Hello? Can you hear me? Well, yes. Okay. First of all, thank you very much for being here this Friday. I know the normal day is Tuesdays, right? But yes, I was in a conference for for a couple of days. And it's a very important conference. As you may know, academics in general, our responsibilities basically teaching, researching and me. So this was my research time and it was a conference about humanitarian logistics, which is, by the way, my research area. Some of you guys probably know actually not some maybe one person, just one person who met me last semester knows better my area. Well, anyways, thanks again for coming this Friday. Okay. This is the first lecture. These are the introduction to the course. So basically today my main intention is to introduce the course. What you can expect from this course, what you can expect from me as well. Obviously what I expect from you guys definitely master student. So probably you are very clever if students know. Yes, I can see your face. Yes, very clever. But yes, this is a this is a very diverse and interesting cohort. You suppose you have 50 students a little bit less than the previous years. Last year, actually, I didn't teach this course because I was on sabbatical. I was I spent some time in Turkey. You have Turkish students here? We don't have Turkish students here. Wow. Every day we have at least 3 or 4. So it's not as diverse as I thought anyways. So yes, I'm very glad I'm teaching this course again. So we have the course. The name is Prescriptive Analytics with mathematical programming. To be honest, most of you guys don't know what this course is about. I'd say most of you guys, at least traditionally I've been teaching this course over the past six years. But last year, but over over the past six years and in January, students think that what's magical programming is related to programming, computer programming or computer languages or things like that that you learn Python or how to build loops or how to build like logical underlying computer codes and things like that. This is what you think about this course. No. Wow. So you're definitely clever. Yes. She does? Yes. You learn Python and seems like that. No, this is not a python course. Come on. So can you tell me what mathematical programming means in this context in the context of prescriptive analytics? What is the difference between prescriptive analytics and predictive analytics? Probably at this point you guys had courses on predictive analytics. Who is teaching you Predictive analytics. Sorry. Anthony. Anthony. Antonia. Antonia. Okay. Antonia. Good, good. Good. Very good. So Antonia is teaching predictive analytics. What is the main difference between predictive analytics and prescriptive analytics? And we have also descriptive analytics, which probably that point, you know, descriptive, right? Yes, Very easy to understand. Descriptive, descriptive. But what about the difference between prescriptive discourse and predictive Antonio's course? Oh, maybe like describe the problem right now to try and to somehow transfer the problem, like the problem business, maybe this problem into mathematical manner. Wow. Actually, I wouldn't put better. Yes, it's definitely the idea of of prescriptive analytics. In this case, we have different techniques. Okay. Prescriptive, prescriptive analytics is still difficult for me. Even after six years in this country. Prescriptive analytics, The main idea is basically to help you guys or to help organisations to identify their problems, their organisational problems, to model and to solve, and to provide insights on how to make better decisions. Okay. And obviously, as I said, we have different techniques that we can apply in prescriptive analytics. We don't have only mathematical programming. Mathematical programming is one of those techniques. And mathematical programming actually is already a very big word. Okay? This is this is the award of mathematical programming is a very big word. Why? Because inside this word, we have all the techniques, okay? All the techniques or all the mathematical models or other optimisation techniques. Mathematical programming for us is basically optimisation or mathematical optimisation or the well, the nomenclature you want to use. Okay. But mainly the idea is what's your name? Valeria. So is like Valeria. The main idea why we learn those techniques is in the end of the day to be able to identify problems and I say problems, business problems because this is a master's in business analytics. But you guys know better than me business in the broad sense. It can be any problem can be a problem out of an NGO, for example, give me one example of a problem that NGO can face and you can use mathematical programming to help support better decisions, for example. Oh, my gosh. The. Maybe something related to food. What was it called again? You should know better. You pass this course. Sorry. Maybe food banks? Yes. Food banks. But what was the organisation? I don't know. You tell me. Guys can be. Organisation that has or kind of manages food banks across the country and they want to optimise the way that food parcels are delivered to the outer population. Perfect. I guess. Effective. Equitable, equitable. Way more optimised way and things like that. So bad gave you one example. It was wonderful. Thank you. But Barra gave me one example of a potential way to perceive one problem in a given organisation. Great. Thank you very much. We can help Trussell trust. We can help Lloyds, you can help banks, we can help any sort of organisation consultancy company because the idea is to learn techniques. Okay, obviously it's just one course. It's a ten week course only. So the idea is at least to help equip you guys with basics, at least you can be able to identify a problem. And putting mathematical problem terms is not an easy task. Okay. People say that mathematical programming and modelling building that is the translation of a given decision making problem into its mathematical programming form or mathematical form, because it doesn't need to be mathematical problem. It can be any other thing can be like differential equations. I don't know if you work with differential equations in the past, can be is mathematical models as well. Differential equations here are not using differential equations. We are using mathematical programming techniques. And to be way more specific, we'll be using mainly two techniques here. We'll be using LP and MIP. So LP from linear programming. Okay. And MIP from mixed integer programming. So basically the main idea is to use linear, okay, equations and inequalities and linear functions to represent a given decision making problem. And you can, you can say, well, but this looks very narrow actually the extend to we can use like this only these two techniques to model decision making problems or real decision making problems. And I can tell you for sure that we can model a vast number of real world decision making problems only using LPs and Mips, if you like this course or if you want to continue in this study from a different perspective. Because our perspective here is the deterministic world. Okay, so everything here will be deterministic. You know what it means being deterministic in this context. Being certain. Exactly. Being certain or not being uncertain or random. Okay. If you want to study these problems under uncertainty, you have to undertake the next course, which is stochastic programming. Okay, So in stochastic programming, the main idea is to extend the models and basically the solution approach we see in this course to take into account uncertainty parameters and uncertain sources and things like that. Okay. But obviously it's you need to undertake this course first to be able to undertake the other one, assuming obviously you don't have the requisites, but I can see like from your faces, the most of you guys are very comfortable with the idea of linear programming and mixed integer programming. Am I right? How many of you already know linear programming? Okay. Yes. Ten students mix integer programming to. Only linear programming simplex. Only branching branching coach. Just a little bit. So probably industrial engineering courses. No, You did industrial engineering, No courses. Yes. You. So yes. In general? Yes. I'm industrial engineer myself in general. We have like all those techniques when you do our UG programs. Well anyway, so basically this is what you can expect from this course. The idea is to present some, I would say, some tricks or some ways to identify these problems, to model these problems, to translate these problems into linear inequalities and linear equations, how to model the criteria, What can be the best option for a given decision making problem after that, how to solve this problem. Because again, we are dealing from the computational point of view. You're not dealing with problems, okay? Theoretical problems. So we are dealing with problems that we want to solve once you have the numerical solution of a given problem. Okay. For example, but I gave you one example. Let's assume you have a given food bank in Edinburgh and you have to distribute the food parcels to other towns and municipalities in Scotland. So to solve this problem, we need an input, we need numbers, we need data. Okay. This data can be from different sources. Data can be from. Your predictive analytics course. Okay, so that's the main engine in predictive analytics. You'll learn how to deal with this, with this data, how to predict behaviours, how to anticipate trends in certain data sets and things like that. But you don't learn how to make decisions out of this data. Obviously you can use regression in a lot of different techniques to try to. Attempts are given solution to this decision making problem. But this is not the main okay objective. The main goal of the of predictive analytics courses. So that's why in this masters you have both courses and the idea is you learn how to deal with this data and you use this data to improve decision making. Okay, So, so that's the main idea. Okay. So let me introduce myself first just a little bit because we have a lot of things to to discuss today. So as I said before, I have a background industrial engineering. I have a master's in P&G in applied mathematics and computer science. But we focus on basically management, science and operational or operations research or business analytics. Like I don't care like the name you use. I'm very old school, so when I start my masters, I used to call only management science or operations research or in the operational research. Nowadays basically what we have is the BA paradigm. The BA is the business analytics. So everything basically was transformed into business analytics and everything involving analytics, data analytics, what else? Supply chain analytics, food analytics, production, planning, analytics, everything. Now is analytics. Everybody now is basically a data scientist just because they know how to build a macro in Excel. So I'm pretty sure this is not your case. That's why you're here, to try to learn a little bit more. I really hope you can learn a little bit more, at least out of this course. Okay. So anyway, so this is exactly what I teach is exactly my background. Okay. Eventually, you know, big universities, not necessarily we teach exactly our expertise. And this is exactly my expertise, mathematical problem. So please take advantage of me in a good sense. Obviously you okay? Take advantage of me. I'm very approachable, but obviously I am approachable. As long as you guys are putting at least minimal education on what you have to do. Okay. What else? I being assistant professor in Brazil. I'm Brazilian for seven years doing my research and everything. So in 2018 I got this offer. So I moved to Scotland and I've been here for almost six years. Okay. I'm almost Scottish. I'm kidding. I am not. As you can see, based on my accent. So currently I'm associate professor or senior lecturer in Business Analytics. Okay. The inverse of Edinburgh and I'm also programme director. I don't know if you know, but you have running from this from this year on two programmes in business analytics. This one there on campus or in person business analytics and we have the online one. So I'm director of the online programme. The online programme is a little bit different. The name is Data and this is Decisional, so it's way more focussed, fewer optional courses. It's for people who have been in industry for a number of years and they don't have time. So it's part time, it's two years instead of one year. But the main core course is machine learning. We are calling for the proper names. I decide to call for the proper name as let students know what they can expect. Right. Prescriptive people don't know what to expect, but this is my opinion. But this is how it is. But you have machine learning and optimisation. That's it. This is a very straightforward one. But yes, in terms of lecturers and every everybody is basically the same because we are in the same group. Okay. The group is the management science and the business economics group. So we have around 27, 20, 25 or 27 colleagues, lecturers and your lecturers and professors in this group anyway responsible for the analytics side of the business school, the contents of the the business school courses. Okay. What else I anticipate a little bit in my research interest is basically rely on application or mathematical programming. Why do I say application? Because we have different types of research. Okay, I start using this area in academics, so we have research that basically their main focus is on the development of theory. So they want to advance the state of the art of the theory involving mathematical programming, technique, solution messages. Eventually more computer scientists working on like more efficient algorithms and things like that. My main research is try to translate because there is this this missing I call this missing knowledge. We have like amazing theoreticians developing state of the art models and algorithms and super sophisticated theories involving mathematical programming on how to solve efficiently, effectively are given decision making problem. And this from one side and the other side we have basically practitioners that they have a lot of very difficult and complex decision making problems and they don't know how to solve them unless they are using an Excel macro to solve and eventually they are not even there yet. So do you understand that we have this gap, this knowledge gap here? We have a lot of things that people are trying and building and we have the practitioners that don't know how to make the decisions better, how to improve their organisations based on overall mathematics. So my research, basically my idea is to try to bridge this this gap. And obviously I cannot embrace the word and the area that I feel especially inclined to investigate, to understand is humanitarian problems and supply chain management problems in general involving, as I would say, some humanitarian crisis. Okay? Disruptions because of Covid disruptions because of earthquakes or floods or now basically some problems that can help support sustainable development goals as well, including poverty, including access to water. Now, it's impossible because it's here. Why? It's not because. Yes. Okay. Yes. So anyways, this is my research in general. I have a couple of students that I supervise in this topics. Okay. At this point, probably maybe this this can sound like broad and very difficult to comprehend. But obviously you have a lot of examples. I know some years the students don't like too much the examples and the applications I provide because in general they are involved with humanitarian logistics and they think this is not business. Okay? And I can say for sure this is business as well. Okay? Crisis. They impact business way more than you may know right now. So it's. Very important to understand the crisis, to support the crisis and to support economic development as well. Okay. So but this year, my idea is to try to diversify a little bit the examples and why the examples are important because sometimes we model a given problem. And if you okay, so with these techniques, we only can model this problem. But this is not true. The techniques are more general. Even if you are discussing, for example, a problem involve food aid distribution among his foot banks. The main idea and mathematical structures can be used to model any other problem. Okay, regardless of the main application. Okay. So I try my best to diversify the examples and the case studies so as to provide a better overview for you guys. Well, what else here? I have some examples, guys. Just one spoiler in general. I'm doing that in general. I do that in the first lecture, but not necessarily. I follow my own slides. Okay. I always prepare these slides and I'm sorry I was very late with uploading these slides right now. Okay, but in general I upload some days in advance days slides. Obviously you should use this light to learn a little bit more because I always provide links and extra material and eventually examples I don't follow, especially to this day. Slides. Okay. There is light is more like for you guys, you know, like the main content of that lecture. Then for me to go for each slide and it's like, I don't do that. Okay, so you see that I provide several examples and several links, including this first lecture. You guys feel free to click. If you have questions, you can knock my door or you can email me, but don't expect that you follow IPS little. It's okay. These lights. I'm not here to read these lights for you guys. Okay. The idea of these of these lectures is for me to try to share a little bit of my knowledge and my experience in mathematical programming. If you are just want some slides, I can refer the books and you can reach the books. You don't need to be here, right? You don't need me, right? So that's why in general, I don't do that as much as possible. I, I you use the whiteboard. We will try to build a given problem together with you code as well. So, yeah, as I see some of you guys already brought to your laptops, you need to bring your laptops in some specific lectures. That's why you indicate here. Okay. Okay. So here, basically, guys, I just put some examples. If you are like, okay, what this guy is doing, you can click here and you can go, okay, I put some because sometimes it's a bit distant right now. I know you guys need you to undertake a dissertation like one. No, not in one year. Six, six months. Wow. Anyways, in six months, you need you should be very aware on how to search keywords, literature. So I just put if you are interested in like what this guy is doing, if this guy maybe can be a match for me to supervise my master's dissertation, you can have a look. Okay. My profile and since I have interest in special, you already know. But you can see some of my papers that were recently published or at least, you know, kind of the things or the subjects that I'm interested in. Eventually you can be interested in similar things as well. So I provide several, including supply chain production plan. So it's very diverse. Feel free to click and to talk to me if you want. Anyways, what is prescriptive analytics with mathematical program then? So I anticipate this. This is one one of a number of techniques that can be or operations research can be mass management size can be be a business. Analytics is one of these techniques and again this is a word of order techniques. Okay, What else? The idea of descriptive Valeria already already said that, but the idea is to identify a given decision making problem to be able to solve. But why? We want to solve the problem? Because we want ultimately to answer the question what is best in this situation? So probably you guys face different problems in your lives, personal problems or professional problems. At some point you thought, but what is the best decision, right? So the best decision was to come to this country, to Scotland, to Edinburgh. To undertake this master's program. I really think most of you guys had different offers and other offers, and you face this decision. How did you make this decision in the end? You said yes. I looked at the course choices and I looked at the cost of living and the fees. And even though you your option was even the fees and the living expenses costs overall. Yes. So basically, as you made a decision based on information, so what we do, we always do that well, considering we are rational decision makers, what do we do before making a complex decision? We try to be surrounded by precise and accurate information based on precise and accurate information. We will try somehow to take the best decision that we obviously best decision can be very myopic, but in general, we try to make the most of the information we have to make this decision right. So this is exactly with mathematical programming. We need accurate information. We need precise information in this comes from different forms. First, we need data. Again, I told you guys, we are solving numerical problems. We need data to feed. Okay. The optimisation problems, optimisation problems are computational problems. In the end of the day, numerical problems, garbage in, garbage out. If you have a given decision making problem, for example, in your case, if you didn't evaluate very well the fees and the living costs, obviously you'd have made a different decision. So again, probably an inaccurate decision or a bad decision for that time. She had to choose between Edinburgh and probably a different program or program in a different country. Okay. So again, it's very important and we understand that even organisations that we work in the future that work now, it's very difficult to get this precise information. Okay. But again, this is your, your predictive size, Okay? So use your knowledge in predictive analytics, machine learning and visualisations. Get the proper data. After getting the proper data, you can try to propose an optimisation to help or to support any sort of complex decision you want to you want to make. Okay. We have we have, for example, what happens statistics. What if in simulation we are answering the question again, what's best? I'm just just saying that we can have like what happened in statistics. What if simulation? What do you have forecasting or predictive analytics? What would an expert should do and why? This is expert system, but this is a little bit old school expert systems. People are not using this approach anymore as such. So prescriptive analytics is one of the best and most developed and used branches of business analytics or NMS. So obviously it's very difficult to find appropriate definition for prescriptive analytics or mathematical program, but it's very useful to think about the allocation of resources and when to say the optimal allocation of resources so scarce resources, resources can be anything. These are not necessarily a physical thing, can be time, can be, services can be anything. Okay. So when we say allocation of scarce resources, it means that we don't have. As much as we should have to fulfil all activities or to make the best decision based on the complete set of resources. We have scarce resources. We have a set of scarce resource. What we want to do, we want to optimise its allocation. If you optimise the allocation of scarce resources among competing activities, but competitive activities again can be anything can be a decision. You cannot be enrolled in more than two programs in a row. So you have one resource, which is you, your money, your energy, right? So you have a scarce resource and you have to make a decision. So how to do that? You can use mathematical problem, you can model the situation using the idea of mathematical programming. Okay. Why is that? This is it's very intuitive to think about allocation of scarce resources, because this can help us build the main constraints or restrictions of a given decision making problem we want to solve. If we don't have a problem of scarce resources, again, in a very broad perspective, we don't need optimisation. And this is a very common mistake, especially because you have a group project you undertake and the group project is all about the identification of a given decision making problem and you have to model this decision making problem and you have to solve it you code and to provide managerial insights. It's very common when we start identifying these problems. You basically come up with some ideas involving decision making problems that are actually are not decision making problems or they are not based on the allocation of scarce resources. It's something that basically doesn't tell any decision as such. So it's very important for you guys when you identify a given problem that you think about what should be the best decision in this case, how to get this decision, the best one, considering what we have right now, the situation we have right now in terms of resources, in terms of restrictions or we call constraints, not restrictions, but constraints are restrictions imposed by the decision making problem under investigation. Okay. What else? We have another link about facts about the origins of operational research. It's a very interesting and very recent non-academic. Okay. Text about the origins of or how you can use or why in practice some organisations that are being using or to make better decisions. So please go to the the links I'm providing to learn a little bit more. Well, our course. Now, let's be more precise in terms of what I expect from you guys and vice versa. So prescriptive analytics is a quantitative course. Obviously at this point, you know. Right. It's based on mathematical modelling, heavily concerned with the modelling of decision problems as mathematical programming or as mathematical optimisation. They study of their structure. So you have a given structure, mathematical structure, okay, formed by equations in inequalities and a given affine function. So the idea is let's study the structure of this mathematical problem. Maybe we can get some insights after studying the structure structure, the equations of this model and the choice design of an appropriate solution method. Again, sometimes you are very good at identifying amazing decision making problems and translate this decision making problems into mathematical problem. But you don't know how to solve or you propose something so, so, so difficult that it cannot be solved. So if propose something very elaborate but cannot be solved, how this model will help decision makers to make better decisions. And it is impossible. Okay. So there is a balance between, I would say. Accuracy of the mathematical programming formulation. Okay. How like the degree of details you are incorporating in the mathematical structure and the tractability. Okay. So obviously we know if we start including a lot of details about the real world problem, what will happen? We will get a mathematical formulation that will be very hard to be solved. We call tractability is not exactly tractable. Okay, guys, for computer scientists, I don't know if you have computer science here. It's a little bit different, but we can use that. Okay. Tractability in terms of will be very difficult to solve. Okay. In the end of the day, if you learn well mathematical programming, if you manage to go to your organisations and to propose mathematical programming, depending on the decision you want to make. With the help of these models, you cannot run in the computer these models for a week or for a couple of hours. Do you agree with me? So let's assume you are in an Amazon. So something happens. So basically you are determining the best path a given parcel should follow in attempt to minimise overall costs, which is basically what they do. And in week five you have a seminar, an Amazon seminar, okay. And as a scientist, obviously you'll be online. I'm sorry for that. But they are United States. And yes, we cannot bring these people from United States for like one hour seminar. I hope you understand that. But anyways, she'll explain. Luciana she's being a research scientist, a principal research scientist, and also over the past few years after being academic. So she knows very well what she will talk about. So they have to make this relatively simple. All decisions are simple in the sense that it's very intuitive, okay, we have to minimise cost. So obviously instead of going from point A to B in ten hours, you prefer to go from point A to C in five hours, for example. Okay. If you want to minimise overall travel time or costs. So what I said that sorry, I lost my rationale. Sometimes I do that. Talking about the Amazon. How they have to optimise. Yes. Thank you. Yes. So if something happens in this network, there is a disruption. They have to rerun their algorithms to find. Okay, the optimal path from point A from, I don't know, distribution centres to demand zones. They cannot have the algorithm running for ten hours. They need to run the algorithms for a couple of seconds, a couple of minutes. So because they need a new solution every minute or every seconds. Okay, so this is tractability in our case, depending on the problem is you have a more strategic problem to solve, for example, budget allocation in a given organisation. They do that every year. So in December they unite the main stakeholders to decide on budget allocation, for example. Okay, so you can run this model, this algorithm for a couple of hours, five, six, seven hours, even a week. This happened in the past. But if you have a very operational problem, if you have a problem for for example, in which you want to minimise the number of vehicles that you will be used to dispatch a given commodity from distribution centres to demand zones, you cannot run this algorithm for hours, for days. You need something very, very quick. So that's the main idea. Sometimes we are forced to simplify decision making problems if we want a quick decision. So this is completely fine, but we need to be aware that what we have is an approximate solution for a given problem, or at least a solution that will allow us to manipulate what is happening in reality. Okay, you'll be like a support for us. You'll be like a guess, a good guess, but not necessarily the solution that in the end of the day you'll be implemented. Okay, so the idea of identifying the problem and finding the proper balance between the details, the real world details that should be included, and if you be able to solve this problem in the end, this is a very delicate but it's very important. Okay. And again, most of you guys and in the past this this has happened. Okay. I identify a given problem, but the problem is not here. It's not here. The problem is here. NLP non-linear programming. So eventually you propose a given formulation. The formulation will be composed by, for example, the multiplication of different decisions, decision variables. When we multiply decision variables, we don't have a linear formulation anymore. We have a non-linear formulation. It's completely fine to use non-linear formulations. The problem is in general it is possible to linearise non-linear formulations into linear formulations or mixed integer formulations and why we prefer to do that, because we know how to solve these problems. It's easier to solve these problems. Solving this problem is not necessarily it can be very complicated in nonlinear problems. We need a lot of mathematical properties to be able to design the proper solution method. And obviously we're not covering here, so it's a bit pointless. I cannot assess your knowledge if you propose something which is completely out of the scope in terms of what we are doing here. All right. What else? The material torch is meant to enhance students skills in business analytics. As I told you guys, the idea is to to look at you guys as business analytics students, and the idea is to provide a number of tools or techniques that can be very helpful for you guys. Well, in the course of this Masters in the future, obviously. So basically the course will be devoted to this course, mathematical optimisation. And the topics include how to represent important business. Sorry. Such was mine was exactly mine. That's fine. And topics include how to represent important business analytics problems as mathematical problems and a little bit of the theory. And I just emphasise that a little bit of theory and a little bit of algorithms. Okay, That is how to solve. Why a little bit? Well, first, because it's a choice considering this is a course in business analytics and in general alcohol, which is composed of students from different backgrounds, not only computer science students, that they had knowledge in mathematical programming before. So the idea is this is very basic. Then if you guys already know everything, I'm sorry to say yes, you feel a bit bored, but I hope it is not your case. But you can always learn something. Okay, because I always change examples and some some lectures devoted to case study. But the point is this is not a course in which I ask you guys to implement a given algorithm. Okay. Implement a simplex or a branching bound node is not. But you need to know how to use a simplex or when to use a simplex, when to use branch about how to boost. The resolution of a given mathematical problem formulation by simplex which parameters are more important. So the idea of doing that is like more Hands-On. You have this optimisation package called gums, but you tell a little bit about the specifics of the course, but the idea is to use optimisation packages because they are like easier to validate, to implement your models, they are easier to understand and to make your interpretations. Okay. At this point, you know that programming is not programming in the sense of computer programming is in the sense of planning. It's a very old school. Okay. Refer to preparing a schedule of activities. This was basically coined in the 50s, the term. Okay, mathematical programming. The programming like in the origins of O R well. And why mathematical optimisation? Why we want to optimise something. Okay. But first, because mathematical optimisation models, they rely on well-defined objective functions and constraints. And I explain objective functions and constraints, objective function. Basically your main criterion why what you want to optimise, you want to optimise your resources, you want to minimise the living costs of living in Edinburgh, for example, you want to maximise your satisfaction because you want to live in UK or otherwise you want to live in a country or in a city with certain characteristics, for example. So we have different objective functions. We can translate this overall criteria into objective functions mathematically. Okay, so this is the main idea. And in mathematical optimisation, it's crucial we cannot have such a thing. Okay. I don't know exactly what I want to optimise. It doesn't work this way. You want to define precisely mathematically using equations. What do you want to optimise the proper decisions you want to make when you do that? Okay, you ended up improving the accuracy and the precision of the problem you are modelling. That's why a lot of researchers and practitioners, they say when you use mathematical programming, sometimes we don't solve the mathematical programming formulations. So this is something interesting. Amazon, a number of different organisations, they propose the mathematical problem formulations. The general models by the end of the day can be very difficult to learn to solve these mathematical formulations and they prefer to go for risky methods. Probably heard of risky methods. You learn a holistic method using soft computing. There is a course here soft computing if you want to go for that. So basically it is you don't need to model the mathematical program formulation, the mathematical structure, but you can implement an algorithm that will give you a solution. Okay. Go from point A to B following this rule, that's fine. You don't know if this is optimal, but this is a solution for your problem. So this is in general what holistic method is. They provide a solution that not necessarily is optimal or like we like to say, don't provide these methods, don't provide the optimality certificate. You cannot tell. Eventually the solution can be optimal. But sometimes we use mathematical optimisation even knowing that solving these models will be very difficult. Why? Because it helps us to identify the problem, to define the proper criteria of the problem, to identify the constraints these cars, like when these cars have resources, in which circumstances we can improve the situation. This can be done if we model, if you have the mathematical structures, okay, underlying a given decision making problem, what else We have you here. The shipping companies like Amazon and Fedex, they handle millions of packages daily. Obviously you know better than me determine the optimal path for each package. For example, considering factors like destination weight of the package delivery time is a massive task. We always experience this kind of thing. Amazon tells us, okay, the package should be there by three and it doesn't happen. The package is at four. We are not there at four. And basically we miss completely why they have that because they have disruptions still not optimal, but it's basically a daily challenge to try to overcome all these disruptions in their supply chain in attempt to provide timely delivery, for example, mathematical. Meditation techniques can be used to ensure packages follow the most efficient route possible. See, now I'm not even talking about costumes, but we just said the most efficient route possible. Obviously we can define what is efficient for us. Okay. It can be in the most effective way or the most equitable way, depending on the circumstance. So it depends on us to define it properly. Okay. The criteria we want, considering current logistics constraints, saving resources, increasing our client satisfaction. So we have other reasons why generally industry and academics, they use mathematical problem. We have the issue of scalability, speed, holistic view, consistency, consistency is very important. Flexibility and cost savings. Consistency basically is if you have a mathematical programming, it doesn't matter if you solve this model or Valeria will solve this problem. The model is there. They cannot just just because they feel so. There are no subjective biases in the mathematical model. It's like x one plus x two is less than or equal to three. This is not subjective at all. This is very subjective. So regardless who is responsible for running this model, the solution should be the same. It's very consistent. Okay, so this is one of the most important things when you manage to solve a given decision making problem by means of. Not necessarily optimisation, but mathematical models. You reduce subjective biases in decision making. Okay? And this is very important, especially in some contexts. Okay. Regarding our preliminary course structure. So today, introduction to Prescriptive analytics. Next week we'll have a preliminaries in mathematical optimisation. So basically the preliminaries mathematical optimisation, we will discuss basically a little bit of the critical aspects of model building. And we start with model building. Okay. Some, I would say simple formulations. After that we have model building basically dedicated to LP linear programming, model building dedicated to IP integer programming, model building education, MIP, mixed integer programming. Okay. This week basically is reading week as you may know. So no lectures after that. We have advanced model building. Again, I'll just say like model building. This is what this course is basically about. We have solution methods after one one lecture of solution methods here. Sometimes it depends. It depends a lot. Sometimes we have two lectures. Dedicated solution method is eventually. It depends. If I feel we deserve more a case study than an extra lecture involving solution methods. So. You'll be a case study. Otherwise, if you feel that. Okay. In the previous lecture we didn't mention discuss with the details the main algorithms and we called it, but there was no time for us to discuss. Eventually we can have two lectures involving solution methods. Okay, so this is the flexibility we have here. We have one in-person guest speaker, but this hasn't confirmed yet. So that's why I didn't put this person's name again, I tried to invite you here because you have one person from from industry, which is this person from Amazon. And the idea here is to bring a person that basically works in academia but with real world problems are related to a given industrial sector, which you. Yes, you confirm this person again. If we don't get this person here. What you have. Case study here. Solutions. Method. Solution Methods. Okay, so this is basically the flexibility. I wish I could be less flexible here, but we depend on others, especially because here the idea is to have an in person. Okay, we have a budget to invite people, but obviously people. Yeah, should agree of that. In terms of deadline, December 1st, the deadline for the group project. Okay. And Oh, no, no. Sorry. You were here. Yes. So the last the last lecture will be a group, which is the oral presentation. This is basically the moment in which you get the formative feedback. Okay. So this this is a mini workshop, but unless you can encourage your colleagues. Okay. Say you was very cool last year. No. Yes. Did you learn a lot? Did you like the Brownie? Debateable. And that's. Okay. The brown is very good, actually. So the main idea is obviously we could go for a normal group presentation, which you guys come here in front of the class and you have a couple of slides and you start talking about what you have done in terms of group project. But let's be honest, everybody feels this is very boring. Nobody likes that. Nobody really pays attention in like two hours of presentation. Okay, you guys, probably at this point you're not even paying attention may anymore. Some people are already almost asleep. You're like, Oh, so I completely understand that. Okay. But again, this is this is my choice. So in general, I've been doing that over the past years. And even when the students, they don't love the group project, but they, they love the moment of being there in front of their posters. Okay. You have poster show in a minute. And anyways, but again, what I change regarding the previous years based on students feedback, I used to grade these presentations and so students were like very nervous, which is normal because they were they're very formal. And eventually it happens like blank, right? Because I ask, for example, okay, explain me this constraint here. You explain this constraint here. I'm going to let you forget this. I'm sorry. Obviously, I'm raging. I'm embarrassed in this person's knowledge. So I have tomorrow. So I suppose this was a little bit difficult and tricky because I knew some students they knew more then than they they were able to show in that 10 minutes or 5 minutes I was there. So I changed that. So this group presentation or oral presentation or workshop is a workshop. It's not graded, but it's the moment you guys have to get my feedback. And I suppose this is important, obviously if you don't feel my feedback is in part because I, you mark the report, be my guest. Okay. I cannot say, well, it's a class. It's it's a lecture, so you should be there. I cannot obligate you guys because again, it's not graded, you know what I mean? But I really hope you. Yes. You make the effort to be there to build a nice workshop and nice poster and you'll be there like 2 or 3 hours. I know it's a lot, but it's very fun. You have to trust me in that. Okay. I don't know if you guys been in conferences before. Have you been. Have you been to conferences and attend conferences before academic conferences? Academic conferences? No. What conference. Was that? An energy conference? Well, an energy conference for, like, renewable energy, stuff like that. Okay, well, yeah, but the same thing, Like people talking about the boring stuff. Probably energy anyways, you know the drill. But here is not the case. It's not boring stuff. It's like stuff you guys are doing and like basically stuff you guys chosen to do because this is about your project and the project is very general. As you show in a minute, you can choose the any decision making problem you want to work with because of, I don't know, it's more personal problems or more professional decision making problems. I don't care because I'm not judging you in terms of the decision making, obviously should be a decision making problem, not something crazy like regression. This is not a decision making problem. Right. But yes. So anyways, this is at the moment which you guys will be there. We very fun. We have catering. You have brownies and biscuits. Okay. Maybe it's not the best one, but it's for free. Well, not for free interviews, you know what I mean? And there is coffee and tea and it's very nice. And this year you have like, something different. The best poster, you'll be selected and there will be a prize. Yes. Well, I don't know. I cannot. Yes. No spoiler. But there is a price and the price is very cool. Very cool for the whole group that will be there. So if you are part of this group that basically were awarded the best, the best poster presentation, but you are not there. Oh, I got I don't care. You don't you don't have. No, no, it's not for you. It's for people who will be there. And obviously it makes sense because all the effort of building the poster, being there and responding the million questions not only from me in general, I invite students and other colleagues to be there as well. So it's an event, it's really an event and it's very cool. After that, you just confirm it's very cool. Okay. I have even some pictures showing like how cool the poster presentation is. Do you know? Don't show my pictures, please. Anyways, so what else? So this is the deadline. So after that, see, you don't have plenty of time after this, but you have so are you provide feedback and in general, because obviously if everything is like not good, it would be very difficult to provide feedback. Okay. In general, I provide precise feedback in attempt to improve your guide's potential grades. So for example, okay, there is like this graphic here and I can say, well, this this solution sounds a little bit too let me see the mode. Okay, there is a mistake here. That's fine. But in the end, us there is a mistake. So your grade is basically not good now? No, there is a mistake. You have to to fix this mistake and have to rerun and update the report because you still have some time. Okay. So this is the main idea and another another aspect of being there. The other presentation, you have an individual assignment. Okay. This course is 100% coursework. You know that, right? One 100%. The deadline. Sorry. The individual assignment is like. It's like a take home exam. I can put it this way. So you have you have 48 hours, you'll be released. Five. Okay. December 5th and you will have 48 hours to submit, which will happen like September sorry, December 7th. Okay. So we have 48 hours to undertake the main the main activities. This is this covers all the course content. So there will be questions like very silly questions like blah, blah, blah, blah, blah, blah model and solving this decision making problem simple. And there will be questions related to your guys project group projects. So for example, in your project you propose, I don't know, a production planning problem to minimise carbon emissions in this and this in this context, however, your main assumption was this and that propose a new model. But overcoming these main assumptions and using this assumption that so you have to extend your mathematical formulation if you don't participate in the group's projects. If you participate, trust me, you have amazing grade. Because statistically wise, over the past six years, everybody who really joined the group project to really contribute to the group. They had a good grade. Yeah, I don't remember if your case, but yes, yes, she she got good grades. Okay. She's not she didn't say okay guys in her masters but yes, basically it was a UG. We have like a similar course here in Denver because you have a path here which decision analytics. And there is one course that I teach which is called I. Yeah, yeah, yeah, yeah. This is the course advanced analytics with mathematical problem and it's very similar. Okay. So anyways, this is extra Amazon seminar I put in here because guys, this is extra. You don't need to attend, okay? There is no attendance, nothing like that. But you'll be obviously this is for you guys, not for me. So if I invite this person, if I have zero students online, will be very awkward. Very, very awkward. I suppose this can be very interesting because again, especially if you have interest in work in Amazon in the future, you can make questions about that. And Lucien is a very nice lady. Anyways, this is the preliminary course. Yes, I'm still on time in terms of course assessment, 100% of placement is coursework. It means that blah blah, blah. We already know that in terms of the group project. And so 40% is the group project in 60% is individual assignment group project is approaching analytics. And the individual assignment I already mentioned is like the format is like four eight hour exam. Okay. Have typical questions here. Anyways, you can. We can follow these lines. Okay. Have you more important things to say? This is this is important. Statistically speaking, six 7% of students have a worse grade two comparison to the group Project Grade. Well, yeah. So. Yeah. Anyways. But. Analysing the data. I can tell that in general, the six 7%, they don't. They didn't contribute to the project. I'm afraid it's very common because the project would be like 4 or 5 students. I'm not sure because I don't know how many students exactly you have here. Probably 50. So groups of 4 or 5, maybe five is okay. Five It can be a lot in a group, but this is what we have actually. And sometimes someone just says, okay, I don't need to contribute. There are a lot of people in way more vocal than me, but trust me, it's important to activity and you can practice how to deal with a very diverse cohort. And another thing that you tell you guys, obviously I don't decide on the groups, okay, you guys have to decide on groups. I don't do that. Okay. Even over six years is true. They came to me. Okay. Please assignment your group. No, I always say no. You are adults. You're adults, and I have to treat you as adults. You're not children. Children. We assign to groups because they don't know how to behave. I really hope this is not your case. So you choose. Obviously, I understand your conflicts. But again, guys, sorry, it's not on me. Okay? If you have a lot of conflicts, you have the proper chain here in the universe of people that can help you guys. I hope this is this was never the case. Your master students are adults and very mature students. Okay, So please. But if you have a problem, then that these problems are somehow impacting your academic performance in this course? Yes. Please let me know. And I try to do my best to help you guys. Okay. I understand that eventually some people are very shy and introspective, and this can be very difficult. If this is the case, you don't feel comfortable with the group, please let me know. And I give you guys some days to choose the proper groups. And after that, some groups are done. I can assign. Okay. The remaining ones. I'm just wondering because on the learn website, the dates are. The one thing. Yes. It says that the individual has to. Sorry. Sorry. Let me come back then. Watch what it says. Is on the 29th of. November. 29. Oh, no, I'm sorry. Yes. Because in general. Well, it's generally the secretary uploads like these things. Maybe I don't know if she uploads incorrectly or if I gave the wrong dates or eventually we try to mimic what happened the last less year. And I didn't teach this course, so I don't know if it was just replication, but don't worry, are you? I will update this. Okay. I will just make sure sometimes we change you guys. Sorry. Eventually she changed something, but 29. It's too much change because you don't like to have clashes. Okay? We don't like, for example, you have two deadlines in the same day. So we try to anticipate one course or to postpone one day just to avoid clashes. This is done by the secretary general. Okay, guys, are you verify that she emailed me just to make sure. Okay. In the end of the class, please. So I remember to to catch up with Heather, which the course secretary does, to make sure we have the proper deadlines. Okay. Thank you for letting them know. Okay. What else? The group project will be basically real life prescription analytics. The main objective of the group project to let you have hands on experience in dealing with an optimisation, a decision making problem. So your text will involve identifying the decision making problem, developing mathematical problem formulations, coding, solving the corresponding models, performing simulations and concluding comprehensive analysis and providing managerial insights. I know it's a lot, but yeah, it's a group of projects is 40%, but it's up to ten pages only. You already have the description. Theoretically, you can verify after learning ultra assessment. Yes assessment and probably will be group project. And you have the PDF okay. File with this description and with a template on how I want to see the final report. The final report will follow a kind of research paper or technical report with some sections. Introduction Problem Description. Mathematical problem formulations, computational results and conclusions. Okay, you have this structure ten pages every year. A lot of students may you may know ten pages is not a lot. Please, can I deliver a report with 20 pages? No, you cannot. Okay. There's only ten pages. Trust me. This is for your own good. You don't want to have 20 or 30 pages and really don't want to mark 20, 30 pages. Seriously, I have to market this during my Christmas time every year because it's when this semester. And then I really enjoy Christmas with my family in Brazil, not in this country. So I deserve to market this synthesise reports because basically you have two pieces of assessment and one is individual. So I have 50 okay to mark. So the idea is and on top of that, you cannot deliver up 20 pages because in general you don't have even content for 20 pages, you have content for ten. Trust me, you are not basically finding the cure for cancer with this project. This is not a paid project. If you feel this can be translated during a project. Yes, talk to me. Maybe after your masters I invite you to come and do a PDF for me. But this is not the moment. This is a moment for you guys to produce a report. A normal report. Okay. The rubric will be there. I'm sorry I didn't upload the rubric of the project, but you'll be there. Okay. You have a given how I mark the project, what is really important in the project. But keep in mind it's mathematical based. So if the model is wrong. Right. There is nothing for me to do. That's why it's very important to make sure during the group the workshop presentation. I look at your models and I say, Great, it's correct or no, it's wrong. You have to change that completely. Okay. This is important. Anyways, Deadline, Maybe this is correct, you know? No, no, it's all wrong. I don't know. Anyway, so formative feedback. Yes or no presentation. I already said, Oh, this is this is just to. Yeah, this is one example of I don't know when some years ago, but this is the idea for those who don't know what is a poster and a well, several students in the past, they didn't know what it was a poster. So now I have this slide. This is a poster. Okay. Again, you have all the templates that you provide, the templates, the sizes we have in the University of Edinburgh Business School, these poster boards here. So you need to arrive five minutes before you stick the poster in the poster board and everything. You'll be fine and you'll be like in front of your poster explaining, you know, very politely like the content. So, yes, no mystery. Okay? There is no mystery. And you have here the poster presentation tips, whatever. Okay. Questions so far, because I want you to introduce some preliminaries in optimisation. Questions about the course, the course, content expectations, whatever. This is the moment. Wow. No questions. No questions. You understood Everything all right? This place is full of numbers. There is a maximum limit. Something like that. A maximum of five. What? I said between 4 and 5. Because I'm not sure. Sometimes, even after the welcome week, the first week, we still have some students enrolling. So I just need you to have the final number if it's 50. I mean, pretty straightforward, but eventually I have 49 or 48. So eventually I decide between 4 and 5. Yeah, it's something like that. A lot of for members groups can be a lot as well for us because we have two hours, almost three hours, and I have to evaluate and provide feedback to all groups. That's why you don't have many. Otherwise you need like two days only for the workshop presentation, which is completely beyond the scope of this course. Okay, so try to stick with five if you feel comfortable only having four because you want to work with specific colleagues, that's fine as well. Okay. It's not a big deal. Okay. Between 4 and 5, I suppose it's more than it's the more than fine. Just one tip, if I may, in terms of suggestion, something that I've seen in the past and it works very well, it's I know some of you guys eventually have colleagues or. Yes. You came here to this masters with someone you already know, for example, from, I don't know, your country or other you did. So try to diversify. It's very important to diversify. Okay. In so many aspects, it's important to diversify. You have this opportunity to learn, like, well, to learn with different colleagues from different cultural backgrounds. So this is obviously just a piece of advice, but you don't need to follow this piece of device whatsoever. Okay. Do you have any more questions so far? Just, you know, you know our groups. No, this is all. Of course, Secretary thinks so. I suppose Heather will email you guys with the nice reminder that basically you haven't you I don't know which day to provide the names of the groups because she has to build the folders on learning for your Dropbox submissions or something like that. So she will have at least one member of group responsible for this folder. You know the drill and you have the online because everything is online, okay? The submissions and everything is online, so they need you to build this folder. Okay. It's on her. No more questions. No. So that's great. We still have time. So yes, as I predicted. Now I just want to basically introduce a little bit of notation. Okay. It's very, very simple. Actually. But so we can start next week with the proper mathematics and things we really want to discuss. Okay. Basically, this is the general mathematical optimisation formulation. Okay? So what we have, we have. To indicate what we want to do with this criterion. Okay. We can minimise or we can maximise a given functional or a function in general. In our case a linear function f x. Okay. I'm using this bold notation here because x obviously can be a function of several variables. Okay. Can be X1X2XN. Obviously finite. Okay. We are solving finite problems subject to x. Belonging to this given set here. Okay. What we have in terms of notation we have X is what we call our decision variable decision variable is the problem's output. You have to solve the problem numerically computationally to obtain the level of the decision variable. Okay. Is the decision you want to you want to make or something you want to decide on, for example, whether or not you are coming to Edinburgh. Okay. X can represent X can be one. If your decision is to come to Edinburgh, X can be zero if your decision is to go somewhere else. Okay, so it's the decision you want to make. F x This function. This is what we call our objective function, our criterion. But we can have multiple criteria. Okay? Eventually what we have and this is more common that we think. In the general form. What we have here, we have eventually we want to minimise f x, we want to minimise g of x, we want to maximise another function H of x, we can have multiple, again a finite number of functions, objective functions. Obviously when we have what we call and we you see this technique just a little bit, one lecture probably dedicated to what we call. Much objective optimisation or objective mathematical programming or whatever you want to call. So the main idea or the main challenge when we have different objective functions is how to combine those objective functions because we cannot solve a problem. This is what we call an ill. Define it. Problem. Okay, so you define a problem is not a well defined problem. It's well defined. We when we know how to combine these objective functions to produce a given solution. Okay. So this is one challenge because we have different ways, different techniques to combine different objective functions, and we have other challenges involving like how to rescale the objective functions because this is a numerical problem and eventually what we want. You want to minimise apples and bananas together. Can you understand that? Okay. From the mathematical point of view, that's fine. But from the practical point of view, that's fine. Sometimes from the practical point of view, sometimes it doesn't make sense. So it's very common that the students, they propose objective functions in which they want to maximise, minimise the costs of something. For example, a given distribution problem of Amazon. There is a term for minimising the costs, plus they want to maximise, for example, the number of clients served until, I don't know, a given a given time period. So basically we have the same function we are summing or we are combining costs or monetary units with people. This doesn't make sense. So when we have such a framework, in the end what we have is a more objective formulation. We can have one objective relate to cost minimisation. Eventually, another objective relates to the minimisation of travel times, or another one relates to the maximisation of the number of clients covered or served by a given time period, for example. So in general that's the point. Sometimes you model, I give an objective function using what we call a single objective formulation, but your problem is naturally multi objective. And if it's much objective, you cannot just putting together or combining potatoes, bananas and apples and everything together and chocolate in the middle. No, you have to define one objective for potatoes, one for bananas, unless you find a different way or a conversion metric to transform, for example, bananas and apples into something unique. For example, how to transform bananas and apples into something using one scale only or one unit. You can do better. Milkshake metric. Well, yeah, but no guys, no unit weight, energy. Money can be money. Okay. You want to minimise overall costs of your milkshake. So bananas will cost six, apple will cost six. So you have the decision variable. How many bananas, how many apples in the production function, but they'll be multiplied by the cost of bananas, the unit cost. So in the end of the day you have the objective function in terms of costs. This is very important. You guys sometimes don't care about that. Make sure the in terms of units, everything makes sense. You're not doing crazy things or crazy combinations or crazy milkshakes. In your case, we have here X. This calligraphic vertical calligraphic x here is as such. Okay, so we can use a set theory to address this. Calligraphic x. X can mean a lot of different constraints of your restrictions of your decision making problem. So X is what we call feasible set constraints and domain. It contains all feasible, viable solutions. What is again, what's your name again? I'm Mira. So Ameera. So basically you are here in Edinburgh studying these masters, so we know this solution was feasible. Viable? Why? Because she's here. She took this decision. She's here. I don't know if you stay, but hopefully you stay here. And this solution will remain feasible for the entire year and you get your degree with distinction. Right. So. Okay. Can you tell me probably you were able to identify when we were basically identify your options? She identify your options? Probably all you guys identify several options regarding this problem. Where to start? At least two options. If you have at least two options, you have first to file first. Are those options viable? Feasible? And after what is the best. Basically, this is basically what optimisation is all about identifying the options and selecting the best one to optimise a given criteria. So can you tell us if that's okay to say one infeasible solution or one identify one basically an alternative for your problem, but you realise at some point this is not viable for me. There was such a thing. There was. Yeah. So if I was choosing between universities in Edinburgh and in London, the option in London turned out not to be viable because the cost of living is really. Perfect because she managed to identify her restrictions, her constraints. So she had your budget. So if x, if X represents how much you can spend, I say yearly or if you put that in a spreadsheet or monthly, there was something like that. Let's call. This is a constraint. Obviously. So X is the total expenditure or the total money you have or your budget that you can spend during this one year studying abroad. And so this is your decision. You have to calculate this one to minimise and here is. Your parameter, your data. You calculate that? I don't know. I have. 50. Thousand pounds to spend this year. And London is 51 overall infeasible. Okay. Why is feasible? Because basically X, which is your solution must be is not should be. It must be less than or equal to £50,000. Okay. So this is normal. This is very intuitive. We do that all the time. Why identify solutions in this calligraphic x? Here is the search containing all the viable, feasible alternatives or solutions to a given problem. Okay. If something is not viable, it's not feasible. This solution X bar, let's go this way doesn't belong to this feasible search. Okay. In this case, did you realise that I included here an implicit constraint? Because in this case it doesn't make sense to take into account like negative values. This is very, very common. Okay. 99.999 9% of the problems. We have to make sure we write down the domain. Of the decision variables correctly. This is a very, very common mistake. Trust me, you have to pay attention. Sometimes when you start coding, you forget you will be thinking a crazy solution. Everything is right. You say everything is right. It's not impossible. My solution doesn't make sense. Okay. Did you put the domain correctly? Okay, I forgot the domain, but it's not a big deal. Yes, it is a big deal. Okay. Because you have different, feasible sets. If you have a problem. If you have a given decision making problem involving two decision variables. Okay, let's assume just X1X2. So we are in R two. We can represent the set of decisions here. We agree with me. Okay. In general, again, we present you here. When x one and x two are both. Okay. So in general, when you try to find viable, feasible solutions, you'll be looking at this quadrant here, the first one. All right. This is what you said. Obviously, we can have like different forms, feasible sets can be any C. We can have, for example, one hyperplane here. One hyperplane here. One here. One here, one here. So we have one, two greens, two pinks and one brown. And we have, in the end of the day, this region. This area for us is or contains all the feasible solutions for our problem. In this case, each of these I call in a general way hyperplanes. They are constraints, okay? They are simply constraints. For example, x less than B another constraint. Another constraint. Another constraint, another constraint. So in end of the day, we don't need to have this shape. You can have different shapes. You can have like a shape like that, for example. Okay. Can't have anything. But it's important to realise that depending on how you design these constraints, this feasible, feasible set will change. And definitely if it changes, you change it as well. Your feasible alternatives, your feasible solution and your optimal solutions. Because in the end of the day, nobody wants to take only feasible decisions. We want to make the optimal decisions. And why is that? Because the optimal decision. If you are minimising costs, we can assure the cost is minimum. If you are maximising profit, we can. If you have the optimal solution, you can rest assured that the profit should be maximum and so on and so forth. That's why in general we go for optimal solutions. It is possible to get your multi always. No it's not. We learn that. What else? More preliminaries. So we have again our given solution X bar is called feasible when it satisfies all the constraints of the mathematical program. So if this is x calligraphic x, we say that a given solution x bar. If we write down this expression, X bar belongs to calligraphic X, so we know that x is variable feasible. So x is here. Eventually x. X can be. This is a given solution. Okay. X can be in the interior or can be in the vertexes of this polytope. We discussed that a bit. This is eventually the difference between optimal and being feasible. But anyways, if x belongs to this feasible area, x is feasible. So if you have a problem sometimes you say but only this constraints. I cannot, I cannot satisfy. But it's enough to have only one tiny, tiny, tiny constraint. If you don't satisfy this one constraint, the solution is infeasible. Okay, This is very important. What else? So again, if X belongs f is feasible, f belongs to x. Otherwise x is infeasible. A given solution x bar is called optimal. When? Obviously to be optimal we need to be feasible first. Okay. And if feasible solution. That's it. It's done. There is nothing to do. Should be optimal. It needs to be feasible and it needs to return the best possible objective function that is f x. In the case of minimisation, obviously in the case of maximisation is the different different sign f x or f f evaluated in x bar should be less than or equal to f x for all the x's in the feasible set. All right. If x is the empty set, then the mathematical programming model is infeasible. Okay. Sometimes you have something like that. When we are giving our first step. Modelling your decision making problem is very common. But I call you this problem is infeasible. Why is infeasible? It doesn't make sense. So sometimes you have something. You have one constraint. That model here and one constraint here. And the way you design your sign is greater than or less than or equal to this is your feasible area and this is your feasible idea. What's the problem with this problem? You cannot satisfy. So we have one feasible area that is feasible only for x two, and we have one feasible area that is feasible only for x one. You have the intersection is the empty set. So if you don't have intersection or if your feasible set is the empty set, actually there is no solution inside, there is no solution in this side. So the problem is trivially infeasible. In this case, we don't want you guys. To develop models that basically will the output of this model is infeasible. It doesn't make sense. Several people, they say, well, if you build an infeasible problem because you don't know how to model, okay, some people say that. It's not like you don't know. Sometimes we build a given problem generically using mathematical programming formulations based on a given data set we have. But you have to keep in mind the mathematical problem formulation is more general. So theoretically, if you try different data should work. You cannot have one problem or optimisation problem that works very well for a given data set. But if you change this data set or actually the solution is infeasible. We want to build models that are always feasible. This is ideal. There like some ways to address this issue, we can include auxiliary variables, we can include dummy nodes. There are different ways to do that. It's a little bit more sophisticated, but it's way more practical because even the transportation problem I don't know if you heard of the transportation problem, but the transportation problem, people say, oh, it's very general. Not really. It's not super general. The transportation probably only provides feasible the optimal solutions for a specific case in which the parameters, the input data, they are balanced. Will you talk a little bit about that? If they aren't balanced, the solution is infeasible and you have to formulate the model. Our main challenge here is to identify those formulations, this classical traditional formulations, there is a way to generalise those formulations in attempt to have feasible solutions always regardless of the data input. So this is our main challenge and this is your challenge to okay, in terms of other concepts, we have the concept again more about decision variables. Decision variables. They describe the quantities that the decision makers would like to determine. Okay, they are the unknowns or the output data of a mathematical programming model. Typically, we will determine their optimal values within an optimisation method. Why? I said typically with optimisation method optimisation, what can be more general? You can determine again a feasible solution. You don't need to build a mathematical problem formulation like that, but like that minimising f x subject to x belong to calligraphic x. You don't need to build the formulation. Again. You can use a simple here key rules, for example. I forgot your name. Yes. I mirror a mirror. I don't think she built a mathematical program formulation to decide on that. No. Why not? I didn't know how. She didn't know how. Now you know how from next lecture. Only you know how. But even though the solution was feasible. How's that? Because she follows some rules. So basically what she did probably was what we call a greedy heuristic. She knew about her budget, so she tried to feed the decision to the budget. Right. We can do that like monthly. I do that. Okay. For example, today I have you only, I don't know, £10,000 in my bank account and I go to the shop. I'm not going to Sainsbury, I'm going to Lido because I know my budget can fit Lidl, not Sainsbury necessarily. And I keep shopping, shop and shopping unless. Okay, I spend you already, I don't know, £50. This was my limit today. I didn't use any optimisation. What I did, it was a risk I was updating. Okay. My budget ate after every product I bought. So that is we can have feasible solutions, not study optimal. We don't need mathematical formulations. Okay. We don't need. But the mathematical formulations can help us to simulate different situations, different circumstances and solve obviously more complicated problems. So decision variable is the output you want to decide on parameters, components of the problem or input data. Okay, guys, you have to to keep in mind, there is no such a thing. There is no constraint in optimisation that is only based on parameters. A constraint in mathematical programming optimisation is a combination of decision variables and parameters. You have to keep this in mind because a very common mistake when you start modelling, you have a constraint only formed by parameters. So for example, it's basically to say that. Do you think this is a constraint? So why not? What is it? Actually, this is not a constraint. Objective. This is something. This is an equation. This is an equation. This is inequality. It comes with. Better Now, guys, this is a statement. Yes, right. This is a statement. 160. Yes. Is less than or equal to 200. A good is a statement. This is not a constraint. Can you understand that? Yeah, But this is very, very, very common when you start building your modules. This is very common because you will have the numbers, you have the parameters and in general we are modelling the general form of the mathematical optimisation. So we are dealing, for example, assuming this is a. B, C and this is D, Okay, So sometimes you just put that A plus. B plus C plus. Yes. Less than or equal to D. I was not working because you have to realise A, B and C are not decision variables. This is not decision variables. Parameter parameter parameter parameter. So this is not a constraint of a mathematical optimisation. So this is very important. You have to able to identify very well input output input data, A, B, C, D, but you need decision variables. Okay. For example, A, X plus B, Y plus C, z, less than or equal to Z, Xis X plus Y plus Z, less than or equal to E. Now we have a set of constraints and you have to define X, Y and Z are decision variables of your problem and all of them greater than equal to zero. Now you have something. Okay, so this is very important. What? You have input. Okay, input data optimisation model and output decision variables. So this is the flow. This is the system. A constraint is a mathematical relationship between decision variables and parameters of the decision problem. They define the limitations on decisions, guys constraints. They don't need to have parameters. Okay? Eventually you have a constraint that basically says something like that. This is a constraint. Okay. The decision on X should be less than or equal to the decision on Y. This is a constraint. That's fine. No parameters, but this is not a constraint. Okay. That's the main difference. A constraint should be the combination between decision variables or decision variables and parameters, not only on parameters. Finally, the objective function evaluates some quantitative criterion of immediate importance, such as costs, profit, utility, or yields. Guys, objective functions. You can go crazy with that. You can be very creative because at the end of the day, it depends on the problem you want to solve. Okay. And what do you want from the problem? For example, Amir here, she wants to minimise costs, but definitely you want to maximise satisfaction as well because you don't need to come to this country. You come here, you come to you, you already living here or you want to come to the University of Edinburgh to maximise a given satisfaction. Satisfaction can be measured in terms of the amount of new techniques you learn and things like that. Okay. So it can be very, very broad. The concept of objective function and how to build these mathematical entities. Finally, an optimisation system basically is objective function plus constraints. If you have only constraints and you need to find a solution, this is not optimisation, okay? This is basically a linear of it can be a set of linear equations and probably you did that previously in linear algebra or of course that basically you, you undertook in the past, you have a number of equations or inequalities and you need to find a solution. You substitute here and there. Do remember that X is like one minus. Well, this is not optimisation. This is only solving a system of linear inequalities or a system of equations, for example. Okay, you're not optimising anything because you don't have the main criterion. You have optimisation, you need both. You need the objective function and constraints. Well, here, actually I'm lying. You can optimise a given criterion. Okay. Without having the constraints, probably you did that in calculus. If you ever undertaken courses in calculus and this is very easy, right, to determine the solution of a given function. Without constraints, what we call unconstrained optimisation. The first derivative equals to zero. You determine the solution. Remember that? Yep. Remember that it's what we call like first order conditions. We are not dealing with this type of problems here, okay? This is more calculus. What our idea of decision making problem involves necessarily an objective function, well-defined, objective function and constraints. Well defined constraints. All right. Well, briefly, I just want to introduce because one of the main goals of this course is to be able to model in the end of the day are given decision making problem. Right. So this is one of the main important aspects of this course. So we have given, I say, methodology to follow or a very common methodology in management size, operational research or business analytics to follow. So basically the main approach or the systematic approach to model or to identify a given problem to model it by means of mathematical optimisation, we have this number of steps here, so we have problem recognition, problem structuring and definition modelling, analysis, solutions and recommendations and implementation. Obviously this is the first step and this is very intuitive. You cannot model a problem if you don't manage to recognise that there is a problem, right? Again, if you have unlimited resources in your case you don't have a problem, can go everywhere, you don't have any criteria you don't have satisfy, you don't have anything, so you don't have a problem if you don't have a problem. So it's done. You don't need to solve anything. But if you have a problem the first thing or have several problems, the first thing is to realise or to recognise the main problem or the most important problem eventually have problems. So many problems that depend on the first problem and you have to identify the first one. So problem recognition, very intuitive. You have to realise that the problem exists. This is very difficult. Okay, it seems very straightforward, but it's not actually, especially when you are giving your first steps in model building and you need and I ask you guys as a group of projects, you need to sit together and to discuss the problems you want to solve. What is the problem you want to solve is a problem of energy. I don't know how to generate clean and sustain in a sustainable way. Energy for the next ten years, such as the overall resources of X are not violated. For example, this can be a problem. Another problem can be how to set up a new Amazon deports in in Scotland. Such has the overall infrastructure is cheaper than the current structure for example and you'll be easier to reach out to the client is timely. This is another problem and how to how to choose effectively optional courses in DBA program such as you maximise your satisfaction and you make sure you learn new techniques or techniques that will be useful for your for your job, for example. But considering you don't know what your job can be but you have a set of options, this can be another problem. Guys, you have solved so many problems. The main idea is you have to realise there is a problem, okay? And a problem necessarily will involve a given criterion or a number of different criteria and necessarily involve constraints or scarcity of different sorts. Problem requires a decision that needs to be made. If you realise, okay, I want to solve this problem, but actually there is no decision. So this is not a decision making problem. Okay, this is another mistake. Okay? I want to solve a problem. I don't know of having good food. Okay, great. What is the decision? It's the diet problem. So you want to find the proper, I don't know, food items you want to buy considering a given budget. So how to buy those items per day? Satisfying a given budget. So this is not a decision making problem, but just the problem of, oh, I want to solve the the problem in the world. This is not a decision making problem. You should be able to identify more specificities about this problem to be able to model this problem into into mathematical problem. Okay, generic. Here we are using the generic use of the word problem. Okay? Problem in the sense of you have a given system and you have to make decisions on this real system to improve its performance. Okay. It's more in this aligned with this idea in terms of problem structuring and definition. First, you need to make sure that the need to make sure that people can understand the problem and the goals or the limitations, you should be able to describe it very well what you're dealing with. Okay, improper, inaccurate structuring definitions of the problem may result in appropriate analysis or infeasible solutions. So eventually, you know the problem, but you cannot describe. You don't know the constraints and limitations and describe it poorly. If you describe it poorly when it comes the mathematics, the mathematics would be poor as well, and the solutions probably will be imprecise or you'll be nonsensical. Context time horizon decision makers must be defined will be the decision maker of this problem. You. The president, the mayor, the stakeholder who. Stakeholder. Things like that. Multiple decision makers, conflicting objectives. One central decision maker, one rationale and one direct decision to be made time horizon. This problem is for one day. Each day you run your decision making problem. If you update the solution or you will last one year or one decade or one month, one hour. This is time horizon, things like that. You should be able to define modelling, analysis, basic steps, identify the set of alternative solutions, determine the criteria for evaluating alternatives, objective functions. Evaluate the alternatives you need to give the methods numerical method computational methods. Simple explanation about things like that. Choose an alternative. Finally, make a decision Solutions Recommendations. Sometimes you have more than one solution, but you have to make a recommendation. Eventually. It will depend on how easy it is to implement a given solution. Sometimes the optimal solution can be very hard to implement in practice, so you have to choose an alternative solution how to do that? Again, additional information. And the problem refinement is important, especially if you are interacting with practitioners. Final recommendation and we have an implementation phase in which you need to talk to the stakeholder to implement and to see the result of this solution. And that's it for today. Suppose we are. It's almost three. Right? Yes. So next next week, we start with this very nice example on how to best remove one single item from Amazon distribution centres to demand zones in Scotland. Okay. So I want to start with that. And following that, we will give you some glimpses on how to model this using our optimisation package. Guys, I have update Your Edge the Learning page. So I don't know if you had the opportunity to look into it, but you have in one session and course material. So we have these slides. You have several things going on over there. And I suppose I discussed the, the software you'll be using this semester. Did you have a look again? I will use gums because you have license and because it's easier and blah blah blah. You feel free to use any software you want. But in terms of the class, the preparation, the tutorial shows, I'll be using gums in the tutorials. Okay, so even if you don't like gums, it's your choice. But it's my choice for for a software. So I'll be using. So please try to download and try to start manipulating gums because it can be very useful and you can learn a lot from these tutorials as well. Okay, so next week my suggestion try to bring your laptop with gums already working because you have an example or edge based on this problem here and we can advance way more. If you already know how to manipulate this software, at least it's if it's downloaded correctly or edge. Okay. If you have problems, you just may or may, but see you on Tuesday actually don't have much time. Right. So I don't Tuesday our next lecture. That's it. Do you have a questions which you have one minute. No questions. Now. Thank you very much. See you on Tuesday then. Personal questions. Okay. Yes. Yes. I wanted to first inform you that next Tuesday I prefer to be outside because I'm going to be my graduation sermon. Of course, I did not ask. Between school and computing, which you think is more which is better for consultancy services that I was stuck between. I would say both are very important actually. Consultancies are switching from purely deterministic problems to stochastic problems. More and more consultancy companies, Amazon, they are dealing with optimisation under uncertainty are problems. And in terms of competitiveness, I would say that almost no MSC in the UK in the world offers stochastic programming. Yes, soft computing you can find in different programmes. So I would say that it's it's more difficult to learn stochastic optimisation by yourself then soft computing because I. Did it, but I wasn't sure if I would be able to handle operations because I'm not really. Of course you'll be deprived in this course. Yes, but no worries. A The lecturer is is a queue. He's very, very patient and I follow his course last semester as well because eventually when he's not here. Are you teaching this course. It's very pace too. No, don't worry about that. You'll be very nice course. But again, software computer is very nice. If you can undertake both your video. Then I have to remove something. So this is what I have for the second semester. Should I remove then advanced concepts and methods of the. Unless you want. To go for the I would say so. I would say soft computing is more if you like, this area. If you have this idea of going to consultancy won't be important. But. Stochastic computer will be very important. I'll switch it up. Yes, no worries. Good luck. Yeah, I just want to do something. So we were talking about the feasible solution thing. So just taking the example that Amira told us that's feasible solution include all solutions or all the optimal solution. No, no feasible solution. Well, you have a set of solutions. The optimal solution is one of. Those feasible solutions. Eventually, what we have is a case in which you have like multiple optimal solution.