MCDM Techniques using R
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Lecture – 2
Introduction to MCDM Techniques – Part II

Welcome to the course MCDM Techniques using R. So in previous lecture, we started our discussion on this particular course. So we talked about what is decision making. We also discussed a number of examples of decision problems. We defined decision making. We understood the complexity of a decision making process, criteria, alternatives, role of decision maker, subjective preferences all that we talked about in previous lecture. We also talked about MCDM and MCDA and their application in various fields and the influence of various disciplines on the field of MCDM.

So, all these we talked about in the previous course. We also discussed the various steps that are involved in MCDM process, so some of these steps that we discussed. We also discussed the sub-steps that are involved in MCDM process. So at this point, we ended our previous lecture. We were talking about the nonlinearity, complexity and the iterative aspect of MCDM process. So let us start. So in this lecture, we are going to carry forward that discussion.

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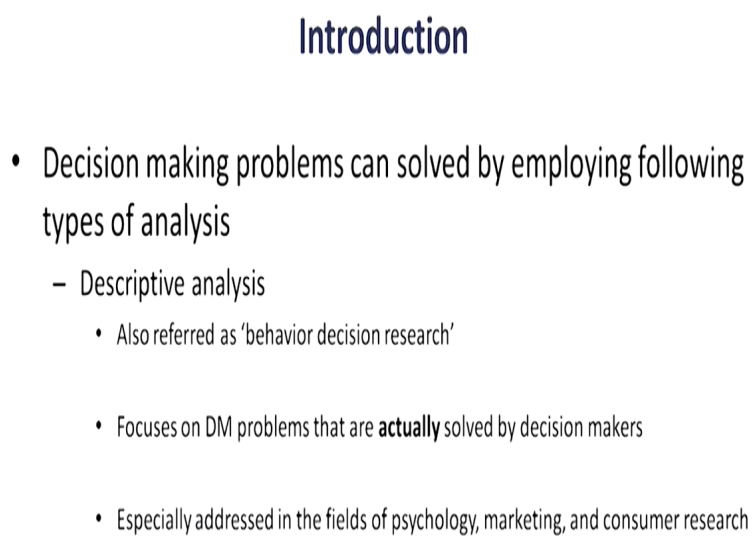

So as you can see decision making problems, they can actually be solved by employing many types of analysis. So some of them we are going to discuss here, the major one. So first one is

called a descriptive analysis. So this descriptive analysis is also sometimes referred as behavior decision research. So this typically focuses on decision making problems that are actually solved by decision makers. What we mean by when we say actually solved by decision maker, it would be more clear when we talk about the other type of analysis.

This particular descriptive analysis is particularly addressed in the fields of psychology, marketing and consumer research. So typically when we say that descriptive analysis focuses on the problems which are actually solved by decision makers, we are talking about the illusional behavior of the consumers, which are typically studied in the fields of psychology, marketing and consumer research.

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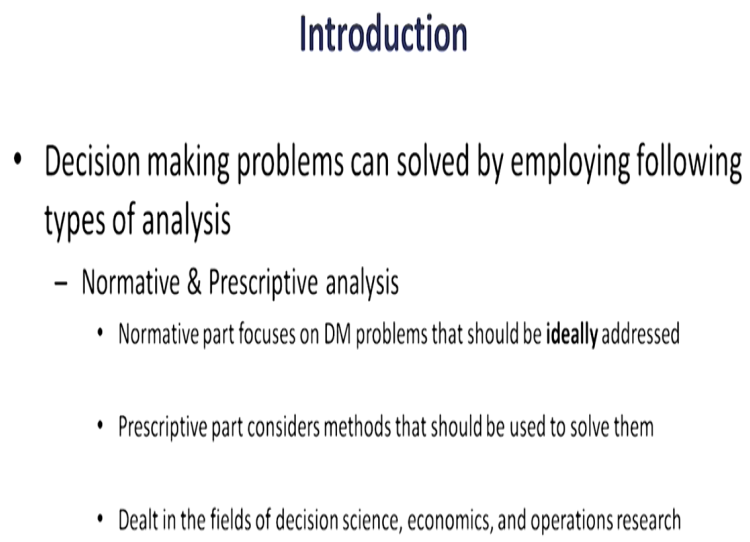

There is another form of analysis that can be used for decision making problems. This is normative and prescriptive analysis. In the normative part, the focus is on DM problem that should be ideally addressed. So we are looking at the ideal case scenario, therefore we are considering that decision makers are going to follow rational approach instead of the irrational approach that is typically studied in the other fields of psychology, marketing and consumer research.

So the normative part focuses on the problem that should be ideally addressed and the prescriptive parts consider methods that could actually be used to solve these problems. So normative part is of the typically ideal case scenario, the ideal case problems are identified and the prescriptive part is about understanding the methods which can actually be applied to

solve those problems. So typically, this kind of analysis is dealt in the fields of decision science, economics and operations research.

Now, let us understand the MCDM problems and the various components that it comprises of. So as we talked about in the previous lecture, we discussed the particular example of a school committee given the task of allocating the scholarships to students based on their performance on various subjects. So there, allocation of a scholarship that was the goal.

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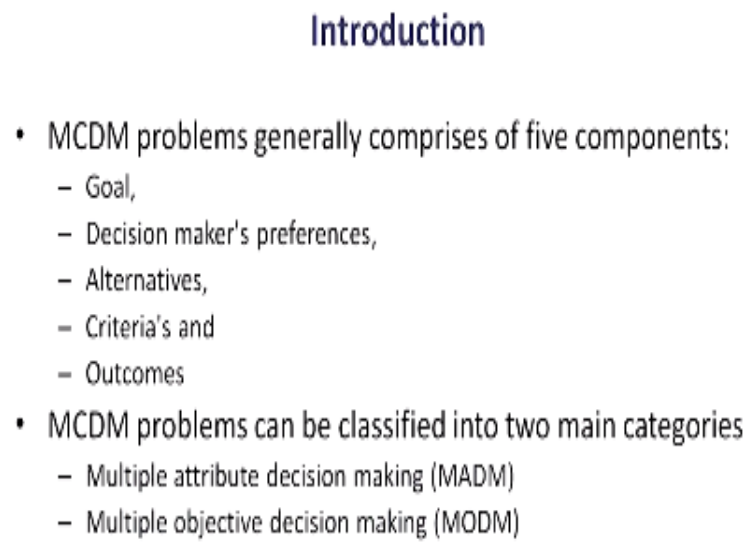

So goal is one important component of MCDM problem. Then decision maker's preferences, so when we said that school committee is playing the role of decision maker and they might prefer to value a particular performance on a particular course more than the performance of the students on other courses, so that would actually be come under this second component which is decision maker's preferences.

Then the third component is alternatives. So in that example, students were the alternatives. Then the next important component is the criteria. So, the criteria were the subjects, so the subjects that are going to be used to actually evaluate these alternatives and then the outcomes. So after understanding these other components, goal, preferences of DMs, alternatives and criteria, we need to arrive at a final decision. So that is part of the last component outcomes.

Now we will look at the MCDM problems and try to classify them into understandable categories. So this further classification has been done. So, two main categories are there. So

MCDM problems can be classified into two main categories. First one is called multiple attribute decision making or MADM. The second one is called multiple objective decision making or MODM. So let us understand these two categories, MADM and MODM.

So typically we see MCDM as the term which is more often used in the literature and not these two terms MADM and MODM, reason being there are more similarities between these two terms so even though these are defined as two different categories, one is MADM, the another one is MODM, but there are more similarities between these two categories than differences. So, let us understand these two categories. So MADM, this is typically suitable for evaluation facet.

The example that we talked about the allocation of scholarships, so that is evaluation facet we are trying to evaluate, that was a ranking problem.

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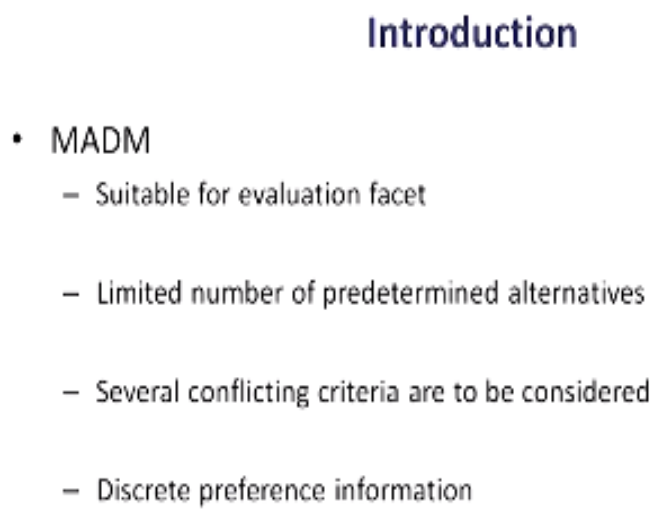

So MADM is more suitable for evaluation facet when we are supposed to evaluate something and limited number of free determined alternatives. When this scenario is there, for example there are going to be in that example that we talked about there are going to be few number of students who are going to be eligible for this scholarship. So therefore, we will have limited number of predetermined alternatives. Then several conflicting criteria are to be considered, in the example that we talked about, the performance on different subjects.

So some DM might prefer one subject to another, the another DM might prefer one subject over the other one. So there might be some conflict depending on the varying differences of

different decision makers. If there is just one decision maker, even then there could be trade-offs that could be involved. So it is not just that if there is going to be one DM, so this conflicting criteria problem is not going to be there, still it is going to be there but the criteria themselves will be conflicting. When there are going to be more than one decision maker, this complexity is going to increase even further.

Discrete preference information. So when decision makers have very discrete qualitative kind of preference information, then all these characteristics typically define MADM problems, multi-attribute decision making problems.

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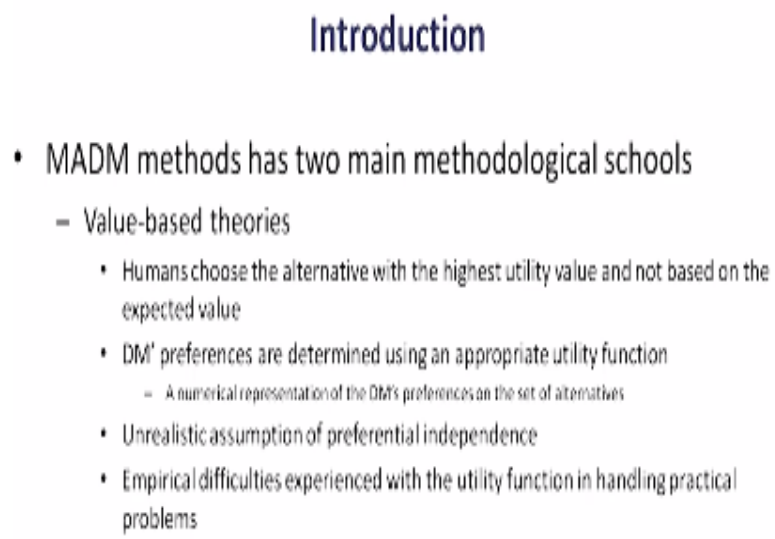

Now, MADM methods they can be further divided into two categories. So they have two main methodological schools. So first one is called value-based theories. So this particular category value-based theories is based on how humans typically evaluate alternatives. So earlier, it was believed that people look at the expected value; however, there are various examples where that is not the case, even though expected value cannot be used for decision making, the people make decisions.

So therefore, it was realized that it is probably the high utility value of a particular alternative that is actually used by humans for decision makings. So these value-based theories actually proposed the importance of utility value instead of the expected value in human decision making. DM's preferences are determined using an appropriate utility function. So how do we determine the utility value for a particular alternative. So typically utility functions are derived and they are used to determine the score for DM's preferences.

So we can understand the utility function as a numerical representation of the DM's preferences on the set of alternatives. So many times this numerical representation is quite difficult to specify and that becomes a drawback of this particular method, value-based theories. Now as you can see unrealistic assumption of preferential independence, this is another drawback of value-based theories because in this particular theory, we assume that the alternatives, the criteria they are independent which might not be realistic.

Now then another point is that empirical difficulties could be experienced with the utility function in handling practical problems. As I said, utility function many times could be very difficult to specify, and because of this, we might face practical challenges in terms of using the approaches the methods under value-based theories.

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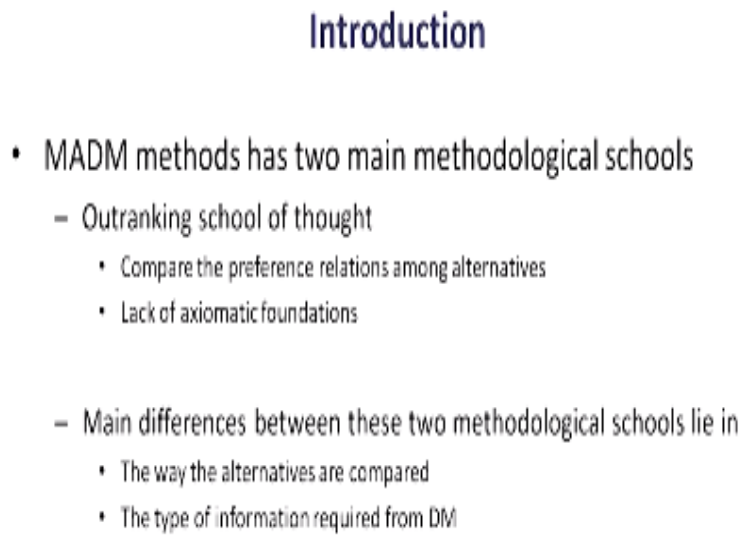

The second methodological school is called outranking school of thoughts. So here we don't have to think about specify a utility function, rather we can compare the preference relations among alternatives and that is to be used for further solving of decision making problem. Now the main criticism of this particular school of thought is there are lack of axiomatic foundations because these preference relations are determined based on the DM's subjective preferences.

So therefore, there is obviously going to be a lack of this axiomatic foundation, so that is one criticism of this particular school of thought. So we need to understand the main differences between these two, value-based theories and outranking school of thought. So few points are

mentioned here. The main difference is the way alternatives are compared. So there in the value-based theory, we have utility functions, every alternative is going to have a global score. However, in outranking, we are going to compare our preferences on different alternatives.

So, the way alternatives are compared that is very different in these two schools of thought. The type of information for this comparison that is required for DM that is also different. So type of information and the way comparison takes place, so all that is quite different and is the main difference between these two schools of thought, value-based theory and outranking.

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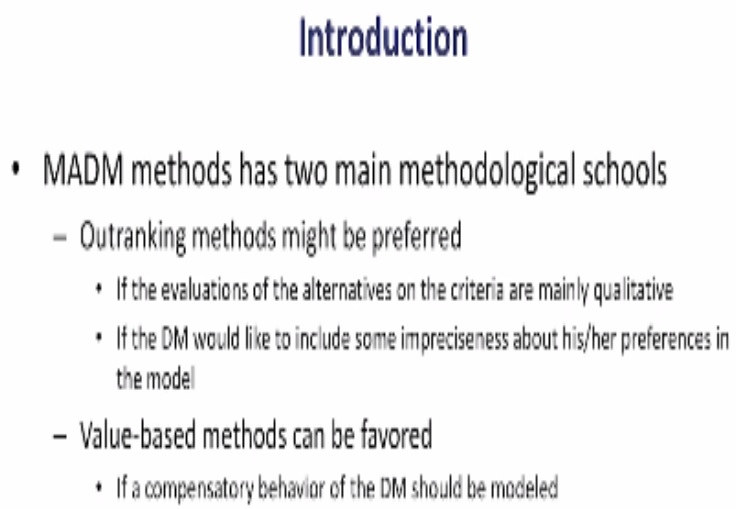

Now when do we know that outranking methods are going to be suitable for our decision problem, when do we know that value-based methods should be preferred. So this is often difficult to decide. However, few things that we can understand from here is if the evaluation of alternatives on the criteria is mainly qualitative, then probably we will go with outranking methods because we need to study the preference relations there, and if the evaluation is qualitative, then that is the more suitable approach.

If the DM, they are imprecise about their preferences in the model, then in that scenario also outranking approach could be the more suitable approach. However, if we need to model the compensatory behavior of the DM, that is preference for a particular criterion over other criterion so therefore that trade-off has to be modeled, so in that case, value-based method

would be more suitable because we will get a global score, which can be used for comparison.

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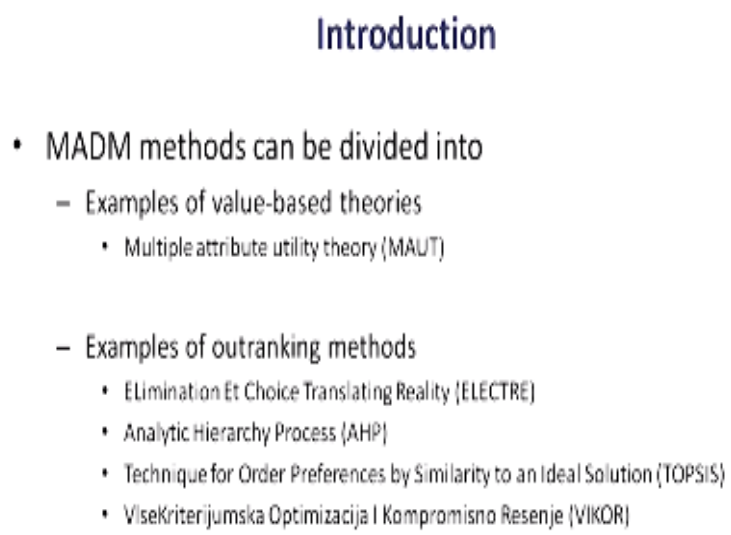

If we look at the examples of these two schools of thought under MADM methods, so value-based theories, multiple attribute utility theory or MAUT, this is the method that is typically used. We look at the examples of outranking methods then we have ELECTRE, AHP, TOPSIS, VIKOR. So these are some of the methods that come under outranking methods category. So what we talked about is MADM. So within MCDM, we talked about two categories MADM and MODM. Within MADM, we talked about two schools of thought, value-based theories and outranking methods.

So let us move forward. So second category within MCDM is MODM, multi-objective decision making. So this particular category is suitable for design or planning facet. Just like the MADM that was more suitable for evaluation facet, this is more suitable for design or planning facet. Aimed at obtaining optimal solution because we are in the design and planning phase, then of course we would prefer to go with the optimal solution, we can apply our optimization algorithms and achieve the best solution that is possible for that decision problem.

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Introduction

- MODM
  - Suitable for design/planning facet
  - Aimed at obtaining optimal solution
  - A set of conflicting objectives to be achieved simultaneously
  - A set of well-defined constraints

So under MODM, so this is the main aim obtaining optimal solution. The conflicting objectives that we talked about under MCDM conflicting criteria. In MADM, we refer criteria as attributes, and in MODM, we refer criteria as objectives. So, the conflicting objectives, the set of conflicting objectives, they are to be achieved simultaneously because we are looking for an optimal solution, we are going to apply optimization methods.

So therefore, this is to be done simultaneously so that becomes characteristics of MODM as well. We have a set of well-defined constraint, so only then we would be able to find a unique optimal solution, so that is also a characteristic of MODM.

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Introduction

- MODM
  - Uses methods of mathematical programming
    - To solve optimization problems
    - Trade-off problem
      - Multiple objectives are transformed into a weighted single objective
        - Trade-off information is required
        - Else use Pareto solutions
    - Scale problem
      - Curse of dimensionality leading to increase in computational costs
        - Handled using evolution algorithms like genetic algorithm, genetic programming, and evolution strategy

We look at the kind of methods that are used under MODM. So there in MADM, we talked about value-based theories and outranking school of thoughts. Here typically, we use methods

of mathematical programming to solve optimization problems. So, there are some issues with the methods that are associated with mathematical programming. For example, there is going to be a trade-off problem right because we are going to have multiple objectives and they would have to be transformed into a weighed single objective.

So we need trade-off information how multiple objectives are to be transformed into a weighted single objective, so that trade-off information is required. If trade-off information is not available, then we will have to go with the Pareto solution. So this issue can always be there with the mathematical programming methods that are typically used in MODM. Then, there is going to be scale problem. What if the number of objectives that are to be used that are being used in a particular decision problem, they increase.

So the curse of dimensionality is going to be there and the computational cost will actually increase because remember we are talking about finding an optimal solution and we are talking about applying optimization algorithms for these kind of MODM problems. So therefore, the curse of dimensionality is an important issue that we have to deal with and it might lead to computational cost. So there are various mechanisms to handle some of these scenarios.

For example, this curse of dimensionality can be handled using algorithms like genetic algorithm, genetic programming and evolution strategies. Some of these approaches and algorithms can be used to deal with this these scale and trade-off scenarios.

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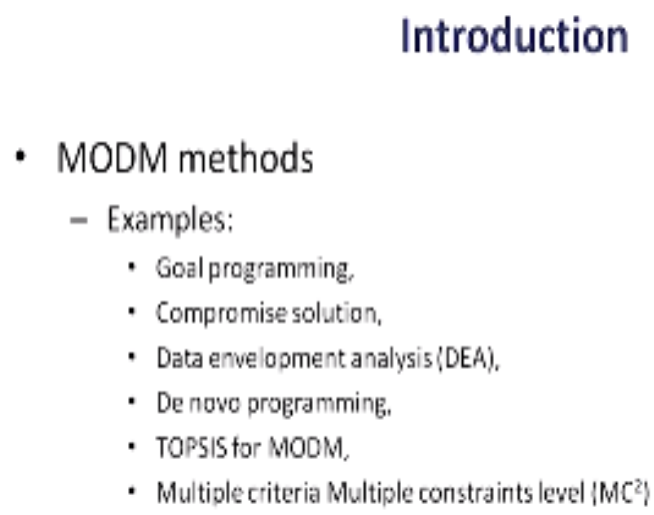

Now, we will look at the examples of MODM, then goal programming, compromise solution, data envelopment analysis DEA, de novo programming, TOPSIS for MODM and multiple criteria multiple constraints level. So these are some of the examples of MODM methods that are popularly used. So within MCDM till now, we talked about two main categories; MADM, multi-attribute decision making and MODM, multi-objective decision making.

So in MADM, again we have two schools of thought, value-based theories where more common example method is MAUT and then we have outranking school of thought where we have a number of methods ELECTRE, TOPSIS, VIKOR and all those methods are there. In MODM, we typically use mathematical programming and different examples for these methods we already discussed. Goal programming, compromise solution, DEA; all these are the examples.

Now after having understood different kinds of categories for MCDM and within that different kinds of approaches or schools of thought, let us understand the type of decision problems that comes under the domain of MCDM. So as we talked about previously, there are four main problems which are more common; choice, ranking, sorting and description. There are other types of decision problems as well which are solved under MCDM, but these are the four main types. So let us discuss them one by one.

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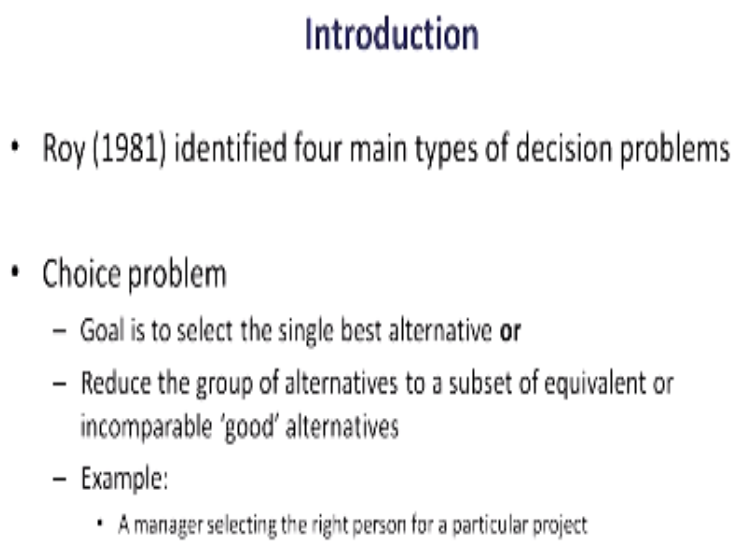

So first one is choice problem. So what these problems are about. So in choice problems, goal is to select the single best alternative or at least reduce the group of alternatives to a subset of equivalent or incomparable good alternatives. So, either we are looking single best alternative

or at least we should be able to reduce the set of alternatives to an equivalent or incomparable set of alternatives. For example, a manager selecting the right person for a particular project.

So for a particular project, the manager would need just one person, so he would obviously look for single best person for that particular project depending on different criteria and depending on the given the number of alternatives, number of employees that could be suitable for this particular project. So this is more of a choice problem. So it might so happen that manager might be able to identify a single best person or at least may arrive at two or three persons which can be considered as good alternatives

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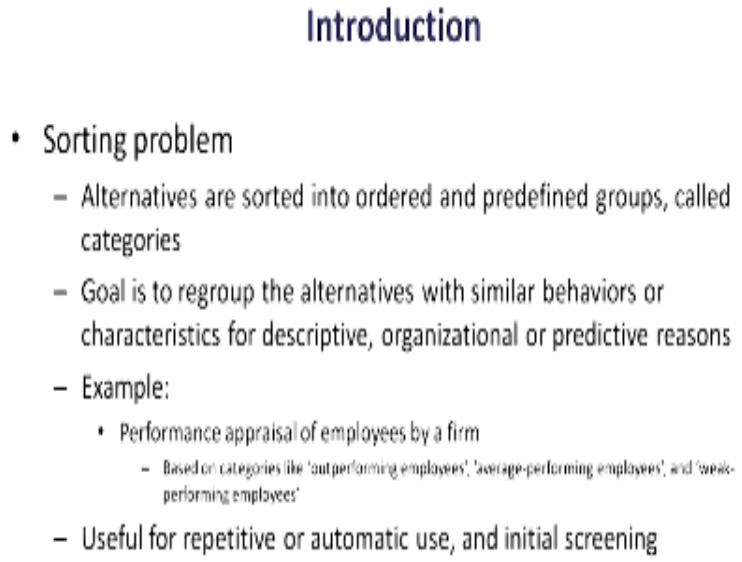

Then the second kind of problem is called a sorting problem. So in this particular problem, the alternatives, they are sorted into ordered and predefined groups. So these categories are predefined and the sorting problem is about sorting the alternatives into one of these categories. So goal is to regroup the alternatives with simpler behaviors or characteristics for descriptive organizational or predictive reasons.

So the idea is there are number of alternatives, we would like to sort these alternatives and regroup them based on the similar behaviors that they might have. So, one example of this kind of sorting problem is performance appraisal of employees by a firm. So a firm would like to categorize employees into outperforming employees, average-performing employees or weak-performing employees, so because that would be important for the firm to distribute bonuses or give hikes in the salaries.

So that becomes a sorting problem. So typically, these kinds of problems are useful for repetitive or automatic use or some sort of sometimes in initial screening also, if we have to do some sort of initial screening, then also this problem can be suitable.

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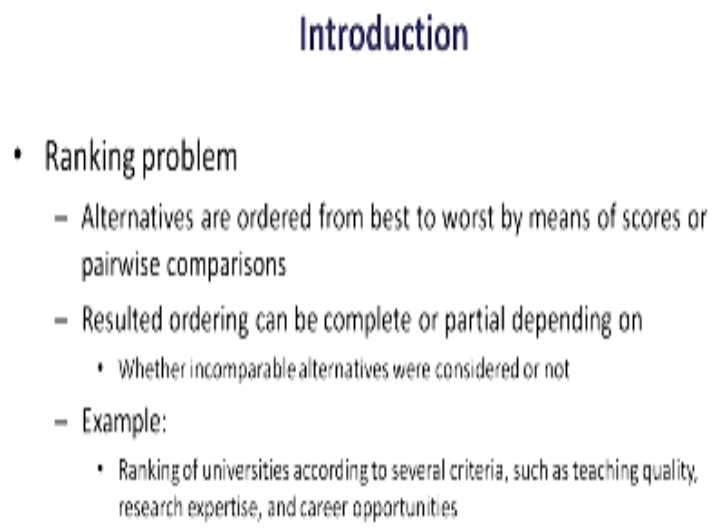

Then there is another type of problem called ranking problem. So in this particular problem, alternatives are ordered from best to worst by means of scores or pairwise comparisons, so the aim is to get that full ranking from best to worst based on certain scores. So, they could be global scores or pairwise comparisons which can be used to perform this ranking. Now, this resulted ordering can sometimes be complete, can sometimes be partial, so that depends on whether among the alternatives we have some of the incomparable alternatives as well.

If incomparable alternatives are also being considered, then we might end up with the partial ranking, otherwise we might get the complete ranking. So example of ranking problem is, this particular example we talked about in the previous lecture as well, ranking of universities. So ranking of universities according to several criteria such as teaching quality, research expertise and career opportunities. So, this example is a ranking problem example.

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Introduction

- Description problem
  - Goal is to describe alternatives and their consequences
  - Typically done as a first step to understand the characteristics of the decision problem
- Other problems types
  - Elimination problem, Design problem, elicitation problem
  - Group decision method
    - When several decision makers are involved

Now let us talk about the fourth type of decision problems, this is called description problem. So typically, this description problem you would like to solve if we are dealing with a complex decision problem and we are not able to understand the problem itself, then probably we would like to formulate a description problem first. So let us understand what we mean by this type of problem. So under description problem, goal is to describe alternatives and their consequences.

Sometimes it might be difficult to even understand the characteristics of alternatives and in case we prefer one over the other, what are going to be the consequences. The trade-offs and value judgment that is sometimes difficult to understand, so this kind of description problem and the method that are used to solve this problem, they help achieve this goal; describe the alternatives and their consequences.

So as I said typically these problems are solved as a first step to understand the characteristics of the decision problem itself. So if the decision problem itself is very complex, we can take it as a description problem and first try to understand the problem itself. Then there are other problem types also, for example, elimination problem. So the elimination problem is a type of sorting problem itself. Then there is another type of problem called design problem.

Then elicitation problem is there. For example, subjective preferences of DM. If we find it difficult to understand the subjective preferences of DM, probably elicitation problem they can help. Then we also need to have group decision method if more than one DM are involved. Several decision makers are involved, then probably we need to have a group

decision methods as well. So overall in this course, we are going to mainly focus on choice and ranking problems and we are going to cover most popular MADM methods.

So in this particular course, we are not going to focus on MODM methods, we will mainly focus on MADM methods and within the MADM method, we will look to focus on choice and ranking problem. So, the exercises that we are going to perform in this particular course, they would be typically on choice and ranking problems.

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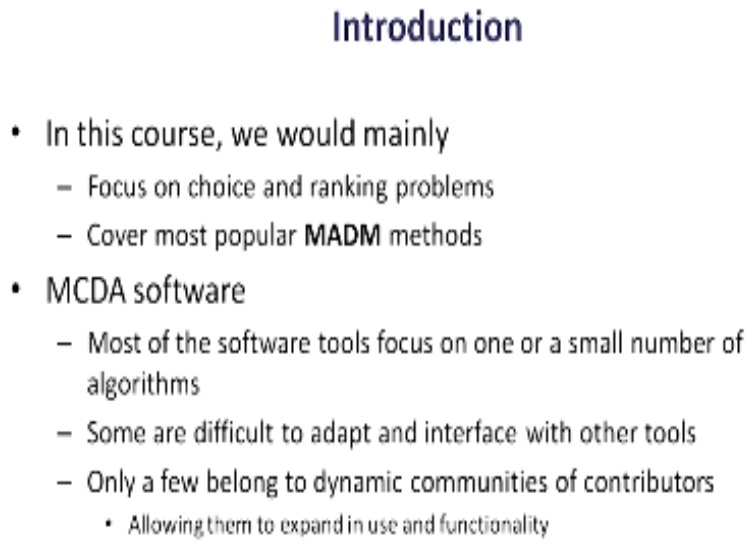

Now many of these methods that we use in MCDM, they are quite technical in nature, so therefore why software's have been developed and there is a huge list of software's that used for different MCDA methods. These software's typically provide one particular method or two or three. There is not one comprehensive solution that covers all of them, are all different versions of different MCDA methods.

So as you can see here, most of the software tools focus on a small number of algorithms, some are difficult adopt and interface with other tools. Sometimes, we have to use a combination of tools or methods, then some of the software's are difficult to do that. Only a few belong to dynamic communities of contributors. So in the sense once a software is developed, whether that software is maintained and upgraded and new versions are released that is also not applicable for all the software.

So there are only a few software where there are dynamic communities which keep on contributing for the development of those software's in the sense they allow them to expand

in terms of functionality and use. So because of all these problems in this particular course, we are going to use R statistical environment.

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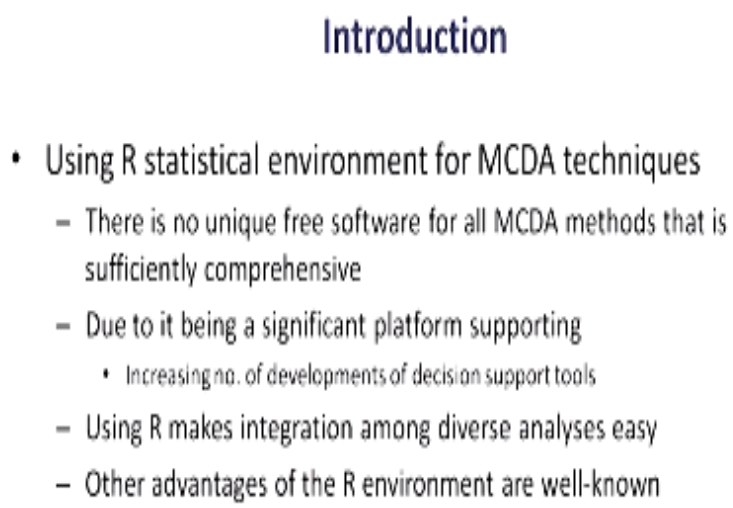

So R statistical environment has not been quite often used for MCDM. So in this particular course, we are trying to attempt and bridge that gap. As you can see here in the slide, there is no unique free software for all MCDA methods that is sufficiently comprehensive. So, R is one platform that can provide, that can fill that gap, and can be a comprehensive platform where most of the techniques can be covered, and because we have a large community of contributors for R software platform, therefore expansion of these methods in terms of functionality and uses can always be there.

So this R platform R environment is also a significant platform where lot of decision support tools are being developed. Integration as talked about integration among diverse analyses can become quite easy if we are using R, and then there are other advantages of R environment which are well known it being statistical software environment, also provide data mining techniques. So, there are so many other advantages very popular.

So in terms of skills and expertise, there are more resources that are available to understand R and how to use R, not just for decision support tools or MCDM, but even for analytics and statistical research purposes.

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Introduction

- Relevant R packages in CRAN repository
  - MCDM, ahp, topsis, FuzzyAHP, FuzzyMCDM, decisionSupport, Outranking Tools, MCDA
  - Other useful packages
    - kappalab, RankAggreg, agop, ConsRank, FuzzyNumbers, pmr, FuzzyR, RXMCDA
- For an introductory lecture on R
  - Refer my previous course on NPTEL
    - "Business Analytics & Data Mining Modeling using R"

We look at the relevant R packages that are available to use MCDM methods. So some of these relevant R package, I have mentioned in this particular slide as you can see here. So CRAN repository of R, there are number of packages which cover a number of techniques belonging to MCDM. So there is package called MCDM itself covering a number of techniques. Then there is a package on ahp, topsis, FuzzyAHP, FuzzyMCDM, then there is another package decisionSupport, Outranking Tools, MCDA.

So these are some of the packages that are available and support a number of techniques. Then there are other useful packages which can be used in conjunction with these relevant packages which are mentioned here in the slide itself. Now if you are not familiar with the R environment and R programming and how it is done, so you can refer my previous course on NPTEL it is called Business Analytics and Data Mining Modeling using R, so this particular course you can refer.

There is a particular lecture on introduction to R and that can actually be used to understand and to familiarize yourself with the R environment itself. So we will stop at this point and we will continue our discussion on MCDM and the software packages in the next lecture. Thank you.