MCDM Techniques using R
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Lecture – 1
Introduction to MCDM Techniques – Part I

Welcome to the course MCDM Techniques using R. I am Dr. Gaurav Dixi from Indian Institute of Technology Roorkee. You must have seen me in the video lectures of my previous course on Business Analytics and Data Mining Modeling using R. So in this particular course MCDM, the full form is multi-criteria decision making, we would be talking about the decision making, the decision making process and the different criteria and the related theories, methods.

We would also be doing examples and exercises using R for this particular course. So let us move forward. So as I said the full form of MCDM is multi-criteria decision making. So let us start with understanding what is decision making

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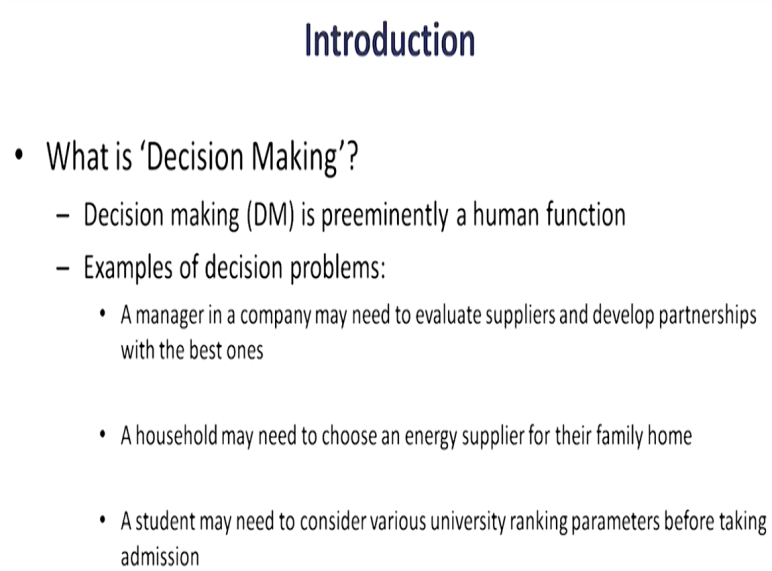

So we will look at decision making from logical perspective. Preeminently, this is a human function, so it is the job of human because humans are supposed to be responsible for the decisions they take and any machine or AI based machine or robots even if they are taking decisions, probably they will not take accountability for those decisions. So in that sense, decision making is preeminently a human function. Now to understand more about decision makings, let us have a look at some of the examples which are presented here in the slide.

So some of the examples of decision problems as you can see, a manager in a company may need to evaluate suppliers and develop partnership with the best ones. So, this is an example of one typical decision that a manager has to make. So just think about how a manager will go about making these decisions because if the company is a large company and is having higher revenues, then they would be able to attract a number of suppliers. Now, how do a manager goes about selecting a best supplier for their company.

So this process of decision making, selecting a supplier, is actually what we are referring as the decision problem here. The another example as you can see in the slide is a household may need to select an energy supplier for their family home. So in a particular city if there are more number of companies which are willing to provide energy supplies to different localities of the city, then the households will have a number of choices, a number of alternatives.

So for them in that sense, it would become a decision problem how they go about selecting a particular energy supplier. Whether they would go by the cost, the price that is being charged for per unit kilowatt of energy or it could be the availability of energy twenty four seven availability or the supplier's credibility, the billing process. There could be a number of criteria that could be important for a household to make such a kind of decision.

Now, let us take another example, third one. A student may need to consider various university ranking parameters before taking admission into a particular university. So, here also if we look at, when the students are looking to take admission in undergraduate and postgraduate and even Ph. D programs, they would try to take a look how good the university is, how is the teaching quality there, how is the research there, what are the carrier opportunities that are going to be available for the student over there.

So, these are some of the criteria which a particular student would like to take a look before making a call in terms of selecting a particular university and a program for taking admission. So, we look at some of these examples, so these in a sense are decision problems. So we as individuals whether we are making a decision for our personal decision, for our household or we are sitting working as a professional in a company, we are often faced with many decision making scenarios and we have to apply ourselves to make the best decisions.

Now to understand a decision problem and decision making process in a more detailed manner, specifically in MCDM context, the context of this course, let us take another example. This is a more detailed example as you would see in the slide.

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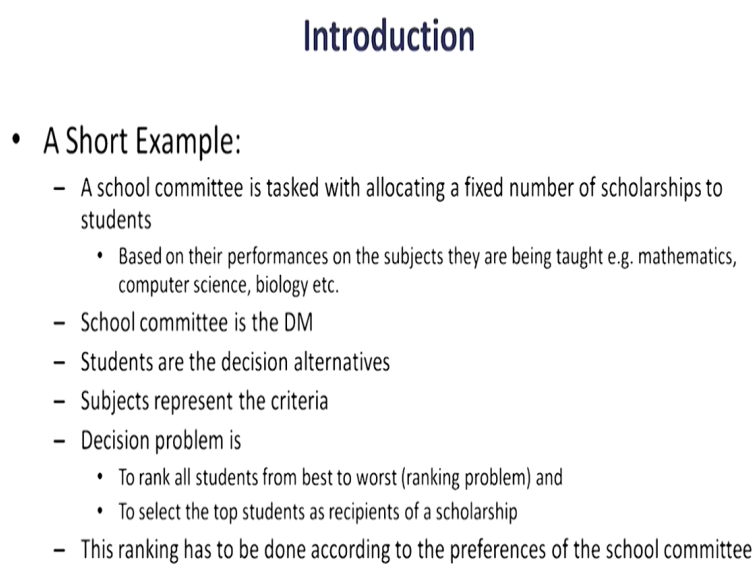

So there is a school committee which is tasked with allocating a fixed number of scholarships to students and it has to be based on their performance, performances of course on the subjects that they are being taught. So the typical subjects could be mathematics, computer science, biology etc. So the performance of the students on the subjects that they are being taught that can be taken into account and the school committee then accordingly, they can take a call in terms of allocating scholarships to meritorious students.

Now in this problem if we look at the school committee, so here school committee is playing the role of a decision maker which we have denoted as DM here in the slide. Now if we look at students, they are decision alternatives because the decision maker which is the school committee, they have to allocate a scholarship to, they need to identify meritorious students based on their performance.

So each of the student which is eligible for the scholarship, they are one alternative, one option, for this particular scholarship allocation. So, the students here are the decision alternatives. Now, we look at the subjects that these students are being taught. So, the subjects represent the criteria. Now here you would also see that the different students might be into different programs and therefore they might be studying different subjects. Some of

them are going to be common like we have core courses, elective courses and that kind of thing.

Then depending on the department that a particular student is studying, the courses, the subjects which a particular student is being taught, they might be different from one student to another student. So you would see that that increases the complexity of the decision making for the school committee which is playing the role of decision maker.

So depending on the performance of students on the subjects, so the performance on the subjects, so that becomes the criteria for solving this decision problem. Now what the school committee as a decision maker is required to do, so that is we can write in a decision problem statement. So you can see here in the slide decision problem here in this case is to rank all the students from best to worst, so this being a ranking problem. So, this being an example of a ranking problem.

So we need to rank, the school committee need to rank all students from best to worst, only then they would be able to find out who are the meritorious students whom the scholarship needs to be allocated. Now the second part of the problem is to select the top students as recipients of a scholarship. Now ranking and then selection of the alternatives which are students in this case. So these are some of the parameters of this decision problem.

Another important aspect of this decision problem is that the ranking has to be done according to the preferences of the school committee. So the school committee might carry their own preferences in the sense that they might value a particular course over another. So therefore, they might value performance of students in mathematics courses more than the performance of a student in humanity courses or some other courses.

Therefore, those kind of preferences of school committee will also have to be incorporated in the decision making process. So we look at this overall example and the few things that we talked about identification of decision maker which being the school committee, identification of alternatives all the students who are eligible and the performance, the criteria being the performance on different subjects. We understood the decision problem and then the subjective preferences of school committee.

So just like the previous example that we were talking about the university ranking, so there we might have teaching quality, research and the carrier opportunity that are available. So therefore for any university ranking and the way it is actually determined, there are going to be different weights that are assigned to some of these criteria.

Some university ranking methodology might prefer to give higher weight to research, some might prefer to give higher weight to carrier opportunities, some might prefer to give higher weight to teaching quality. So therefore, these subjective preferences are going to play an important role in a way how the ranking is determined. So depending on the subjective preferences of decision makers, the ranking results might change. So the same thing we can understand in this example as well.

Depending on the subjective preferences of this school committee, the performance on different subjects might vary and therefore the ranking of the students might also reflect that. Let us move forward. So whatever we have understood from these four examples, we can put that we can use that to define what is decision making. So a decision making is a complex process as we have understood.

There are so many parameters involved. Alternatives, criteria, and who is the decision maker and their subjective preferences and then the decision problem itself and then the method that we are going to use to model this decision problem. So all this makes this decision making process a complex process.

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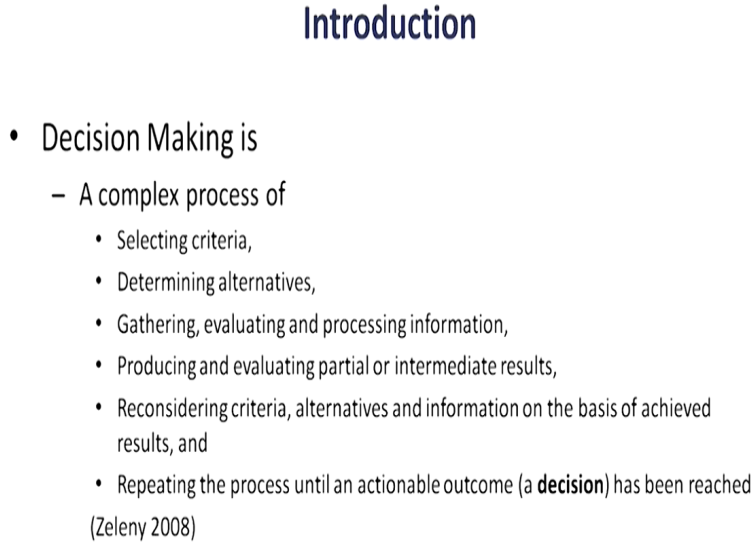

So decision making is a complex process of selecting criteria. For example in the previous example, the criteria was the performance on subjects. Determining alternatives, for example in previous case, the students were the alternatives. Gathering, evaluating and processing information. So therefore, we need to get the information on a student's performance on different subjects that they are being taught. Next, producing and evaluating partial or intermediate results.

Now depending on the subjective preferences of DMs, we need to evaluate and produce the intermediate results and now these results then they need to be examined. So, the next point is reconsidering criteria. Depending on the results and then depending on the decision makers, again decision makes analyzing the intermediate results and they might feel like changing a few of the criteria or their preference about their criteria.

So reconsidering criteria, alternatives and information on the basis of achieved results, so that is to be considered in the next step and repeating the process until an actionable outcome or a decision has been reached. So as you can understand, this is going to be a repetitive iterative process until a consensus between decision makers is reached and we have a final outcome or decision. So this is how we can define a decision making process.

Now here itself you can see that when we call this particular course and this particular area as MCDM, multi-criteria decision making, here you would often feel that most of the decision making, the important key decision makings that one has to perform in personal or professional lives, they typically involve multiple criteria. So one might also say that decision making is actually multi-criteria. So there is no decision making when only single criterion is involved.

So more often than not important decision involve multiple criteria, therefore, one might also say that most of the decision making that one has to perform in their personal and professional lives, they have to be called multi-criteria decision making. So from the definition of decision making itself, we get this feel of the multi-criteria and why it is called MCDM, multi-criteria decision making.

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Introduction

- Individuals and firms don't rely on just one criterion for their decision making
  - Consider multiple criteria (MC) in their decision process
- Main types of decision problems
  - Choice problem, sorting problem, ranking problem, description problem
  - Complexity of these decision problems is higher
    - Due to involvement of several criteria

So as we have discussed, individuals and firms don't rely on just one criterion for their decision making. So even if we are using just one criterion, still it would be considered a decision making; however, as I have said that typically we rely on many criteria for our decision makings and the whole process becomes complex when some of these criteria are conflicting in nature.

So therefore if you are trying to give more weightage, more value to a particular criterion, it might come at the cost of lowering the value for some other criterion. So there are trade-offs involved and now these trade-offs are used as a subjective, they are to be evaluated, they are to be given as subjective preferences of decisions makers as we will discuss in this particular lecture. So typically firms and individuals, they consider multiple criteria in their decision process.

Now, we will look at the main types of decision problems that we have to face. So there are choice problems, sorting problem, ranking problem and description problem. There are other types of decision problems as well, but these are the more common types of decision problems. So given these types of decision problems and the involvement of several criteria as we have talked about, the complexity of decision making process is much higher. So therefore, we need certain methods and techniques to structure the decision making process.

This particular domain, this particular area of multi-criteria decision making is about understanding, learning those methods and techniques, which can actually be used to handle

the complexity of this decision problems. Now if you want to define in a sentence or write in a sentence what multi-criteria decision making is;

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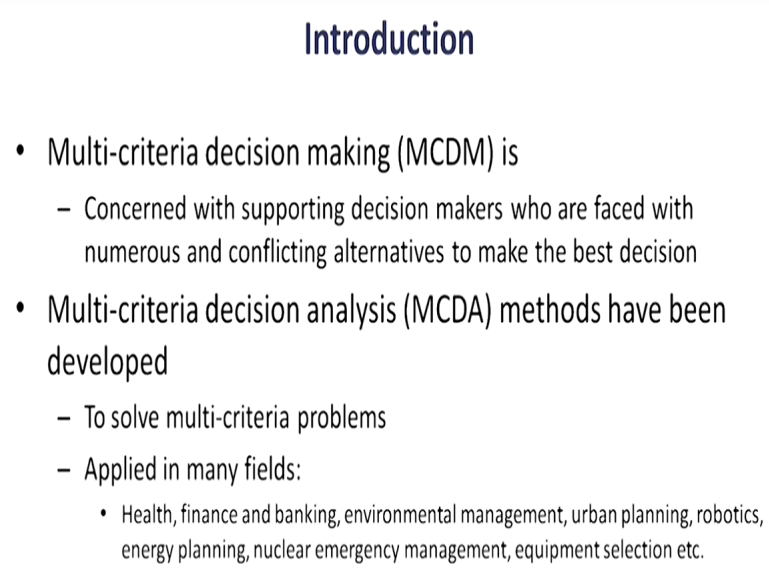

So as we can see in the slide, concerned with supporting decision makers who are faced with numerous and conflicting alternatives to make the best decision. So decision makers will of course have their own judgments, their own subjective preference; but because of the higher complexity of these decision problems, they would require the help of analyst in terms of following a structured methodological process and these analysts are going to aid the decision makers to make the best decisions.

So these analysts are going to use some of the methods which had been developed in past many decades to actually solve these decision problems. So as you can see in our next point, multi-criteria decision analysis methods, a number of them had been developed to solve these multi-criteria problems. If we look at the applications of these MCDA methods, so they had been used, they have been applied in many fields.

Few examples are written here starting with health, finance and banking, then environmental management, urban planning, robotics, energy planning, nuclear emergency management, equipment selection. So, there are number of fields where the multi-criteria decision making decision analysis methods have been used. So in terms of applicability of this particular course and whatever we are going to learn in this course and the methods and techniques that we are going to learn, they can be applied in a number of engineering, management, social science fields.

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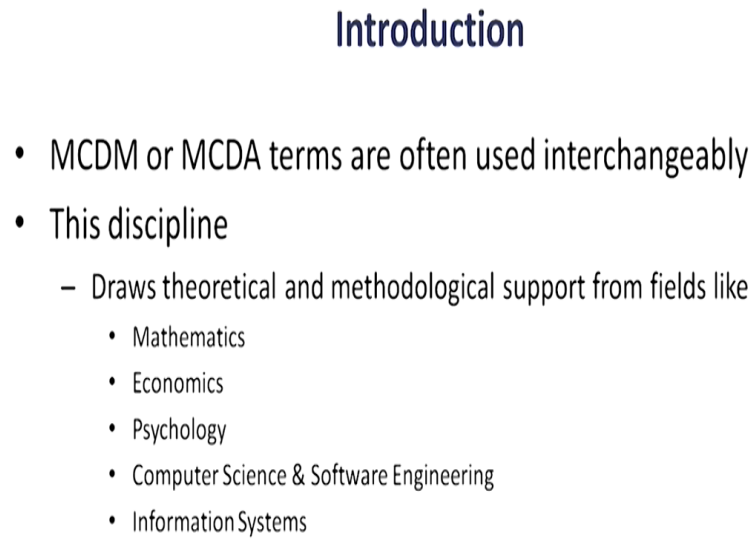

Now you might also see that often these two terms MCDM, multi-criteria decision making, and MCDA, multi-criteria decision analysis, these terms are used quite often they are used interchangeably. So, this you will come across quite often. Now if we try to define this area in terms of the theoretical and methodological support that this area takes from other disciplines, so here we have mentioned some of the prominent disciplines.

For example; Mathematics, Economics, Psychology, Computer Science and Software Engineering and Information Systems. So these are some of the prominent fields which are actually from where this theoretical and methodological support, this has been drawn for this particular field MCDM. Now, let us understand MCDM in another way.

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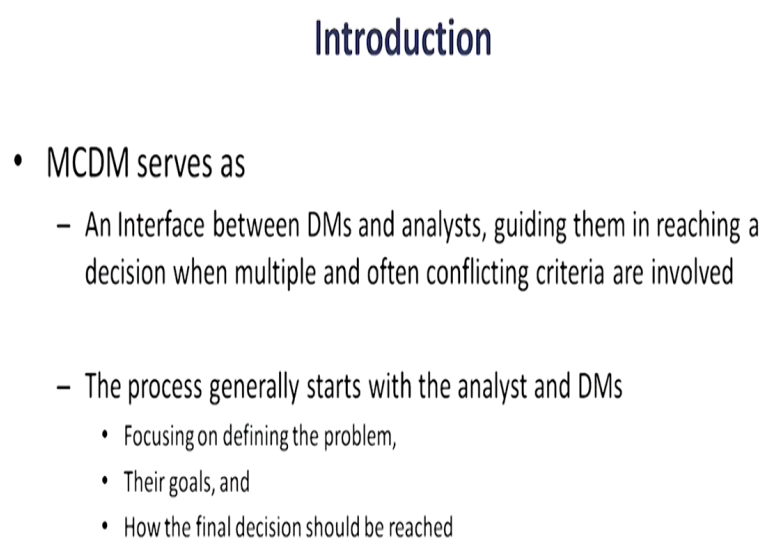

So in another way, we can say that MCDM serves as the interface between DMs and analyst, guiding them in reaching a decision when multiple and often conflicting criteria are involved. So the analyst, they use these techniques in a way aid the decision making process and help and guide the DMs to make the best decisions. Now, let us have a look at the process of this MCDM. So the process generally starts with the analyst and DMs focusing on defining the problem, their goals and how the final decision should be reached.

So, first step defining the problem because that buildup and that will also in a way include identification of criteria, the alternatives. So there are going to be a number of sub-steps understanding the context of the problems since there are going to be number of sub-steps which are going to be part of the first step itself. So focusing on defining the problem, their goals and how the final decisions should be reached, the kind of method that we are going to adopt to reach the decision.

So, the process would actually involve some of these steps. There are some other important aspects of MCDM related to final decision.

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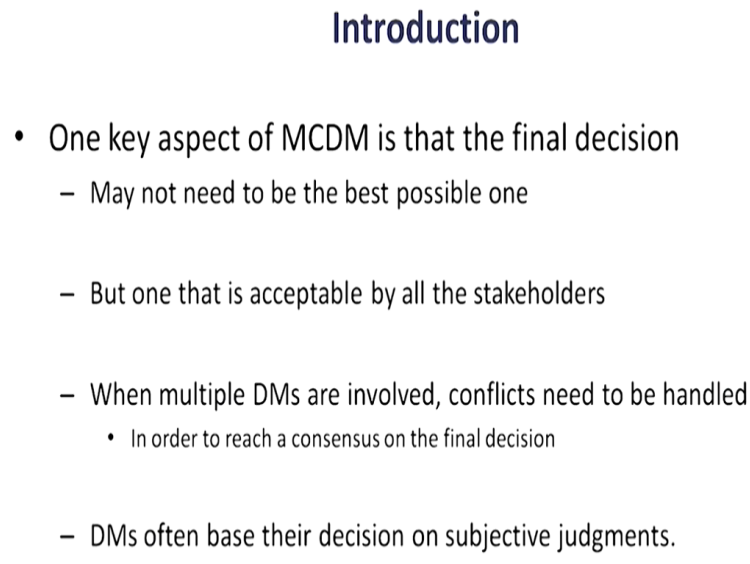

So the final decision that we typically get after applying MCDM techniques MCDM methods, they may not be the best possible one, but they are of course going to be one that is acceptable to all the stakeholders. So if there are more than one decision makers, so that consensus has to be reached and therefore all the stakeholders which typically are identified in the very first step when we are trying to understand the problem. So, the solution, the final decision, has to be accepted to all the stakeholders.

When multiple DMs are involved, conflicts need to be handled because the subjective preferences of different DMs could be different, therefore we need to reach a consensus so that a final decision could be made. So DMs often base their decision on subjective judgments, so this is part of the methods that we adopt in MCDM. So subjective judgments are taken in consideration and typically based on the subjective judgments of DMs, the final decision is made.

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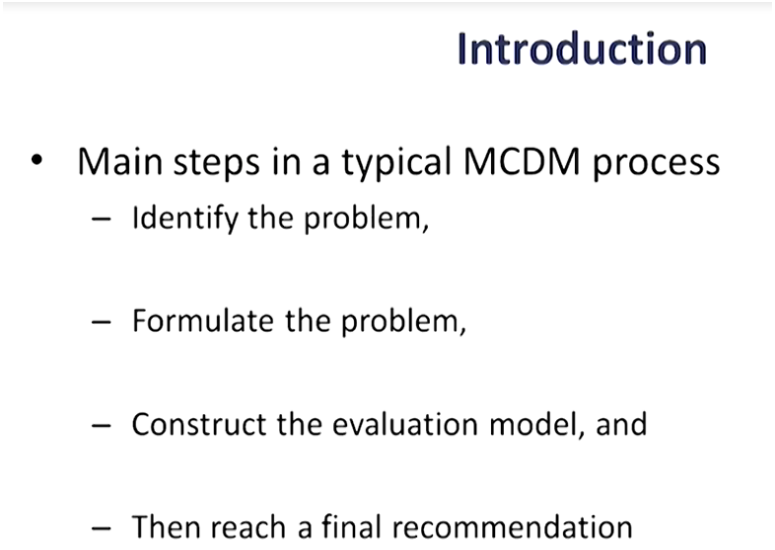

Now let us understand the main steps of a typical MCDM process in a bit more detail. So, the first step as we talked about is identify the problem. The second is formulate the problem. So the previous steps that we talked about, so we have broken down the first step into two here, identify the problem and formulate the problem. The next one is construct the evaluation model, so the model that is going to be used to evaluate the alternatives with respect to the criteria that we might have.

Then final step, then reach a final recommendations how we are going to arrive at the consensus. So these are four main steps and each of these steps can have several sub-steps. So let us discuss them one by one.

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Introduction

- Sub-steps in a typical MCDM process
  - Identify the problem
    - Identifying the stakeholders (or actors),
    - Identifying the context of the problem,
    - Identifying the objectives of the decision and its respective properties

So first step, identify the problem. So, there could be a number of sub-steps. For example, identifying the stakeholders or actors who are going to participate in this decision making process. Then identifying the context of the problem, so whether it is a decision problem related to personal or professional life, whether it affects the company, whether it is about the suppliers, whether it is for the internal functioning, whether it is for external functioning and the overall context of the domain that is of course going to influence the whole decision making process.

So therefore identifying the context of the problem is very important. Then the next sub-step could be identifying the objectives of the decision and respective properties. So, this we need to figure out, only then later on in the next step, we would be able to apply our methodologies. So, we need to have clear understanding of the objectives of the decision and the properties that we want to have there.

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Introduction

- Sub-steps in a typical MCDM process
  - Formulate the problem
    - Identifying the decision alternatives and their criteria,
    - Identifying the type of decision problem, as well as
    - Managing multiple DMs and their different perspectives

Now next main step formulate the problem, it can again be broken down into many sub-steps. For example, identifying the decision alternatives and their criteria. So as we talked about the example where a school committee was there, so that example that we discussed, there also we were able to identify the alternatives, so different students were the alternatives and then their criteria. So the performance of the students on different subjects, so that was the criteria. So that identification is sub-step under this formulate the problem.

Then the next sub-step could be identifying the type of decision problem. So the school committee problem that we talked about that was the ranking problem. So in another scenario, it would be choice problem, sorting problem or description problem. So we need to understand the type of problem that is going to be there because that is going to influence the later steps of the decision making, this MCDM process.

Managing multiple DMs and their different perspective. So while we are formulating the problem if there are more than one DMs or DM involved, then we need to understand their perspective as well regarding the formulation of the problem.

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Introduction

- Sub-steps in a typical MCDM process
  - Construct the evaluation model
    - Choice of a mathematical model and its tuning
      - To reflect the perspective of the DM
    - A resolution method needs to be selected
      - In order to provide a recommendation to the decision problem
  - Then reach a final recommendation
    - Recommendation is presented to the DM
      - Validates the recommendation,
      - Asks for additional supporting analyses, or
      - Revisits previous steps in order to refine the solution

Now, next step is construct the evaluation model. So this step is can also be broken down into a number of sub-steps. So for example choice of a mathematical model and its tuning, so what particular model what particular method we are going to select and then tuning of that particular model or method as per the perspective of DM because DM is supposed the person who is going to be responsible for the final decision that is to be made. So therefore, their perspective has to be understood and analyst has to see the perspective of DM and then the choice of mathematical model and its tuning has to be done accordingly.

Another subs-step could be a resolution method needs to be selected because the recommendation for the decision problem that is to be how that recommendation is to be made, so we need to have a methodological approach there. So this resolution method has to be decided which will actually finally we use to provide the final recommendation. Then the next step is reach a final recommendation.

So even after a final recommendation is made to DM and it is presented to DM, there could be various sub-steps depending on which one is picked by decision maker, so there could be various paths. So the DM can validate the recommendation, so in that sense, the decision would be immediately made and the final decision of whatever was recommended by the analyst that would accepted or decision maker can ask for additional supporting analyses.

So that can also happen because depending on the subjective judgment of decision maker and their own perspective, they might require additional supporting information analyses, so that might also happen, that is going to be different path and we might end up repeating the whole

process again as we talked about previously. So another path that can be taken by DM is revisit previous steps in order to refine the solution.

So the particular solution which is recommended to DM if he or she might see some possibility to improve the solution, and therefore previous steps could be revisited by the DM. So that covers the four main steps and sub-steps that could be part of the decision making process.

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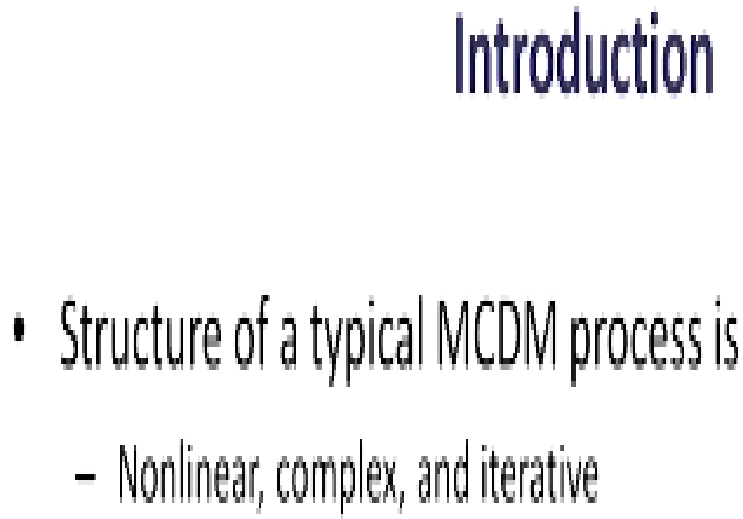

Now whatever we have discussed about these main steps of MCDM process and the sub-steps as well, we can understand that the typical MCDM process is nonlinear, complex and iterative in the sense that decision making process involves many parameters and any path can be taken by the decision maker. So there is going to be iteration. If a particular solution requires refinement, there could be different paths that can be taken across a number of steps that we just talked about.

So that whole thing makes it nonlinear and iterative and therefore complex as well. Complexity as we talked about also is coming from the conflicting criteria that we might be handling in the MCDM process. So at this point, we will stop here and in the next lecture, we will continue about discussion on the introductory part of MCDM. Thank you.