Automation in Production Systems and Management
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Flexible Manufacturing Systems - II
Lecture - 41
Operational Problems in FMS:
Tools and Techniques – 1, Problem Formulation

During this week, the 9th week, our lecture sessions have been planned in such a way that youe become aware of the different kinds of problems you may be dealing with while an FMS is in operation.

Basically, we will be referring to different kinds of problems. First we will identify those problems related to FMS operation, and then we will formulate those problems and we will suggest the solution approaches.

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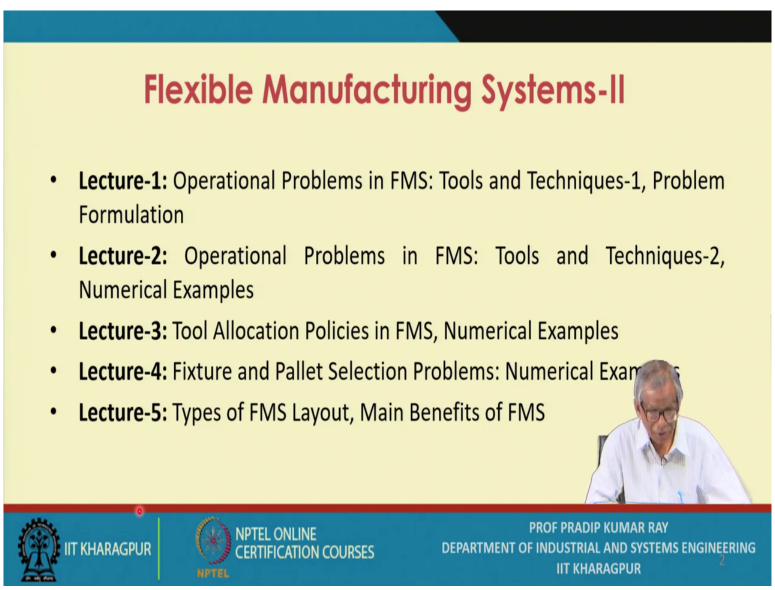

During the first lecture session we will be referring to different kinds of operational problems in FMS.

In the next lecture session, lecture 2, we will be referring to the kinds of operational problems in FMS. The second set of tools and techniques for dealing with; we are calling them tools and techniques 2 and the numerical examples we will take up.

In the 3rd lecture session, tool allocation policies. We have already come to know that in an FMS there will be machine tools and at each machine tool you will have a tool magazine. The tool magazine holds different kinds of cutting tools. Those are to be used for processing the parts on a particular machine tool.

The tool allocation policy in FMS is a very important aspect as far as maintaining and improving the FMS performance is concerned. You have installed an FMS and there is an investment. You must verify at each point in time whenever the operation starts what kind of the cost you incur for carrying out different types of operations; whether this is within control or not.

Important consideration is the minimization of the cost of production.

The tool allocation policies may determine your production cost. So, if you lose control on the tool allocation policies, or arbitrarily you set the policies, even if the quality management system is all right, you will be losing heavily in the sense that we will lose control on the production cost.

In lecture 4, we will be referring to fixture and palette selection problems again and in the last lecture session the types of FMS layout normally we come across and the main benefits of FMS.

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Let us the talk about, during this lecture session, operational problems in FMS and to deal with these problems what kind of tools and techniques you may use to get the problem solved.

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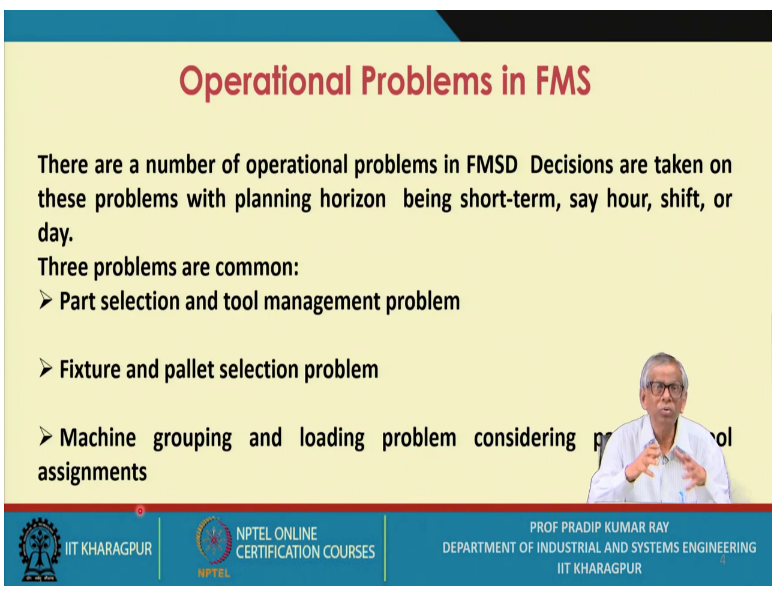

There are a number of operational problems in FMS. Decisions are taken on these problems with planning horizon being short-term, say hour, shift or day. Operational problems means essentially it is day to day problem, hour to hour problem.

These three problems are common. Part selection and tool management problem. The next important consideration is can you formulate the problem?

The problem will be described, then after the problem is described are you in a position to identify the decision variables, are you in a position to identify the constraints and are you in a position to identify the objectives? Ultimately you will be dealing with optimization problems.

Next one important problem in FMS is related to fixture and pallet selection and the third one machine grouping and loading problem considering part and tool assignments.

Whenever you create an FMS, prior to creating an FMS, you need to convert your manufacturing system or your manufacturing module into a cellular manufacturing system or cellular manufacturing module, that is referred to as the CMS.

The grouping principles are used and you start adding another dimension of the problem that is the flexibility dimension.

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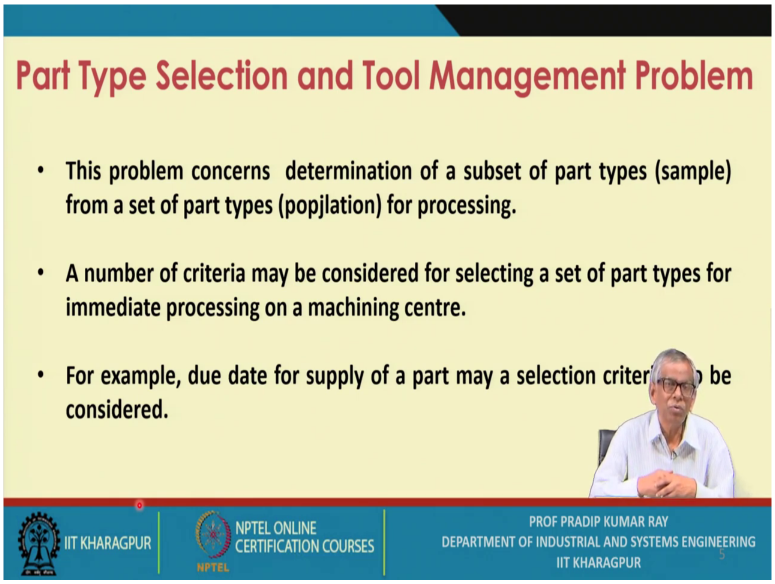

Let us talk about the part type selection and tool management problem. There are a population of parts and from the population you have to take a sample of parts. Once the selection norm is known you form a sample of parts and for this sample of parts, you have to select the tools.

For each part the operation details must be known. Once the operation details are known, the kinds of the cutting tools you need to use and then you check to what extent you are able to make the cutting tools available on the tool magazine.

This problem concerns determination of a subset of part types sample from a set of part types population for processing. A number of criteria may be considered for selecting a set of part types for immediate processing on a machining centre. For example, due date for supply of a part may be a selection criterion to be considered. These are referred to as normally the priority rules

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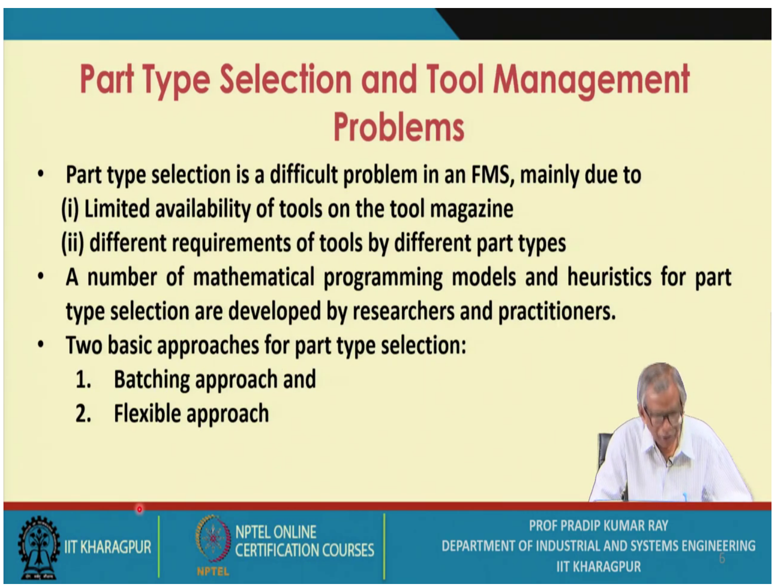

Part type selection is a difficult problem in an FMS mainly due to two important reasons. One is the limited availability of tools on the tool magazine because the capacity is limited – 30, 60 in terms of the number of slots and to hold a particular tool in a tool magazine, how many tools you need? So, limited availability of tools on the tool magazine.

If the number of slots is less, the number of tools that you can hold on a particular tool magazine also will be very less. The different requirements of tools by different part types.

A number of mathematical programming models and heuristics for part type selection have been developed.

For the different types of the problems or the different dimensions of the problem, two basic approaches for part type selection you come across: one is the batching approach and the other is the flexible approach.

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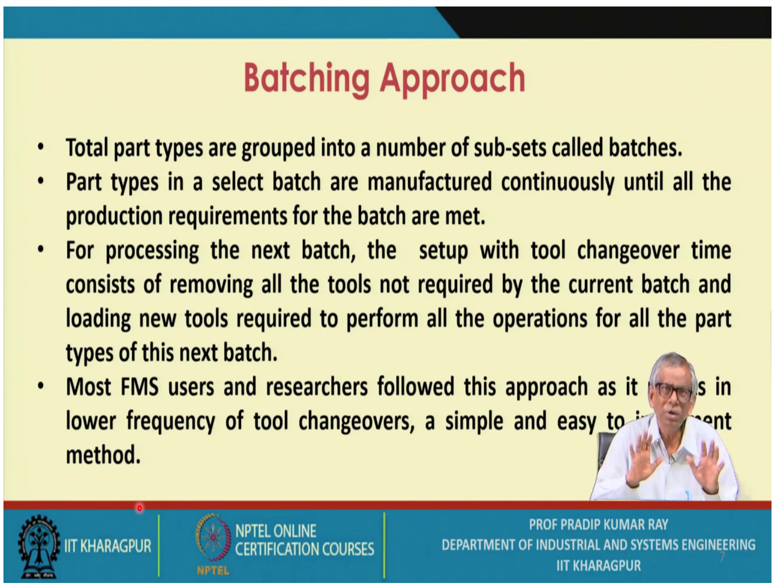

What is this batching approach?

Total part types are grouped into a number of subsets called batches. From the population you form a number of batches. Part types in a select batch are manufactured continuously; you just select one particular batch randomly and then each part is to be manufactured. How do you pick up this part from this group or from this batch?

Randomly you have to select. The part types in a select batch are manufactured continuously until all the production requirements for the batch are met. So, you take up one by one each part.

Suppose there are 30 parts in a set or in a batch. So, you complete processing of all these thirty parts one by one, the batch is considered.

For processing the next batch, the setup with tool changeover time consists of removing all the tools not required by the current batch. For a one particular batch, once you are aware of those operations you select the corresponding tools and put these tools in the tool magazine.

Once the entire batch is manufactured, the tool magazine becomes empty. Now, you pick up another batch and for that batch again you select the cutting tools and put this cutting tool in the tool magazine and you start processing.

We have to load new tools required to perform all the operations for all the part types of this next batch. Most FMS users and researchers followed this approach as it results in lower frequency of tool changeovers, a simple and easy method to implement.

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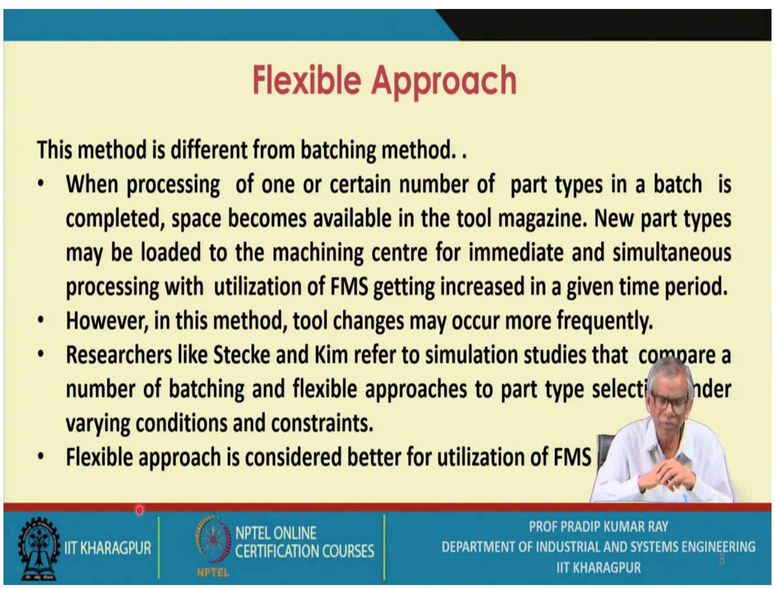

Alternatively, under certain conditions you may opt for the flexible approach. When processing of one or certain number of part types in a batch is completed, the certain part types we have already been manufactured and corresponding cutting tools already you have used and you do not need those cutting tools again for that particular batch.

Those the cutting tools have already been removed from the tool magazine. You have a certain space available for holding new tools in the tool magazine. The new part types may be loaded to the machining centre for immediate and simultaneous processing with utilization of FMS. As soon as you find that certain portion of the tool magazine becoming empty, immediately you consider few more parts and for those new parts you need new cutting tools and put them into the available slots in the tool magazine. So, this is a continuous process and that is why it is referred to as the flexible one, utilizations will be more.

However, in this method tool changes may occur more frequently.

Flexible approach is considered better for utilization of FMS point of view, whereas the batching approach utilization is less.

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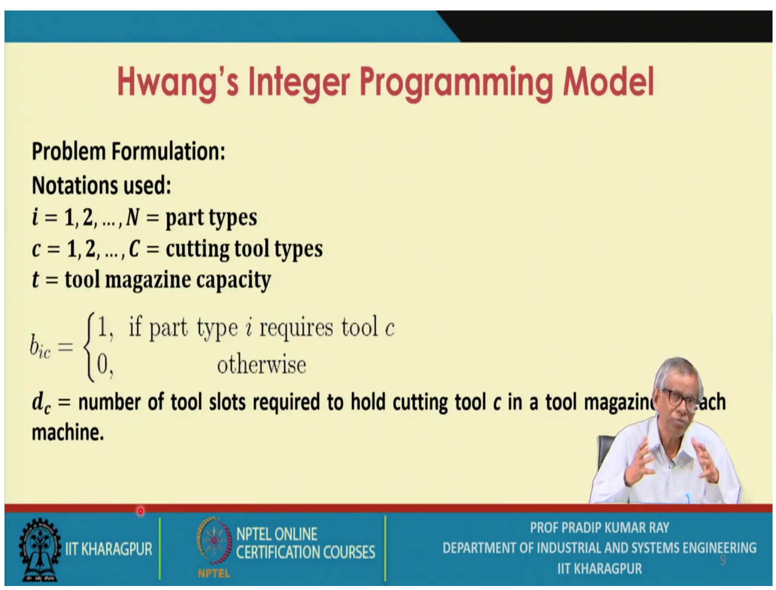

Hwang's integer programming model is well-established and this particular model has been used in FMS.

Part selection problem is essentially linking with tool management. So, there are two approaches batching or the flexible approach for selection of the part and the selection of the cutting tool.

The following notation is used:

i=1, 2,…, N=part types

c=1, 2,…, C=cutting tool types

t=tool magazine capacity

$$b_{ic} = \begin{cases} 1, & \text{if part type } i \text{ requires tool } c \\ 0, & \text{otherwise} \end{cases}$$

d_c= number of tool slots required to hold cutting tool c in a tool magazine of each machine.

$$z_i = \begin{cases} 1, & \text{if part type } i \text{ is selected in the batch} \\ 0, & \text{otherwise} \end{cases}$$

$$y_c = \begin{cases} 1, & \text{if cutting tool } c \text{ is is loaded on a machine} \\ 0, & \text{otherwise} \end{cases}$$

In this model, z_i and y_c are the decision variables. We consider a system of identical machines (all of the same type). In that case,

$$\text{Maximize} \sum_i z_i$$

subject to

$$\sum_c d_c y_c \leqslant t$$
$$b_{ic} z_i \leqslant y_c \ \forall i, c$$
$$z_i = \{0, 1\} \ \forall i$$
$$y_c = \{0, 1\} \ \forall c$$

$$\text{Maximize} \sum_i z_i$$

subject to

$$\sum_c d_c y_c \leqslant t$$
$$b_{ic} z_i \leqslant y_c \ \forall i, c$$
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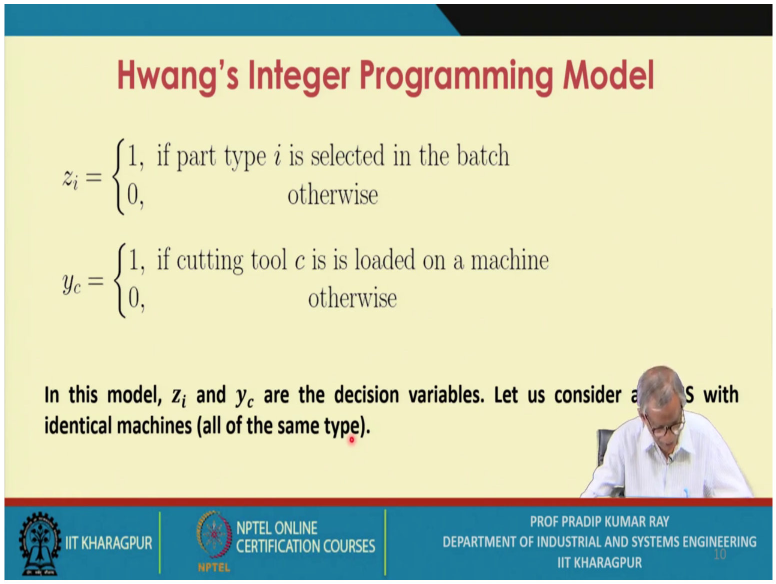

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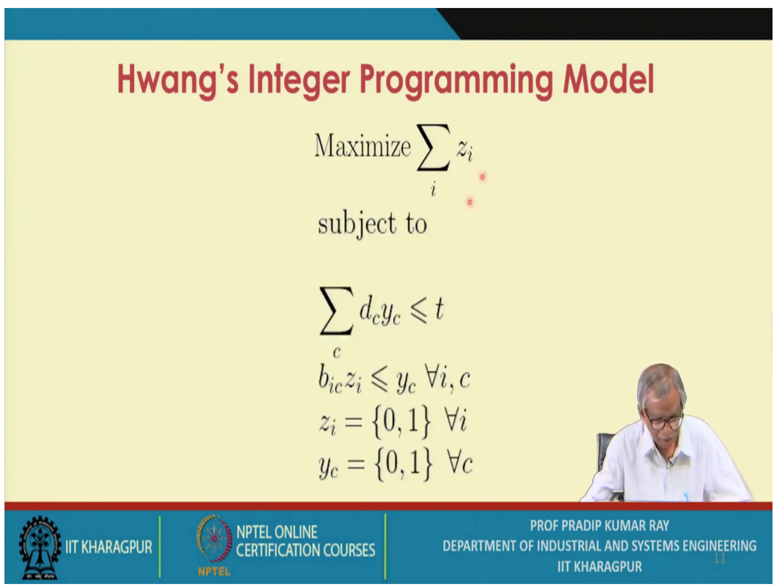

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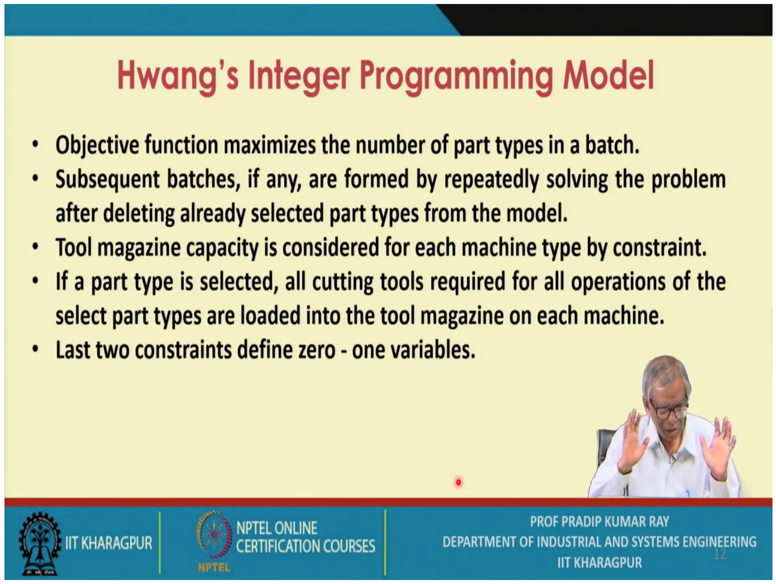

Objective function maximizes the number of part types in a batch.

Subsequent batches, if any, are formed by repeatedly solving the problem after deleting already selected part types from the model. Once one batch is formed that means, those the part types are not to be considered subsequently. You need to reformulate the problem.

Tool magazine capacity is considered for each machine type by constraint. If a part type is selected, all cutting tools required for all operations of the select part types are loaded not only just against one particular part, one particular tool is required because one particular part may require not only one operation but also a number of operations.

Based on the number of and types of operations you need to carry out on a particular part type. You need to select the different types of the cutting tools and all these cutting tools are loaded into the tool magazine on each machine. Last two constraints define 0-1 variable.

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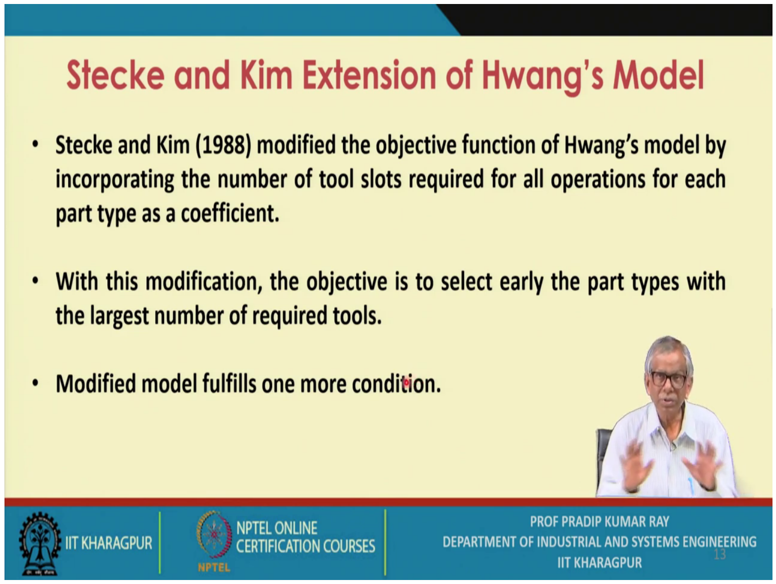

Stecke and Kim have extended Hwang's model. They have modified the objective function, only they have modified the objective function of Hwang's model by incorporating the number of tool slots required for all operations for each part type as a coefficient.

Only the part type you have considered and the tool required. But in the objective function, we have not considered, for holding a particular tool selected for the given part, how many slots you require and the number of slots is a definitely is a constant. So, that is to be considered while you try to maximize the number of parts in a particular batch.

With this modification the objective is to select early part types with the largest number of required tools, that is your selection norm. The modified model fulfils one more condition.

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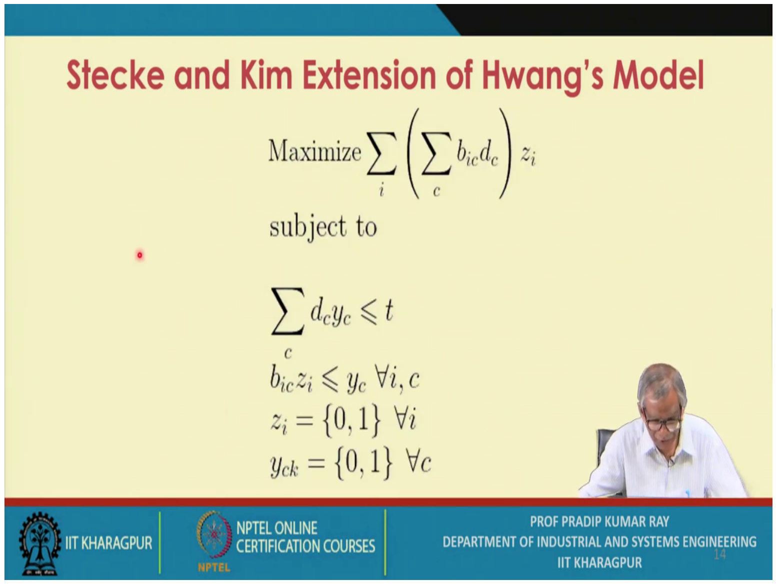

$$\text{Maximize} \sum_i \left(\sum_c b_{ic} d_c \right) z_i$$

subject to

$$\sum_c d_c y_c \leqslant t$$
$$b_{ic} z_i \leqslant y_c \ \forall i, c$$
$$z_i = \{0, 1\} \ \forall i$$
$$y_{ck} = \{0, 1\} \ \forall c$$

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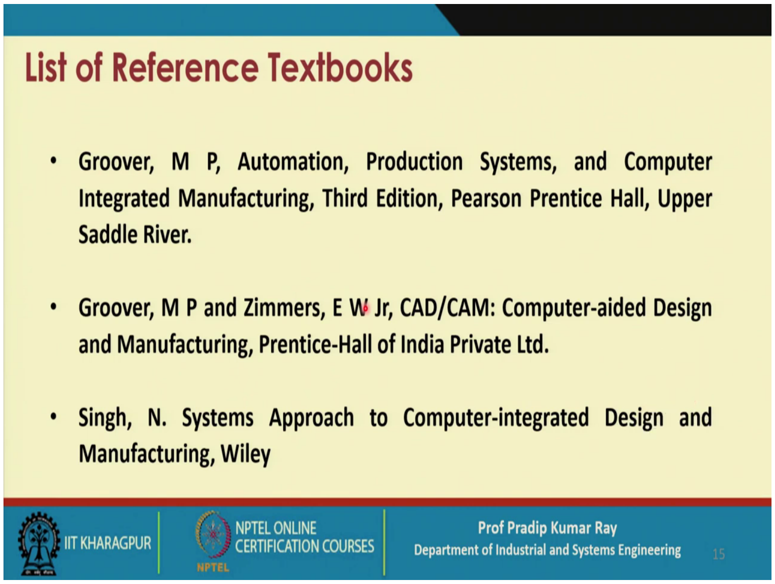

For a given problem in FMS, how do you formulate these problems? You must know before you start formulating the problem, the problem is related to a particular kind of the system or the operations you follow. Like you have to create a batch and for creating batch there could be many approaches.

In this case, the batch creation the method you specify and then you identify the decision variables, the constraints and your objective. Once all these details are known and once the decision variables are known, constraints are known, you apply this integer programming approaches and you get the solution

So, we have discussed up to the formulation part, later on we will take up numerical problems.