is what we call the flow matrix. The flow matrix is determined by multiplying the loads moving with the unit cost. So this is the flow and you can say that if you take this summation of each row what you get is from A, totally 50 units are moving from B, total of 60 units are moving from C, total 65 units are moving and there are no units moving from D. Similarly to A, is coming to B 65 units are coming to C, 75 units are coming and to D 35 units are coming. If you are a vacant row or a vacant column what it shows is, if I have a vacant column like A it shows that A is a source. If I have a vacant row it shows that this is the C, so basically in this problem A is your raw material store and D is your finish goods store. Everything starts from A so there is a movement from A and as far as D is concerned everything is settled down in D for further transportation to customs. So this matrix is called the flow matrix incidentally for this problem we have to construct the flow matrix only once. We have to construct the flow matrix because it summarizes information pertaining to how much flow is taking place between all pairs of departments and we have a 4 by 4 matrix which summarizes this information. Now for the initial layout what did we have? For the initial layout we said that our initial layout is, the 4 departments are placed A B C and D this way.

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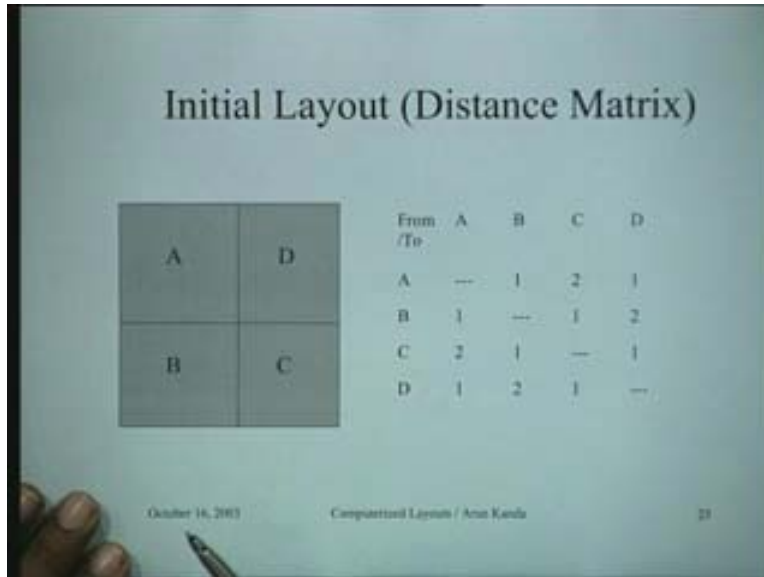
So this was the distance matrix for that particular layout. For instance between A to C there is a distance of two, otherwise similarly B to D is a distance of two, C to A is a distance of two, all other distance is and D to B is also a distance of two and all others are one. Now we utilize this information pertaining to the distance matrix and we compute what is called the material handling effort for the initial layout. So the initial layout is the flow matrix, this matrix that you are seeing is what we are computing.

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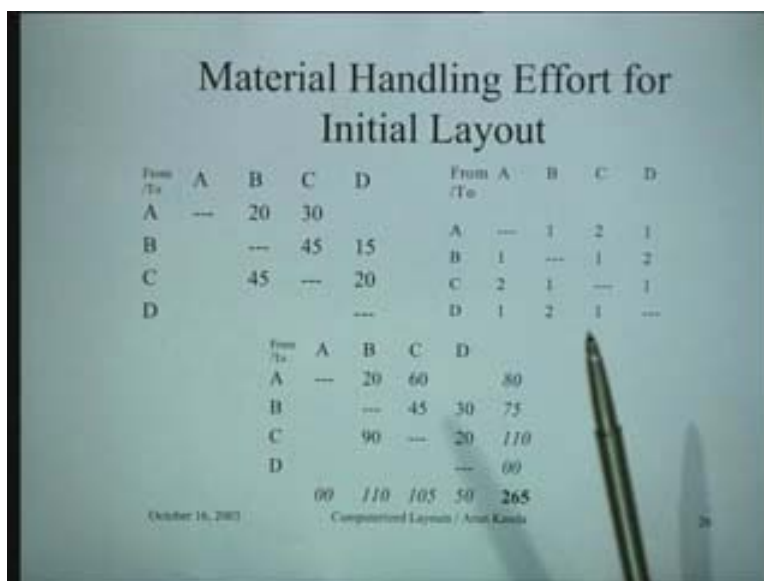
This is the distance matrix for this, so we multiply the flow matrix of the distance matrix. We get the material handling effort. For instance we get the material handling effort A,

20 into 1 is 20, 30 into 2 is 60. Similarly 45 into 1 is 45 and 15 into 2 is 30 and so on, so you get this particular matrix here which is the material handling effort. This is what you are interested in compiling ultimately and then you can sum the rows and the columns. If you so desire actually you need to sum only one of them to get the material handling score. So this is $20 + 60$ is 80, 75, 110 and 0 take the sum of this column which is 265. What is this? 265 is load into distance. It is like saying I move five trolleys for a distance of let us say 100 meters. So load into distance is giving me the total material handling effort, so this is my objective function. This is the crucial value that I am interested in this particular case. So this value has arrived, let us recapitulate now. It has arrived at by taking the flow matrix, multiplying with the distance matrix for the layout.

The distance matrix is the one which is dependent upon the layout. By multiplying these two you ultimately get this figure and this figure summarizes the total material function between A to B. The cost of material handling is 20 unit rupees. A to C is the 60 units, so the total material handling moved from A to all departments is 80. So 80 rupees worth of cost is crud in transportation for all the trolleys that lead from A. Similarly all the trolleys that lead from B, 75 units of money is the cost and so on for C and D. The column totals will tell you the amount of, for instance 110 units of money is the total amount of trolley that land at B from where it is, land from it comes from A and C. So it tells you exactly that from A and C there is going to be dispatches everyday of 20 and 90 units in terms of money to this particular thing. The total material handling cost therefore is 265.

So in a sense what we have done till now is evaluated. We have an initial layout which is an input to the package. We have determined the load and the multiplication of the load and the unit cost as given as the flow matrix. The flow matrix in the distance matrixes as given in the material handling effort can be used for this determination here. So here we have seen how the material handling effort for the initial layout can be calculated. Now our basic intention is to use this information for improving upon the layout. So the improvement in the layout is possible in the case of CRAFT by interchanging departments. So we have four departments A, B, C and D. If we talk about pair wise exchanges between these departments, the number of possibilities is going to be $4C_2$.

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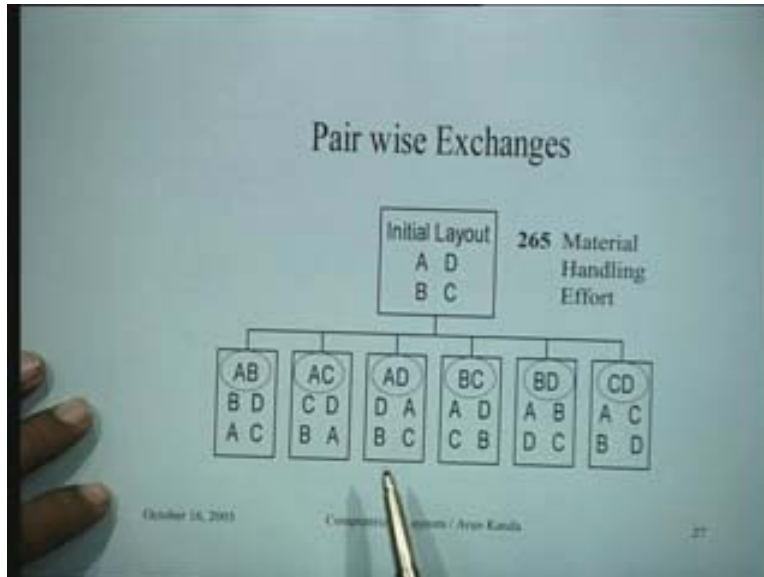
You will have 6 possibilities, what are these possibilities? You can interchange A and B, A and C, A and D, B and C, B and D and C and D. So what happens is for instance that we interchange A and B, what will happen is that this particular initial layout will be modify to B D A C. Similarly if you interchange A and C, the layout A could come here and C could come here and D and B. So this could be the new layout that we could generate from here. So similarly these are the six new layouts which could be generated by pair wise exchange of different departments. We have got all these layouts. You see the intention now is that for each of these new possible layouts which are derived from the initial layout, you can develop a distance matrix. Only thing that changes the distance matrix and the flow matrix will remain. The total loads which are moving multiply the flow matrix, so flow matrix with distance matrix compute the material handling effort for each of these. Let us see for instance how this can be done. For an alternative one which was this, that means we change the layout to B D A C.

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What it means is simply with the distance matrix it will now look like this. The distance matrix is change because distance from A to B, A to C is 1, but A to D is now 2. Similarly other distances are as shown in this particular matrix. So the distance matrix is changed. What we do is we calculate the material handling effort and the material handling effort is nothing but the flow matrix which remains unchanged. This is what we have multiplied it with i.e., this distance matrix and again find out the total score and for this particular case. The total score works out to 220. This could be repeated for the second alternative.

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Second alternative is this is the layout. This is the new distance matrix, the flow matrix remaining. The same total cost will be 265 by this procedure. For alternative three this is the new layout, this is the new distance matrix here. Again the material handling effort which is the flow on the distance will come out to 215 which you can calculate by the same procedure.

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Alternative four, again this is the new layout A D C B in this fashion and again the material handling effort could be the flow matrix multiplied with this distance matrix and this value is now 215. For the fifth alternative the layout is A B C D, this way the

distance matrix is something like thus the total material handling effort is now 265 again and we look at the sixth alternative which is A C B D like this. This is the distance matrix so the material handling effort is flow into distance matrix which is 220. It is quite a repetitive calculation and therefore is the best relegate to a computer. So once it performs all these competition, we started with a layout initial layout which had a material handling effort of 265. We have calculated the material handling effort for all these six layouts. What you then do in graft is you select the one which is lowest. So in this case these two layouts give you the lowest possible square of 215. So what happens is that you can do this or this is a better layout than this one. We can now use any of these layouts as the new layout and continue to repeat the procedure. So what we have illustrated to you is one basic iteration of CRAFT that is how to go from one layout which is at the initial layout, which had a material handling score of 265 to a layout which has a score of 250.

It so happens that all the scores are higher than this score that could show that this is the best layout available so you stop there. So this is the stopping criteria in craft. So we can this way determine the whole thing. After having seen the example of computation of better or an improved layout, let us try to look at some of the limitations of CRAFT.

What you find is that CRAFT yields a good heuristic solution that does not guarantee optimality.

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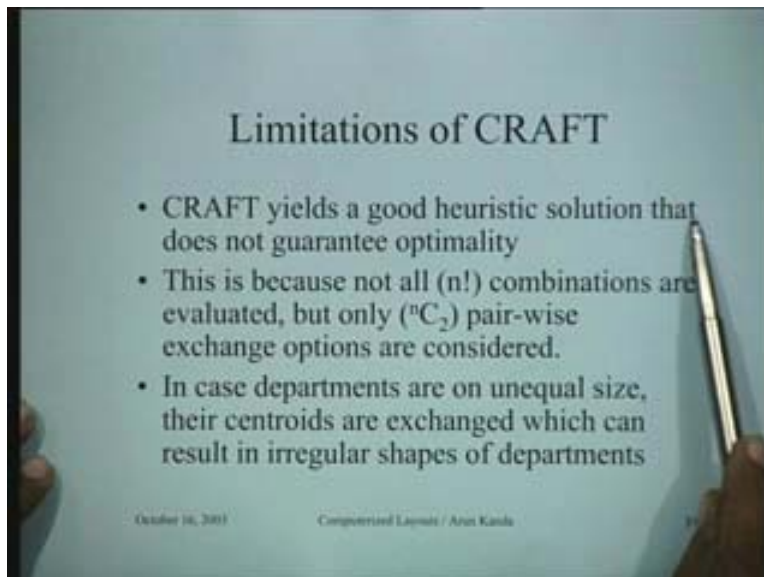
The point that must be there in mind is that you not getting the best solution. You are not getting the optimal solution. You are instead getting a good heuristics solution. Why is this? This is because if there are n departments there are n factorial ways in which you can generate new departments. So instead of generating factorial combinations we are actually using at each iteration only nC_2 pair wise exchanged options. That means since we do not consider three way exchanges, four way exchanges and so on we are actually confining ourselves to only these. So we are reducing the competition effort considerably but we are dealing the pride of optimality in the process. In each in case departments are

of unequal size, their centroids are exchanged which can result in irregular shapes of departments. This is also limitation in CRAFT. This particular comparison between nC_2 and n factorial will give you an idea of how much we are gaining in terms of competition and effort. You can see, n increases the n factorial value is something like this. The nC_2 value is only this particular value.
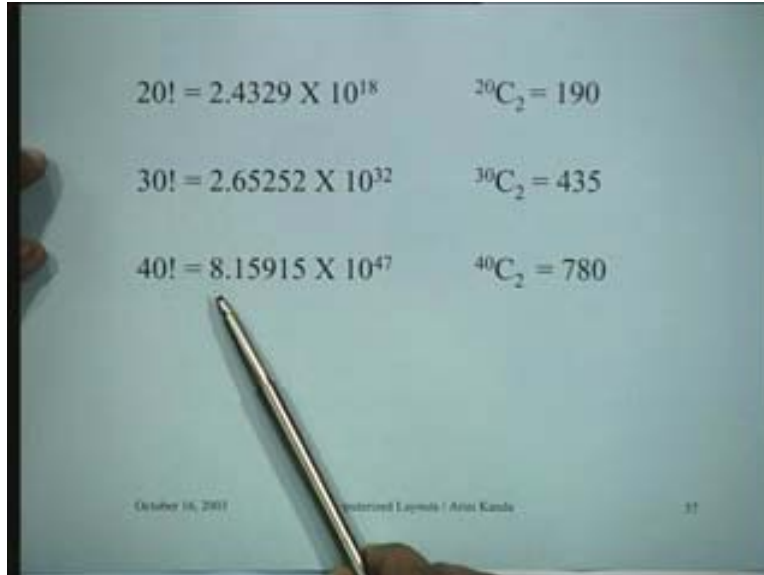
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n	$^nC_2 =$ [n(n-1)]/2	n!
1	0	1
2	1	2
3	3	4
4	6	24
5	10	120
6	15	720
7	21	5040
8	28	40320
9	36	362880
10	45	3628800
11	55	39916800
12	66	479001600

So really speaking the problem of solving for all n factorial values could be an exponential growth. Therefore it could be lead to so many possibilities whereas in CRAFT you are dealing with at a time only a very limited number of options. Of course as n increases, for instance, if n is 20 or 30 or 40, the value for n factorial could be very large. If you try to take it on your calculators or computers you will find that it wont be possible to accommodate that particular value, whereas $40C_2$ for instance 77 and 80 for this possibility.
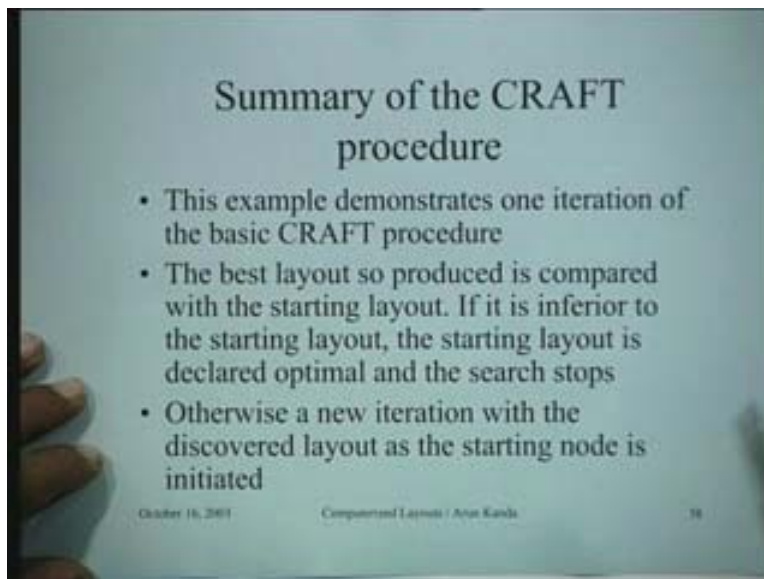
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So much of the computational efficiency of CRAFT comes from this factor that you are evaluating only nC_2 possibilities out of n factorial and therefore doing the solution. Look at the summary of the CRAFT procedure. In the CRAFT procedure this example demonstrates one iteration of the basic CRAFT procedure.

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The best layout produced is compared with the starting layout. If it is inferior to the starting layout, the starting layout is declared optimal and the search stops. So this is the basic logic. Otherwise a new iteration with the discovered layout as the starting node is initiated. So this cycle goes on as for as the start procedure is concerned.

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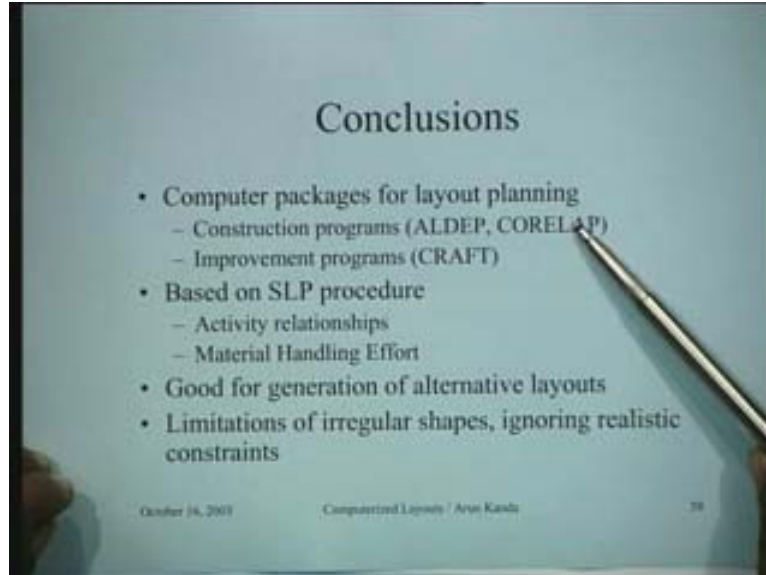
In conclusion what we could say is that as far as computerized packages for layout planning are concerned, we have seen that they could brightly be classified into construction program and improvement programs. In this lecture we had a glimpse of ALDEP and CORELAB which are essentially construction programs that is the derivation of a layout from the scratch. You do not have to supply the initial layout. They generate the layout either through random procedures or by references to the REL chart as the case may be. Then we took an example of an improvement program in the form of CRAFT which was basically a design to take an initial layout and try to improve it through the process of pair wise exchanges. Most of these competitions or improvements are based on the systematic layout planning procedure of Muether which we studied in the last lecture.

There were two measures which we had commonly specified. One was Teffort. For instance in CRAFT, material handling effort was taken as the objective function in ALDEP and CORELAB, the activity relationships determine the objective function. All these procedures are generally good for generation of alternative layouts but they all are limitations. The limitations are in terms of irregular shapes or ignoring any realistic real life constraints, that is why although layout packages have been developed they are never used exclusively for designing a layout. The best use for generating options which the layout planner examines and then you may pick up one and modify the results that are obtained from the package by using whatever realistic constraints are there. So with this we conclude this particular session.

Thank you very much!