Geo Spatial Analysis in Urban Planning
Prof. Saikat Kumar Paul
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

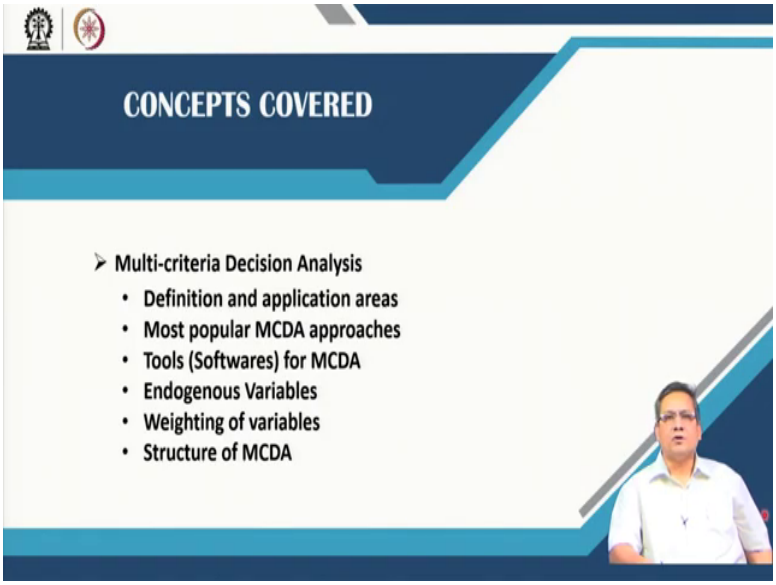
Module – 04
Modeling Geographical Space and spatial analysis
Lecture – 19
Multi – Criteria Decision Analysis

(Refer Slide Time: 00:12)

Welcome back dear students. We are in the penultimate lecture of this particular series of lectures that is lecture 19th and today we shall talk about Multi-Criteria Decision Analysis. So, we shall cover the different types of multi-criteria decision analysis techniques and this is a very big area; I mean, this is a big subject.

So, it is really not possible for me to get into the I mean, intrinsic details of the different types of I mean, approaches to multi criteria decision analysis. But, we will go through the broad and most important I mean, methods of MCDA and in the next lecture we would see an application of one method in an urban area.

(Refer Slide Time: 01:07)

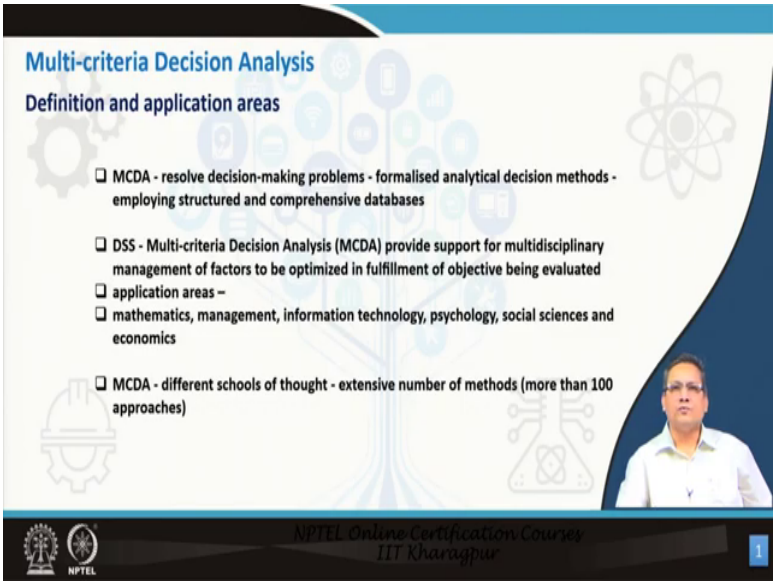


So, the concepts that we are to cover today is we are going to talk about multi-criteria decision analysis which shall include the definition and the application area and we would also look into the different popular MCDA approaches. I mean, there are lot of algorithms which are available different approaches which are available as for MCDA analysis. Now, we will look into the most popular of the MCDA approaches.

Now, we will also look into the different kind of software's that are available for this popular MCDA techniques, we will look into what are endogenous variables. We will look how the

variable weightings are done and we will look into the structure of MCDA; Multi-Criteria Decision Analysis.

(Refer Slide Time: 02:01)



So, let us begin with the first slide I mean talking about the definition and application. So, MCDA is I mean is used to resolve decision making problems; I mean, when you have I mean, a very complex problem and in when you have different variables in it. And, you would like to come to a decision on the different kind of possible outcomes to choose which is the best outcome, then we generally used the MCDA kind of a approach to solve that.

So, these are formalised decision method which are analytical in nature. So, these are mathematical and I mean, this would give you a unique set of solution; I mean, anybody does it they will arrive at the same set of solution. So, in a way it is I mean, very formalised method. So, it also has a very structured approach to formulating the data basis, to formulating the

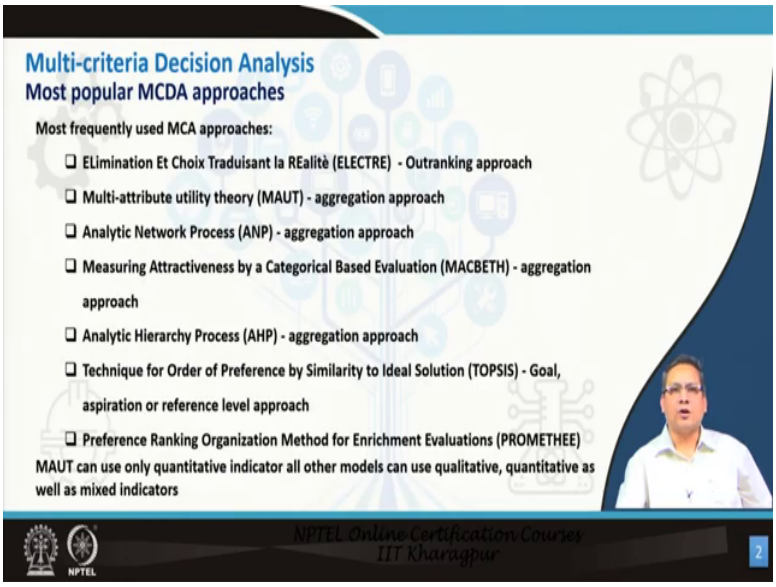
entire methodology of applying this particular multi criteria; I mean, applications it employs a very structured approach to solving this kind of problems.

Now, we can create Decision Support System; so, in short we call it a DSS. So, we can I mean, use a decision support system it gives us I mean, multitude of factors and we can have a management tool based on these factors to come off with the best possible optimized result. So, I mean you can evaluate this I mean, multitude of your different input factors, you can optimize them through some of these multi-criteria decision analytical tools and then you can come to the most objective solution for this particular problem.

Now, there are different applications of your multi-criteria decision analysis. So, we are I mean just suggesting few, but you will see that there are a lot of other applications as well. So, you can see that there are applications in math's, in management, in information technology, psychology, social sciences and economics.

So, there are different schools of thought and these approaches; I mean, are extensive and there are more than about hundred different approaches of multi-criteria decision analysis. So, I mean it is really very difficult to be a champion in all of them. So, we identify I mean, the different important multi criteria decision analysis techniques methods so, which we shall discuss shortly.

(Refer Slide Time: 05:00)



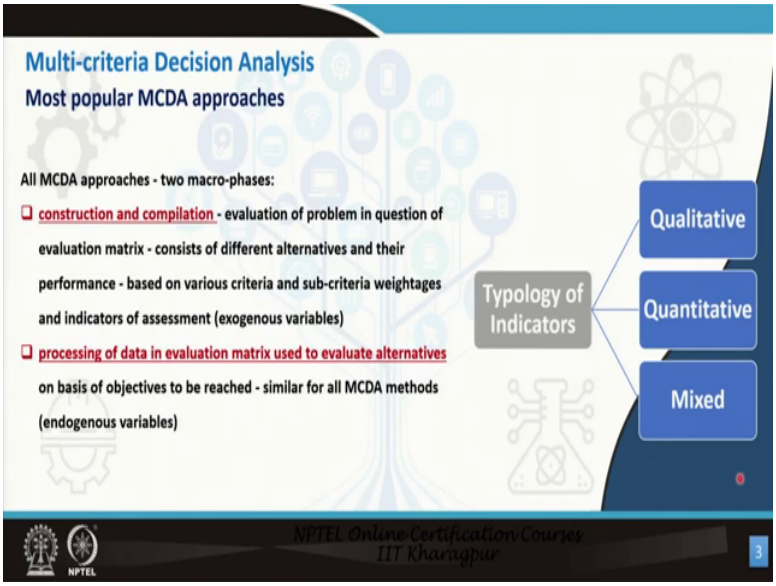
Now, the most frequently used multi-criteria approaches are the ELECTRE which is the acronym for your elimination Et Choix Traduisant la REalite So, it is a outranking approach then we have a Multi-Attribute Utility Theory also known as comprehensively known as MAUT. So, it has aggregation approach then we have the ANP which is the Analytical Network Process which also is an aggregation approach.

So, then we have the I mean, MACBETH which is the Measuring Attractiveness by Categorical Based Evaluation, again this approach uses a aggregation method then we have the analytical hierarchy process. So, in this also we aggregate I mean, we aggregate the different weightages apportion to different criteria and inputs and it is aggregated to find out the; I mean, final rankings of the different alternatives. So, then we have the TOPSIS which is the acronym for tech technique of order of reference by similarity to ideal solutions. So, it is a

different approach where in we talk about the goal aspiration or the reference level I mean, approach.

So, then we have the PROMETHEE which is also used very commonly and it is the acronym for Preference Ranking Organization Method for Enrichment Evaluation. So, of these, it is only MAUT which uses only the quantitative indicator, but apart from MAUT all the other methods, that we have talked about the approaches that we have talked about can use either qualitative, quantitative or even mixed indicators in the model.

(Refer Slide Time: 07:09)



So, it is only MAUT which uses only the quantitative indicator, we can also see the different popular approaches. So, I mean all the different approaches MCDA approaches that we had talked about; I mean, are they have two different macro phases. So, first is the construction

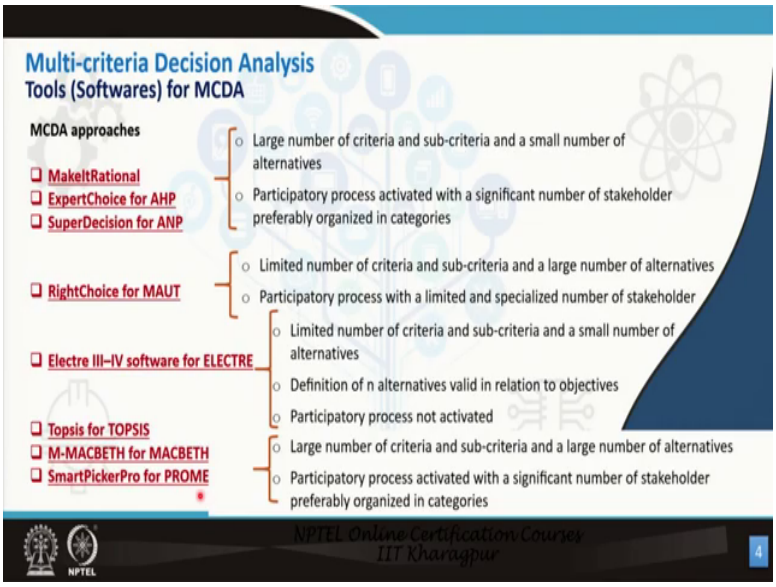
and the compilation. So, in this particular phase I mean, we evaluate the problem using a kind of a matrix or construct we construct a matrix.

So, we evaluate the different problem ah; the problem and then what we do is we have different alternatives and the performance of these alternatives. So, that is I mean, included in this particular matrix. So, and based on the criteria or the sub-criteria weightages we can have indicators of assessments which are basically exogenous variables.

Now, the second phase; I mean, we were talking about two phases. So, first is we construct the problem; I mean, a create evaluation matrix a based on criteria and sub-criteria of weights, the next one is the processing of data to evaluate this matrix used to evaluate the alternatives. So, we would have that the different alternative to a given problem like and then we need to find out which is optimum or the best solution in a given scenario. So, I mean, on the basis of the objective that is to be reached I mean that is the endogenous variables, we do the processing of the data.

So, this method is similar for all the different MCDA method that is the processing of data in evaluation matrix. So, that is the endogenous variables, but when we are talking about exogenous variables that is the construction and the compilation then there would be variability is in the different MCDA approaches that we have seen. So, there are different typology of indicators. So, I mean, in our earlier slide we have talked about I mean, the different types of indicators. So, the; there could be qualitative indicators, you could have quantitative indicators and their also could be mixed indicators.

(Refer Slide Time: 09:35)



Now, the software that we have for this popular approaches. So, it is important that you know about these software's so, that you can use them to process your data and I mean solve a problem. So, we have the first bouquet of software is make it rational, we have expert choice for AHP and super decision for ANP.

Now, this first bouquet of software it uses large number of criteria and sub criteria, but small number of alternatives. Now, these three methods are participatory in nature. So, that participatory approach is activated by taking feedback from the different stakeholders and I mean, preferably we try to I mean, group this stakeholders into different categories; I mean, it is putting this stakeholders in a very organized way.

Now, the second; I mean, method that is your MAUT we have the software which is known as right choice which is used to I mean, model a problem in a MAUT approach. So, in this we

have limited number of criteria, in the earlier three I mean methods or approaches we have seen that we have large number of criteria and sub-criteria, but small number of alternatives.

But, in this right choice for MAU; I mean, MAUT approach we have limited criteria and sub-criteria and large number of alternative. So, it is just the reverse kind of a problem then we had in the earlier three approaches. So, the nature of problem is difficult different, the problem that you would be solving using MAUT approach.

Now, the in this method the participatory approach is limited with only very specialized number of stakeholder. So, in our earlier three approaches ah; I mean, we had seen that we have significant number of stakeholders and we organize the stakeholders into different category. So, in this MAUT concept, there are limited number of participants and there are very specialized stakeholders limited stakeholders for ah; I mean, evaluating your choices or giving the weightages. So, we have very less number of stakeholders in the, who participate in this MAUT approach.

The next approach is the ELECTRE. So, this can be I mean, you solved in this particular platform which is known as Electre III-IV. So, in this, we have a limited number of criteria like the one we were take in talking about for the MAUT approach. So, we have limited criteria and sub-criteria and a small number of alternatives.

So, in this the n alternatives are valuate in relation to the objectives that is identified and in this case the participatory approach is not there which was there in the last two approaches though the participatory approach was limited in case of MAUT. But, in case of electre that participatory process is not activated..

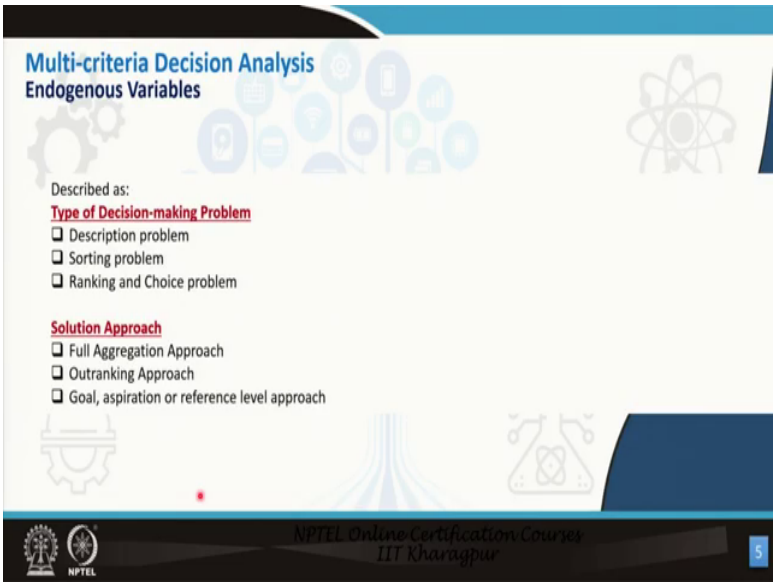
The last one that is your TOPSIS, MACBETH and PROME you have these three software's. For TOPSIS the software is called TOPSIS, MACBETH; I mean, you can solve or optimize this; I mean, using this particular approach. You can optimize a problem by using the software called M-MACBETH and you can come to a solution using PROMETHEE approach using

SmartPickerPro. So, these are the three software's in the, this last group of I mean, MCDA approach.

So, in this there a large number of criteria like what we had seen earlier large number of criteria and sub-criteria, and also a large number of alternatives. So, both are large in this case. So, you can see the first point basically is a permutation and combination among this four groups of software. So, you now know that if you have large number of criteria, large number of alternatives, small number of criteria, large number of alternatives your I mean and vice versa I mean, if you do a permutation and combination of these you can which I mean MCDA approach you should choose to solve this basically.

So, in this these three methods in TOPSIS, MACBETH and PROMETHEE, you again I mean activate the participatory approach that, there are significant number of stakeholders and they are also organized in the category. So, there is a kind of I mean, this has been shadowed by this particular object; so, this is PROMETHEE. So, this is a small typographical mistake that you have; I mean, which is has crop top in this particular slide. So, this smart picker pro is used for PROMETHEE the, or entire spelling is not seen in this particular slide.

(Refer Slide Time: 14:59)



So, you can see that we were talking about exogenous and endogenous variables. So, let us see what is an endogenous variable. So, I mean, it is described as the type of decision making problem.

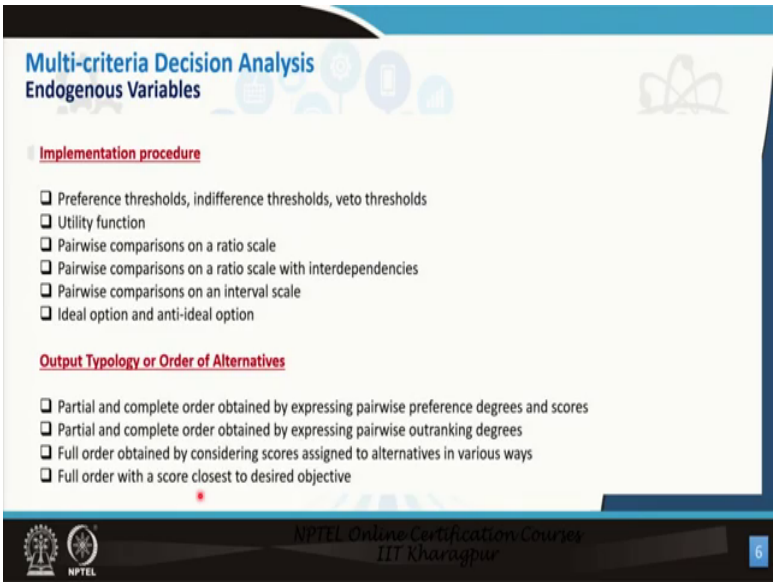
So, now, when we have this type of decision making problem; I mean, it is a description of the problem and it identifies the main distinctive feature for a group of alternatives. So, you can have a description problem and then there could be a sorting problem where in you would have the definition of homogeneous group of alternatives by characteristics, then you can also have a ranking and choice problem. So, what we do is we rank the alternative from the best to the worst. So, these are some of the type of decision making problems that we would come across.

Now, you can also have solution approach. So, in the solution approach, you have the first method which is known as the full aggregation approach. So, in those case your score would be evaluated for each criteria and these are then synthesized into a global score. Now, this approach would assume a compensable scores ah; I mean, that is if you have a bad score for one criteria it is compensated by a good score on another criteria.

So, the next one in the solution approach is the outranking approach. We have talked about the full aggregation approach, now we shall talk about the outranking approach. So, in the case if you have a bad score it may not be compensated by a better score like what we had talked about in our earlier full aggregation approach. So, in this case the order of option it may be partial, because of the notion of incomparability is allowed in this particular approach.

Now, these two options may have same score, but their behavior may be different and therefore, incomparable. We have this outranking approach I mean where in you see that the bad score may not get compensated by a better one. So, then we also have a goal aspiration or reference level approach in which a goal for each criteria is defined. We would define a criteria for each of the goal sorry, goal for each of the criteria and then what we do is we choose the closest options to ideal goal or the reference level would be identified in this particular approach.

(Refer Slide Time: 17:56)



Let us see the other methods in your endogenous variables which are used. So, we shall look into the implementation pro procedure. So, in this we have the preference thresholds ah, indifference thresholds and veto thresholds. So, in this case your pair wise percentage degree comparing the performance of n alternatives is made. And to find this preference level what we do is, we do an evaluation which must consider preference and indifference thresholds.

So, we are talking about preference thresholds and we are talking about indifference thresholds in which a person or I mean, your decision making would be indifferent to the two outcomes. So, we try to identify the thresholds and we also have veto thresholds which would be I mean, which would negate those particular options or conditions which would negate these options. So, on the basis of this thresholds; so, we can have positive, negative or

uni-criteria net and global flows which are created taking into account the weights that is attributed to each criteria.

Now, if we perform an action I mean, this action performs negatively I mean, if we have some kind of an action which is which performs negatively so, according to a single criteria. So, it may also be included in a veto threshold that would definitely definitively exclude that option from the final ranking. So, this is what we have in our preference threshold, indifference threshold and the veto threshold.

Now, we also might have a utility function which is an expression of the measure of desirability or preference of each alternatives with respect to the other alternatives ah. Now, there could be different criteria which are to be considered in function and when we are taking this criteria for each of these criteria we have marginal utility which is determined as representing partial contribution that each criteria belong brings to overall utility assessment. The global utility when we want to find out the global utility, it would be expressed by a global utility score.

So, generally this utility score varies, global utility score varies between 0 and 1. So, this utility; global utility score are commonly calculated by a additive method or as a weighted sum based on the weighted importance for each criteria or by a simple addition. Now, we can also work on pair wise pair wise comparison on a ratio scale. So, if you start reading into the AHP; so, I mean the analytical hierarchy process there we do a pair wise comparison.

So, we ask the stakeholders the experts regarding the importance of the different among the different attributes or the different inputs. So, in this case what we do is we construct evaluation matrix which is also known as super matrix. So, the comparison of elements included in super matrix which are these are organized into clusters of criteria, sub-criteria or alternative ah. It is performed by simultaneously come comparing two elements at a time. So, that is why we have this term called pair-wise comparison.

Because, we are simultaneously comparing only two terms at a time I mean, we also need to take into account any interdependencies between them. So, I mean, thus these

interdependencies is could be in terms of cluster criteria, could be in terms of alternate alternative cluster or there could be correlation between different clusters; so, I mean, based on the influence between elements or clusters.

So, this super matrix that we are talking about is completed considering influence of each note on others and it is expressed on a rational scale that is the satis fundamental scale. So, probably in our next lecturer we shall look into the satis scale. So, in case if there are no interdependence between elements that are being compared, we can assign a vale of 0 in super matrix.

So, we can also do a pair wise comparison on the ratio scale. So, I mean, we have talked about the ratio scale independence I mean, we have talked about the I mean; I mean, ratio scale we interdependencies then we can also do a pair wise comparison on the interval scale. So, in the interval scale what we do is we do a construction of evaluation matrixes which is also known as the matrix of judgments.

So, the comparison is made between evaluation elements that is the alternatives and criteria, it is implemented by a pair wise comparison based on a semantic qualitative scale. So, a, I mean, traditionally the ranking or the I mean quantitative values is it ranges from 1 to 7 and these values are included in matrix of judgments ah. Now, these judgments are relative attractiveness of the criteria and the alternatives that we are talking about are also expressed by considering weights attributed to the each of these criteria.

Now, the next option the; next I mean procedure that we have is the ideal option and anti-ideal option. Now, this is an expression for each alternate of shortest distance to the ideal or the virtual solution and the longest distance from the anti-ideal solution. So, it takes into account the performance of the different alternatives which is referred to each criteria and to weight of each criteria. Now, the distance are expressed by calculating a distributive normalization and an ideal normalization of recorded preference.

The next method is the output typology order of alternatives. So, in this particular method what we do is we do a partial or complete order which is obtained by identifying or I mean,

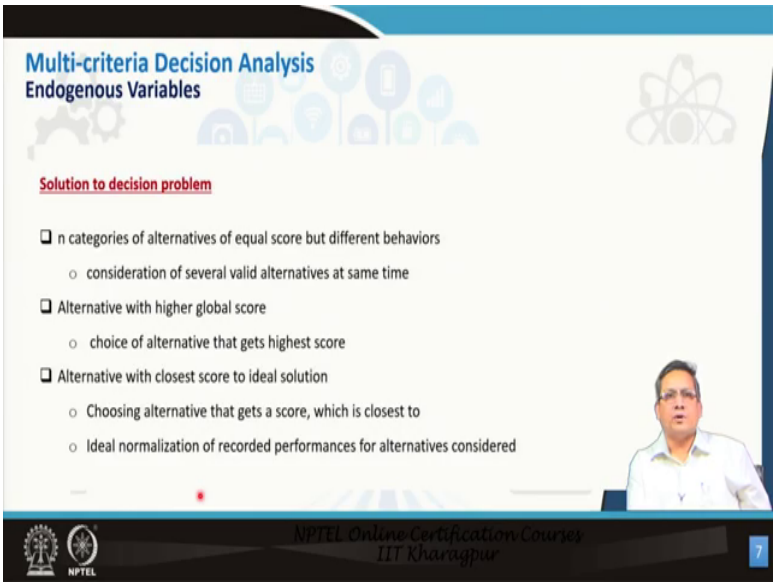
jointing down the pair wise preference degrees or scores. So, what we do is we do a simultaneous consideration of positive and negative global performance flows which are evaluated for each alternative or by simply considering net flows, that make it possible to understand whether alternative is being deliberated obtain a higher rank or a minor rank, if two or more alternatives are incomparable or equally valid.

We also do a partial and complete order which is obtained by expressing pairwise outranking degrees. So, in this we have degrees of reference which leads to a partial rank. So, it could also lead to a total rank of the alternatives and it is traditionally through expression of degrees of concordance or discordance I mean, that is according to the criteria that we are considering. So, we can do a partial or complete order obtained by expressing pairwise outranking degrees.

Now, we can also do a full order obtained by considering scores assigned to alternatives in various ways by a we can do this by complex and general scores and we can and we can do a general approval or ordering of alternatives from the best to the worst in this particular method. So, we can also do a full order with a score closest to the desired objective.

So, in this what we can do is we can calculate the proximity coefficient for each alternative and it is traditionally expressed as ranging from 0 and 1. So, I mean, you are if you have a value of 1 that would express that it has the close closest proximity to the aim or the objective.

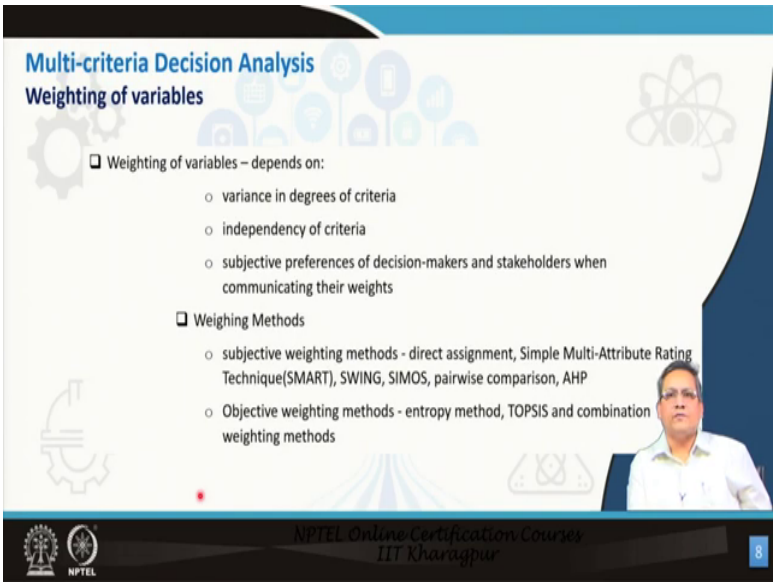
(Refer Slide Time: 27:20)



We have the next method which is the solution to the decision problem. So, in this case you may have n categories of alternate alternative of equal score, but it may behave differently. So, you may have different types of behaviors for this n categories of equal scores, but these are different alternatives. So, what we do is in this I mean, approach we considered the several different alternatives at the same time. And we identify the alternative with the highest global score by choosing the alternative which is I mean, which takes the highest score. So, I mean your alternative closest to the I mean, with the closest score to the ideal solution is chosen.

So, we can also do a ideal normalization of recorded performance for the I mean, for the different alternatives that you have. So, these are the different options when you want to do a solution to the decision problem.

(Refer Slide Time: 28:33)



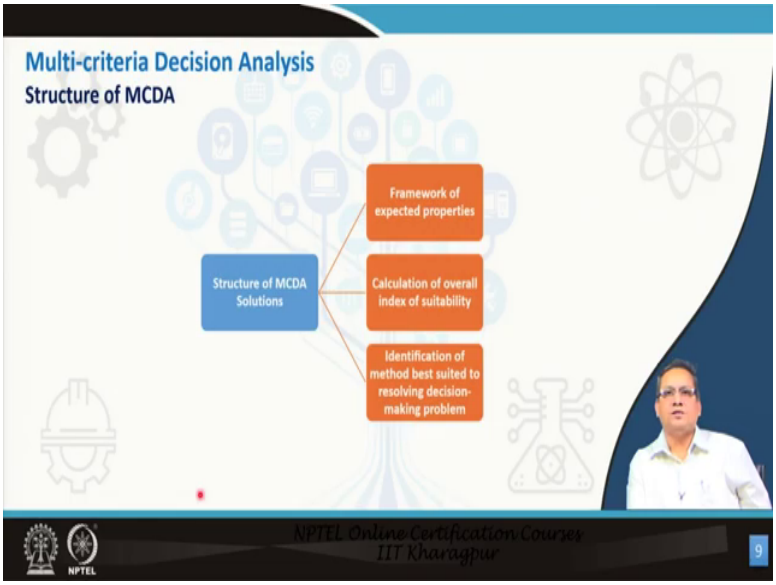
Now, how do we do the weighing of the variables? So, this weighing all the variables are depends on few factors, first is your variable variance in degree of the criteria how what is the variance and we also look into interdependency. So, in our earlier slide we were talking about correlation. So, we talk about I mean, we should look into the interdependency of the criteria for doing the weighing of the variables.

We shall also I mean, we have to look into the subjective preference of the decision makers because everything may not be very quantited quantifiable. So, you could have some qualitative aspects as well. So, there would be preference in terms of decision making, choosing some among the alternatives. So, we look into the subjective of preference and either the decision makers or the stakeholders when we are I mean, putting or apportioning the weights.

Now, we may also have different weighing methods. So, the first weighing method this part is really important that you should learn about the different weighing techniques and methods. So, the first method is the subjecting subjective weighing methods. So, these are weights which are directly assigned. So, these are simple multi attribute rating a technique which is also abbreviated as smart there is SWING, SIMOS, pairwise comparison; I mean, AHP these are some of the weighing methods.

So, I mean we also have objective weighing methods where in we talked about the entropy method, there is a TOPSIS method of object weighing and combination of different weighing methods.

(Refer Slide Time: 30:17)



I mean, if we see the structure of a MCDA solution. We would see that first we do an do a framework of the expected properties then what we do is, we calculate the overall index of

suitability and then we do in identification of the method which is best suited to resolving the decision making problem.

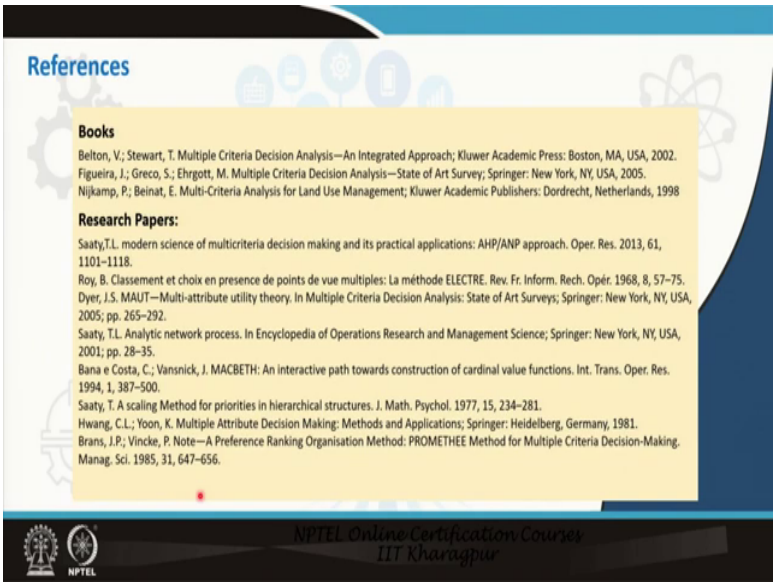
(Refer Slide Time: 30:38)

So, you can look into the few books and references that we shall be talking about. So, our recapitulation of what we have done today is we had talked about the definition of multi-criteria decision analysis, we had seen the different application areas where this can be applied, we had talked about the most popular MCDA approach and we had said that there are more than about 100 approaches for MCDA.

So, we had looked into most of the popular approach and we also know that what kind of I mean, approach can be applied given your the different conditions in terms of your solutions sets or the number of variables in your particular problem or assignment. So, you can choose the appropriate MCDA method, then we had also talked about the tools which you can use for

I mean, your data processing of your MCDA and we had talked about the endogenous variables and we had talked about weighing of the variables. So, and finally, we have seen what is the structure of MCDA.

(Refer Slide Time: 31:46)



So, we have this following books first one is by Belton its I mean, Kluwer Academic Press publication which is titled as Multi-Criteria Decision Analysis. The second book is by Figueira, so all these books are really interesting and good in this particular subject. Nijkamp book is very good I mean it is the Multi-Criteria Decision Analysis for Land Use Management. So, those of few who are working with GIS or remote sensing you would find especially in your urban applications, you would find this book to be really interesting ah; this is from the Kluwer Academic Publishers.

Now, we also have some reference to the research papers Saatys I mean, Thomas L Saatys I mean, who gave the AHP-ANP approach. So, he has written few interesting papers. So, this is one of them in from your operations research joiner ah. Roy B. Classement et so, he has written about your ELECTRE though this paper is not in English, but you will get this particular method in the books that we had talked about ah. There is paper by Dyer who has talked about the multi attribute utility theory MAUT approach.

So, and then you have the analytical network process, ANP paper in ANP; so, this is also by Thomas L. Saaty. Then Bana e Costa there he they have written and Vansnick they have written a paper on MACBETH. So, these are the different approaches another paper by Saaty looking into the AHP that is analytical hierarchy structures.

So, these are some of the research articles that you can refer to while you are I mean, studying this particular methods. So, this is a very interesting area and has I mean, wide applicability for I mean, coming to a conclusion regarding your urban issues and problems. So, this is a very interesting area to work in. So; I mean, the last one is the paper on PROMATHEE which is by Brans, this was published in the management of science general and thanks for I mean being with us in this particular lecture so.

Thank you so much.