

MCDM Techniques using R
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Lecture – 3
Introduction to MCDM Techniques – Part III

Welcome to the course MCDM Techniques using R. I am Dr. Gaurav Dixit from Indian Institute of Technology Roorkee. So in the previous two lectures, we started our discussion on the introductory part of the course. So- let us do a quick recap of that and then we will continue from there. So in previous two lectures, we talked about what is decision making. We discussed a few examples like a manager selecting the best supplier for the company, household selecting the energy supplier, a student considering the university rankings.

So all these examples that we discussed in previous two lectures. Then school committee and allocation of a scholarship, so this was all so discussed. We also talked about what could be a practical definition of decision making. So we discussed all the components, criteria, alternatives, goals. We also talked about the problem, what we mean by MCDM, multi-criteria decision making. So that particular aspect of MCDM was also discussed.

Then, we also discussed the disciplines where MCDM has been applied and the disciplines where we draw theoretical and methodological background. So that part was discussed. We also discussed the steps that are involved in a MCDM process, so that was also discussed. We also discussed sub-steps and then we talked about the different forms of analysis that are used and which are relevant for this course. We talked about the components of MCDM and then different categories of MCDM.

For example, MADM which is multiple attribute decision making and MODM which is multiple objective decision making. So we understood what are the differences between these two categories of MCDM, and we also discussed that in this particular course we would be mainly covering MADM methods. Within MADM, we talked about that there are two schools of thought. One is value-based theories. The main example of this school of thought is MAUT method. Then, the another school of thought is outranking school of thought.

There are a number of methods which are available under this category. For example ELECTRE, AHP, TOPSIS, VIKOR; so these are some of the methods. Then we talked a bit about MODM as well. So what we do in MODM and what constitutes the kind of methods that are available in MODM. So the problems, a few issues that are there in MODM methods, so we talked about that particular aspect as well. For example; goal programming, compromise solution, DEA. So these are some of the examples of MOD methods. So this part was covered.

Then we discussed different types of decision problems where we covered the four main types. We talked about choice problem where we have to pick the single best alternative. Then we talked about the sorting problem where we would like to sort the alternatives into ordered and predefined groups. We talked about ranking problem where we would like to order alternatives from best to worst. So these kinds of problem we discussed. We also talked about the description problem and when it could be used.

Other types of problem also we covered. For example; elimination problem, design problem, elicitation problem. So these particular aspects were discussed. Then we started our discussion on the software platforms and tools that could actually be used to apply MCDA methods and techniques to different problems, so that was also discussed. Then we talked about using R statistical environment for MCDA techniques, which has not been used extensively, very few researchers and analysts have actually tried to use R for MCDA methods and application.

So this particular course also bridges this gap. So few important aspects about why an environment like R could be useful that was discussed in previous lectures. We talked about important R packages which are available. So this was also discussed. We also talked about if you are not familiar with R, then you can refer to my previous course on Business Analytics and Data Mining Modeling using R where you would find a lecture on introduction to R that could be really useful for yourself to familiarize the R environment and what is required for this course as well.

Now, we move to next important point that is about selection of MCDA methods. So till now, we have talked about different categories of MCDA methods, schools of thoughts within

those categories and we have also seen a few of the examples of methods which come under these categories.

(Refer Slide Time: 06:39)

Introduction

- Selection of MCDA methods
 - Task of selecting an appropriate decision support tool
 - Is often difficult to justify
 - None of the methods are perfect nor can they be applied to all problems
 - Each method has its own limitations, particularities, hypotheses, premises and perspectives

Now, how do we go about selecting a particular MCDA method for our decision problem. So this is typically a quite I know difficult task in MCDA domain. So few pointers have been given here, so let us go through them. So task of selecting an appropriate decision support tool, this is often difficult to justify. So there are many methods which can be applied, used to solve the same kinds of decision problem or the same decision problems, and which particular method should be applied.

Sometimes it is quite difficult to justify that why you are picking AHP or other methods, so that kind of justification is sometimes quite difficult to provide. As mentioned in the next point as well that none of the methods are perfect nor can they be applied to all problems. So this is another scenario that we have to face that every method they have their own limitation, they have their own particularities, hypothesis, premises and perspective. Based on that, we have to see which methods are going to be more suitable to solve our decision problems.

(Refer Slide Time: 07:56)

Introduction

- Different ways of choosing appropriate MCDA methods
 - One approach suggested by Guitouni et al. (1999)
 - Look at the required input information
 - Data and parameters of the method
 - Consequently the modelling effort, as well as
 - Looking at the outcomes and their granularity

Now different ways of picking or selecting appropriate MCDA methods have been suggested. So one approach is suggested here. So this approach was suggested by Guitouni et al and you can look at the points how we can use this approach to select a particular MCDA method. So we can have a look at the required input information. So this input information could be data and parameters of the method.

So given the decision problem that we have and given the method that we are looking to apply for that decision problem, what kind of data would be required, what kind of input would be required, and what kind of parameters have to be evaluated. So we can have a look at the required input information and then we can look at the modeling effort that we will have to put forth to solve the problem.

So the kind of input that we have and if we select a particular method, the kind of modeling effort that would be required that we can check and then looking at the outcomes and their granularity. So what all outcomes that we will get after selecting an MCDA method and the expected outcome that we typically receive and whether that is acceptable, whether that is something that we all looking for. So inputs, the modeling effort and the output; so these are the three points that we can look at for selecting a particular MCDA method.

(Refer Slide Time: 09:43)

Introduction

- Different ways of choosing appropriate MCDA methods
 - Example:
 - If the 'utility function' for each criterion is known, then MAUT
 - Construction of the utility function requires a lot of effort
 - Else if using pairwise comparisons between criteria and alternatives
 - Using ratio scale, then AHP
 - Using interval scale, then MACBETH
 - DM needs to know which scale is better suited to yield their preferences
 - Drawback is that a large quantity of information is needed

So if we talk about a specific method, so one example is given here. So for example if the utility function for each criterion is known, then it is typically recommended that we can go for MAUT method; however, it has been noticed that there are practical difficulties in terms of construction of utility function and this requires a lot of effort. So therefore many times, it might not be possible for the analyst to create a numerical representation of the preferences of decision makers and because of that MAUT might not be a practical solution in many scenarios.

So the second point is given if we cannot construct a utility function so what we can do else if using pairwise comparisons between criteria and alternatives. So this is typically the MADM methods that we have talked about, especially outranking school of thought, they use pairwise comparisons. So one of those methods can be used. So few examples are given here. So there also, we can make certain segregation here.

So if we are using a ratio scale for this comparison, then probably AHP is the better approach. If we are using interval scale, then MACBETH is there. Then if we look at the problem with this way of selection of method is that DM needs to know which scale is better suited to yield their preferences because in different methods, they have the requirement of different kinds of a scale. As you can see for AHP, it is ratio scale; for MACBETH, it is the interval scale.

So therefore, the decision maker needs to know what is better suitable for their own preferences, how their preferences can actually be quantified and which scale is going to be suitable. For example in ratio scale, we have the concept of absolute zero which is not there

in the interval scale. So the kind of preferences that decision makers might have whether those to express to quantify those subjective preferences, whether we would like to have absolute zero or not or just the interval scale is going to be sufficient.

So that decision has to be made and according to that we can go for a particular method. If you want to understand more about what is ratio scale and what is interval scale, you can refer to my previous course on Business Analytics and Data Mining Modeling where I have talked extensively about the different kind of variables, ratio variables and interval variables, that are there and of course the associated scales. So that would give you a good understanding of what we mean here.

So selection of a scale also becomes an important aspect here. Drawback of these methods where pairwise comparisons are used is that a large quantity of information is needed. So if you happen to have a number of criteria or alternatives to solve your decision problem, then the number of these pairwise comparisons because this is one criteria compared with another criteria or one alternative compared with the another alternative with respect to a particular criteria.

So those pairwise comparisons can become quite a few and this could put a lot of computing cost. So if you look at these examples, the selection of methods is quite difficult task. So whatever we discussed till now, if you can construct the utility function, the MAUT method is recommended. If utility function cannot be constructed, then we will have to pick one of the methods from outranking school of thought, and there also if we can decide on the scale which is going to be suitable.

For example if it is ratio scale, we can pick AHP; if it is interval scale, we can pick MACBETH. So those kind of decision are to be made and even after that if there are a large number of criteria and alternatives are going to be used in to solve decision problem, then the computing cost is going to be on the higher side.

(Refer Slide Time: 14:59)

Introduction

- Different ways of choosing appropriate MCDA methods
 - Second approach
 - Define key parameters
 - Can use elicitation methods to define these parameters
 - Example:
 - If indifference and preference thresholds can be defined, then PROMETHEE
 - If indifference, preference and veto thresholds can be defined, then ELECTRE
 - If ideal and anti-ideal options can be defined, then TOPSIS
 - If criteria are dependent, then ANP

Now what could be the other approach to select an appropriate MCDA method. So second approach, so what we can do is we can define key parameters and then we can use elicitation methods to define these parameters. So in this approach, a number of methods are there for which this approach can be applied. So few examples have been given. So for example PROMETHEE, this particular method so if indifference and preference threshold, these are some of the parameters which are used under this method.

If they can be defined using elicitation methods, then probably we can go for this PROMETHEE method. Similarly in the ELECTRE method, indifference, preference and veto threshold; so these are the parameters if they can be defined using the elicitation methods, then probably we can go for this particular method. Similarly for the TOPSIS method, if ideal and anti-ideal options if they can be defined using elicitation or any other method, then of course we can go for TOPSIS.

Now if criteria are dependent, then probably we can go for ANP. So till now whatever we have discussed in previous two lectures and even in this lecture, most of the methods in MCDM and even specifically in MADM, they make this basic assumption that criteria are independent. So if that assumption is being violated, then what could be the methods that we can use. So as you can see here itself if criteria are dependent, then probably we can go for ANP, which is actually an expansion of AHP.

So more details about if you are not familiar with the parameters that we are discussing here that we will be discussing in the coming lectures when we discuss these specific techniques,

then we will be discussing more about these parameters and you will get the idea what we are talking about here and how we can select different MCDA methods. Important thing at this point is to understand that there are key parameters under these methods, and if we happen to define these key parameters using elicitation methods, then that can help us in terms of selecting an appropriate method.

(Refer Slide Time: 19:07)

Introduction

- Complete ranking vs partial ranking
 - Value-based methods
 - Utility functions lead to global score for alternatives
 - It is possible to compare all alternatives and rank them from best to worst, with equal rankings permitted
 - Defined as a complete ranking
 - This approach is referred to as the **full aggregation approach**

Now another important aspect of MCDM is the complete ranking versus partial ranking. So under this, we will discuss this is mainly applicable to MADM methods. So under value-based methods, we use utility function as we have talked about. So these utility function lead to global score for alternatives, it is possible because for every alternatives, we can use utility function to get global scores, so therefore it is going to be easy for us to compare all alternatives and then rank them from best to worst.

Also equal rankings would be permitted because we are using utility function. So if through that function we get the equivalent value, then probably that equal relation is allowed. So therefore that comparison among all the alternatives is possible, and therefore best to worst ranking can be created. So this particular aspect is defined as a complete ranking because we would be able to compare all the alternatives and therefore this is called complete ranking. This approach is also referred to as full aggregation approach.

So any method, so whether it is a value-based methods like MAUT or any other method where we can actually produce all the comparisons among all the alternatives, we define it as

a complete ranking and this approach is referred as full aggregation approach. So typically, this is possible under value-based methods.

(Refer Slide Time: 19:34)

Introduction

- Complete ranking vs partial ranking
 - Outranking methods
 - Pairwise comparisons of alternatives lead to preference or outranking degree
 - Some alternatives can be incomparable due to different profiles based on criteria
 - Leading to partial ranking, since a complete ranking is not always possible

If we talk about the outranking methods, so there we use pairwise comparison . So pairwise comparison of alternatives lead to preference or outranking degree. Now what might happen because these are typically based on qualitative data which is subjective preferences of decision makers, sometimes comparison between alternatives might be incomparable, so some alternatives might be incomparable just because due to different profiles that they have.

Because we are doing the comparison with respect to the criteria that could be there and one alternative would be profiled with respect to a set of different criteria and the another alternative could be profiled with respect to another set of criteria and that mismatch between these profiles might render comparison between these two alternatives useless. Therefore they can become incomparable. So because of this, complete ranking is not possible. So we will have to do with the partial ranking that we might obtain.

So under the outranking school of thought the methods that are there, we might not get the complete ranking, these pairwise comparison might lead us to partial ranking. So this is what we meant by complete ranking versus partial ranking. So let us move forward. So till now what we have discussed is MCDM different types of method, decision making process, the steps that are involved and within the MADM method, the categories.

We also discussed a number of issues. For example, complete ranking and partial ranking. Now there are certain assumptions which are quite common in most of the MCDM method. One of them as we have discussed in this lecture itself is that the criteria, they are independent. So in that case if that assumption is violated, if the criteria are not independent and in real life scenario this is more likely case, so the kind of criteria that we use for our decision making.

In real life scenarios they are not going to be independent, they are going to have some sort of interdependence or interrelationship, so in that sort of scenario most of the MCDA method that we can apply, results of those methods might not remain useful. So what we can do about this situation. So structural models are there. So a number of structural models have been developed which actually analyze the structures of these criteria and suggest some solution to overcome these problems. So some of this we are going to discuss here

(Refer Slide Time: 22:29)

Introduction

- Structural Models
 - Multiple attribute decision making (MADM) methods
 - Assume that criteria are independent
 - Only allow the linear structure between criteria and one-way hierarchical relationships
 - For real-life decision problems, this seems to be inadequate
 - Solution is modelling the interrelations between criteria
 - Popular methods that allow modelling of criteria interactions
 - Interpretive structural modeling (ISM)
 - Decision Making Trial and Evaluation Laboratory (DEMATEL)
 - Analytic Network Process (ANP)

So under structural model, let us first discuss multiple attribute decision making, MADM methods. Typically, we assume that criteria are independent as I talked about and what happens in these methods is they typically allow only for the linear structure between criteria and one-way hierarchical relationship. As later in the coming lectures, we will talk about AHP and other methods so which use hierarchical structure.

So in any hierarchical structures, you will first start from the top and then you go to the next level and then you will decide on the elements of the next level, then next, next level which is going to even lower than that. So there are going to be levels and the kind of relationship that

is imposed by the hierarchical structure is one way and typically it follows the linear structure if we just focus on one particular path of it. So because of this, this puts a big limitation on the applicability of MADM and overall MCDM methods.

So as you can see here for real-life decision problems, this seems to be inadequate, that linear structuring that we are assuming, independence between criteria that we are assuming. So, this kind of scenario is inadequate for real-life decision problems. So what is the solution. Solution is now modeling the interrelations between criteria. So these criteria, they might be related to each other in some fashion. The relationship could even be cajoled in nature.

So one criteria might have some cajole relationship with another criteria, so those kind of structures we need to understand before we can pick the appropriate method. So popular methods that allow modeling of criteria interaction. So if there could be interrelations if the criteria are dependent, then we need to model we need to understand their relationships. So there are certain popular methods which are available which allow this modeling and gives us certain information which can be later on used to apply an appropriate MCDM method.

Some of these popular methods, one of them is interpretive structural modeling that is ISM. Second one is Decision Making Trial and Evaluation Laboratory DEMATEL. Third one is Analytic Network Process ANP. If we talk about these methods for example, Analytic Network Process ANP, this is actually expansion of AHP. So in AHP also just like any other MADM method, there is basic assumption that criteria are independent. It is actually there and therefore the criteria are not dependent, then we cannot apply.

So ANP has been expanded where instead of the hierarchical structure, the network structure is being used and that network structure actually allows the modeling of criteria interaction. Similarly DEMATEL method not just allow just to understand the model the interaction between criteria, it also allows us to understand if there is cajole relationship between criteria. So we are looking for that sort of analysis, that sort of insights, before moving ahead and picking a particular and appropriate method.

We can first apply DEMATEL, find out the relationship, understand the relationship between criteria, and then based on the insights that we get from there, then apply the traditional MADM methods. Similarly interpretive structural modeling, this also allows us to understand

the interactions between the criteria. So typically, the approach is for any decision problem where we feel that interdependence between criteria are going to be there, the criteria are not independent and we expect cajole effect or other kinds of association between criteria and that needs to be modeled.

Then probably, we need to select one of the structural models, apply them, gain insights, and then move ahead to apply traditional MADM methods.

(Refer Slide Time: 27:50)

Introduction

- Structural Models
 - Used to understand the relationships between criteria
 - Provide the information for the decision maker to select the appropriate MADM methods

So structural models, they are used to understand the relationships between criteria, so in that self this is what the structural models are about, used to understand the relationships between criteria, provide the information for decision maker to select the appropriate MADM methods. So typically, you would see many research studies are even in the companies or the committees which had been given the task to solve a particular decision problem, the many analysts which use MCDM methods, they typically combine one of the structural methods with one of the MCDM methods or MADM methods.

First they look to apply the structural models and they try to understand the relationship between criteria and then they look to find a suitable MADM methods to solve the problems. It could be choice problem, sorting problem, ranking problem, or any other problem, but sometimes it becomes important to understand the structure of the criteria, the structure that they follow.

So, these are the main references. So with this, we have been able to cover the introductory part of this course, and in the next lecture, we would be starting our discussion on one of the most popular techniques in MCDM that is AHP, Analytic Hierarchy Process. So we will start our discussion with that particular technique.

(Refer Slide Time: 29:32)

Main References

- Tzeng, G. H., & Huang, J. J. (2011). Multiple attribute decision making: methods and applications. CRC press.
- Ishizaka, A., & Nemery, P. (2013). Multi-criteria decision analysis: methods and software. John Wiley & Sons.

These are the important references that I am using for this course. There are other important references as well, but these are the main references. So with this, I end this lecture and in the next lecture we will start our discussion with AHP. Thank you.