IM 2010: Operations Research, Spring 2014

Overview

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Welcome!

- This is an **introductory** Operations Research course designed for second-year students majoring in **Information Management**.
- My plan for today:
  - Ch. 1: What is Operations Research?
  - Quiz.
  - Syllabus.
  - Ch. 2: Introduction to modeling.

What is Operations Research?

- Let's first ask: What is "management"?
- "**Management** is the attainment of organizational goals in an effective and efficient manner through planning, organizing, leading, and controlling organizational resources."[1]
  - Use resources.
  - To achieve some goals.
  - In a smart way.
- Typical tools: intuitions, common senses, and experiences.
  - To make decisions.
  - To decide how to allocate scare resources.

[1] Quoted from *Management* by Daft, the sixth edition.

Tapioca milk tea delivery

- Suppose you want to start your own business by delivering tapioca milk tea to people in NTU.[2]
  - You have customers in the CS and Math departments.
  - Each noon you deliver five cups of tapioca milk tea to each location.
  - You go to Gongguan to buy tapioca milk tea, deliver them, and then come back to the college of management.
  - This must be done in one hour.

[2] Thanks Chih-An Lin for sharing this idea with me. This completely imaginary example is modified from his real idea.

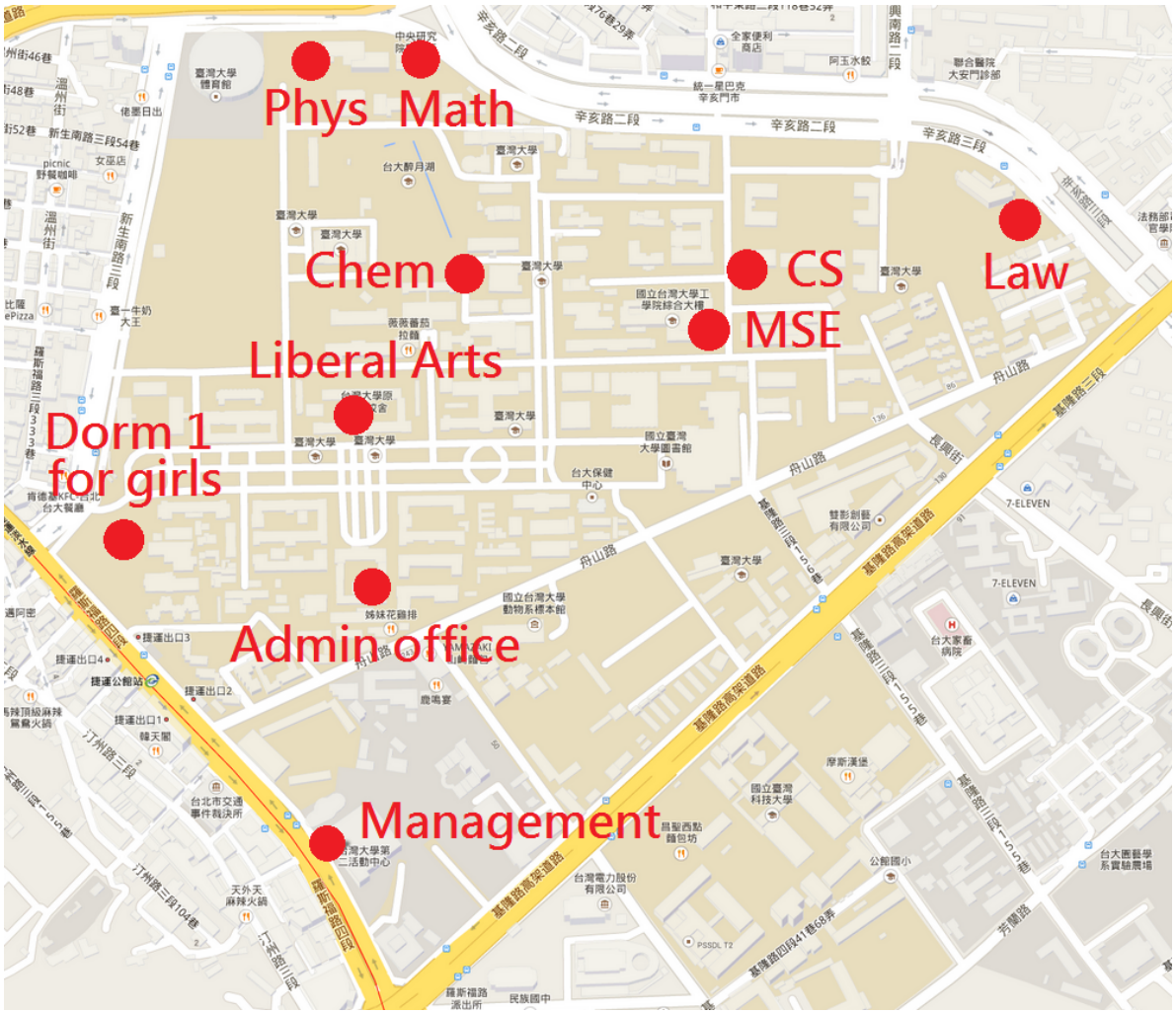
Tapioca milk tea delivery

- To "manage" this "organization":
  - What are the decisions to make?
  - What are the scare resources?

Tapioca milk tea delivery

- One allocation (which seems to be very good).

Your business is successful!



- You now have customers in many different places (including the administration office and dorm 1 for girls).
- They together order more than 50 cups.
- Accept all orders?
- What is the best route?

Your business is really successful!

- If one day...
  - You get orders from the colleges of medicine and social sciences...
  - You start to hire workers...
  - One tea shop cannot make so many cups of tapioca milk tea...
  - Customers start to order more than one items...
- One day you will need a **scientific way** for making decisions.
  - You need to allocate resources.
  - You need to determine the operations **to do and not to do**.
  - You need to "**do research on operations**".
  - You need Operations Research.

What is Operations Research?

- **Operations Research** (OR) is:
  - the methodology to "**allocate** the available **resources** to the various activities in a way that is most effective for the organization as a whole."
  - "applied to problems that concern how to conduct and coordinate the **operations** (i.e., activities) within an organization."[3]
- It aims to **support decision making**.
  - By doing OR studies, we generate some suggestions to **decision makers**.
  - E.g., customer orders to be given up, routes for delivery, a plan to assign routes to workers, etc.

[3] Both quoted from *Introduction to Operations Research* by Hillier and Lieberman, the ninth edition.

Industry applications

- Important questions:
  - How to deliver 6.5 millions items to more than 220 countries each day?
  - In each region, where to build distribution hubs?
  - In each distribution hub, how to classify and sort items?
  - In each city, how to choose routes?
- What do you need?
  - Well-designed information systems.
  - Operations Research!
- Further reading:
  - The application vignette in Section 1.3.
  - The article on CEIBA with the complete story.

Industry applications

- Important questions:
  - How to determine the cities to connect?
  - How to schedule more than 2000 flights per day?
  - How to assign crews to flights?
  - How to reassign crews immediately when there is an emergency?
- What do you need?
  - Well-designed information systems.
  - Operations Research!
- Further reading:
  - The application vignette in Section 2.2.
  - The article on CEIBA with the complete story.

Applicability and limitations

- It aims to support decision making in a **complicated** environment.
  - It is useless if we do not make decisions.
  - It is helpful if intuitions and experiences are not enough.
  - It is required if one's organization has many operations involved.
- It is a collection of **mathematical** methods.
  - Sometimes also **economic** methods and **computer science**.
  - It overlaps a lot with Management Science and Industrial Engineering.
- It is best for **quantifiable decisions**.
  - Those things that can be counted or measured.
  - Quantities to produce, inventory to stock, amount to invest, routes to go, workers to assign, etc.
  - It is not so helpful for qualitative decisions.
- It almost always requires **computers**.
  - So that large-scale computations are possible.

In short...

- What is Operations Research?
- We use **scientific** approaches to solve **managerial** problems.
  - A field of applied mathematics for making **better decisions**.

Agenda

- Ch. 1: What is Operations Research?
- **Quiz**.
- Syllabus.
- Ch. 2: Introduction to modeling.

Agenda

- Ch. 1: What is Operations Research?
- Quiz.
- **Syllabus**.
- Ch. 2: Introduction to modeling.

Prerequisites and languages

- It is assumed that you have some knowledge about:
  - Calculus.
  - Linear Algebra (or Management Mathematics).
  - Economics (mainly Microeconomics).
  - Probability (maybe from a Statistics course).
  - Computer programming (with any programming language).
- Language: **"All" English**.
  - I give all lectures in English.
  - I may speak Chinese in lectures (when it helps).
  - All materials are in English.
  - TA speak Chinese in most TA sessions.
  - I speak either Chinese or English in my office hour.
  - Students may ask questions in Chinese.
  - Students are strongly encouraged to present in English.

Meetings and office hour

- Meetings:

Meeting	Time	Classroom	Language
Lectures	2:20-5:20pm Thursday	Room 201 Management Building II	English
TA sessions	12:20-1:10pm Monday	Large computer classroom Management Building I	Chinese[4]

- Office hour:

Provider	Time	Room	Language
Instructor	5:30-6:00pm, Thursday 4:30-6:00pm, Friday	Room 413, MB2	English or Chinese
TAs	1:20-2:00pm, Monday	LCC, MB1	Chinese

[4] English for 3/3 and 3/31.

Grading

- Homework: 15%. Five case assignments: 15%. Project: 15%.
- Lecture problems: 15%.
- Two Exams: 40%:
  - Plan 1: midterm 20% and final 20%.
  - Plan 2: midterm 15% and final 25%.
- (Bonus!) Class participation: 5%.
- The final letter grades will be given according to the following conversion rule:

Letter	Range	Letter	Range	Letter	Range
A+	$[90, 100]$	B+	$[77, 80)$	C+	$[67, 70)$
A	$[85, 90)$	B	$[73, 77)$	C	$[63, 67)$
A−	$[80, 85)$	B−	$[70, 73)$	C−	$[60, 63)$

"Flipped classroom"

- Lectures in **videos**, then discussions in classes.
- Before each Thursday, the instructor uploads lecture videos.
  - Typically the videos will be no longer than 1.5 hours in total.
  - Students must watch the video by themselves before that Thursday.
- During the lecture, we do three things:
  - Discussing the lecture materials (0.5 to 1 hour).
  - Solving **lecture problems** (1 to 2 hours) in **teams**.
  - Further discussions (0.5 to 1 hour).
- After the lecture, students also need to do homework.

Teams

- Students form teams to do lecture problems.
- Each team has **three** students.
  - Unless a special approval is obtained.
- Once some students form a team for one case assignment, they will be **in the same team** for lecture problems until the submission of the next case assignment.
  - Students may change teammates when submitting case assignments.

Team periods

- The submissions of Homework 1 and the five case assignments divide the semester into six periods.

Week	Submission	Team	Week	Submission	Team
1		–	10		4
2	HW 1	1	11	CA 4	5
3		1	12		–
4	CA 1	2	13		5
5		2	14		5
6	CA 2	3	15		5
7		–	16	CA 5	6
8	CA 3	4	17		–
9		4	18		–

- Your teammates for lecture problems will be identical within each period but may differ for different periods.

Lecture problems

- Lecture problems:
  - For each problem assigned by the instructor in class, students discuss in teams for 5 to 10 minutes.
  - At least **one team** then demonstrate their answer to the class (in **English**) to get grades for class problems.
  - All students who are present get the same grades for lecture problems. Absent students get nothing.
  - Sometimes teams may volunteer; sometimes the instructor determines who to answer.

Homework and class problems

- Homework:
  - Homework will be assigned roughly weekly.
  - For each homework, each individual needs to submit a **hard copy** of your work into my **mailbox** on the first floor of the Management Building II by the due time.
  - The lowest two homework grades will be dropped (i.e., you may skip two homework if you want).
- Case assignments:
  - Five case assignments will be assigned.
  - Students form teams to work on case assignments. These teams are then units to work on lecture problems until the submission of the next case assignment.
  - One's teammates may be different for different case assignment.
  - Each team only needs to submit **one hard copy** into my **mailbox**.

Textbook and online resources

- Textbook: *Introduction to Operations Research* by F. S. Hillier and G. J. Lieberman, Ninth edition, McGraw Hill.
- Online resources:
  - We use CEIBA to post your grades, send group messages, and post materials protected by copyrights.
  - We post most materials at http://www.im.ntu.edu.tw/~lckung/courses/ORSp14/.
  - We invite discussions on the bulletin board "NTUIM-lckung" on PTT.
  - We use YouTube to post lecture videos.

Important dates and tentative plan

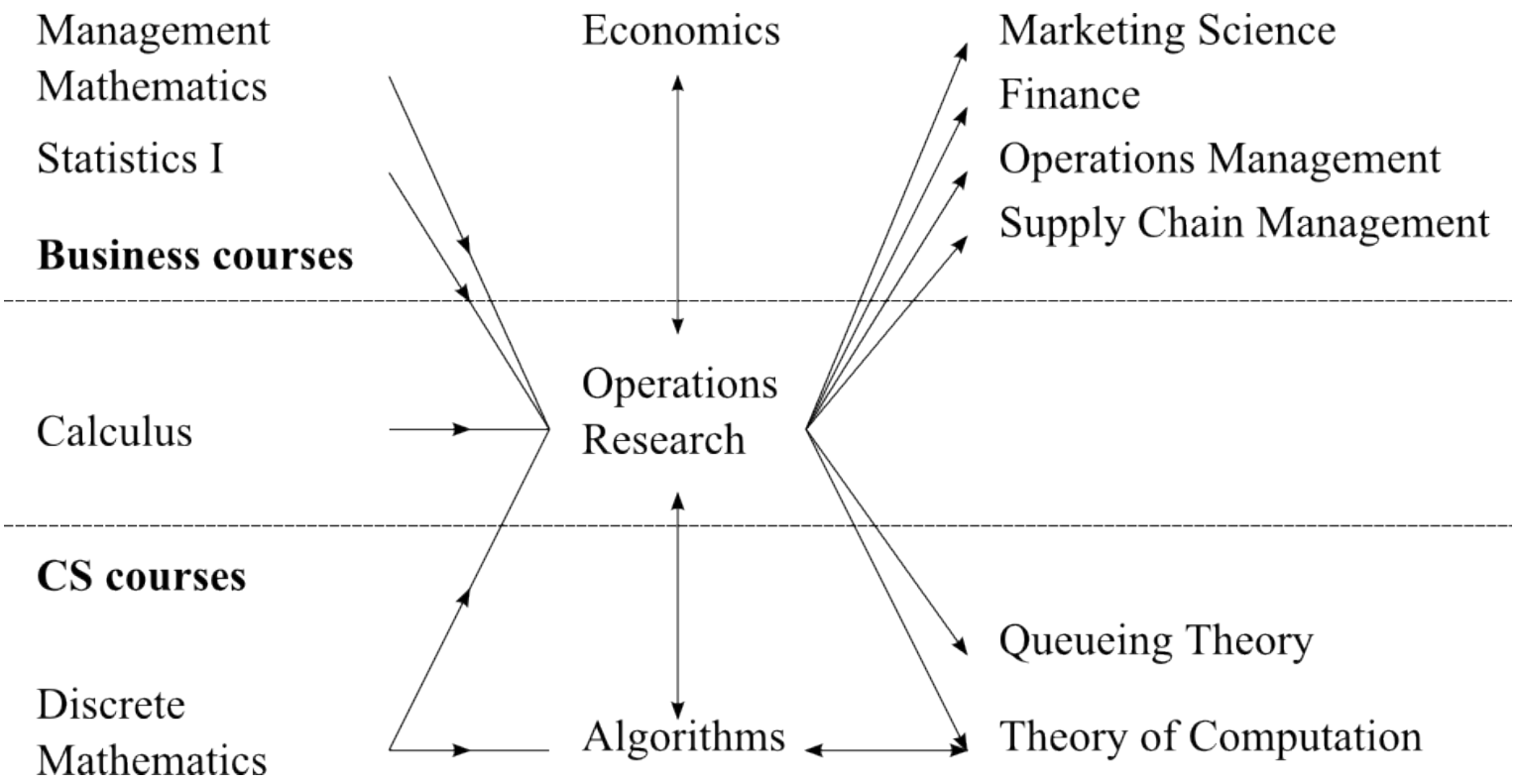
- Please note the following important dates:

Week	Event	Week	Event
1		10	
2		11	
3	TA session in English	12	Midterm exam
4		13	
5		14	
6		15	
7	TA session in English; spring recess	16	
8		17	Project presentations
9		18	Final exam

- Tentative plan:
  - Introduction: One lecture.
  - Linear Programming: Five lectures.
  - Integer and Nonlinear Programming: Four lectures.
  - Game Theory: Four lectures.

The role of OR in our IM department

- Operations Research is one of the few courses that lie in the **interface** between Business and Computer Science.



The role of OR in our IM department

- It is a promising direction if you:
  - Want to learn something that does not require a lot of **experiences** and can help you **run business**.
- It will also be very useful if you:
  - Want to work on **mathematical problems** in Computer Science or other engineering fields.
- For those of you who have not decided yet:
  - Study it so that you will not miss a chance in the future.

Organization of course materials

- We may cover only a tiny part of OR in one semester.
- This course is designed to contain "more applications, less theory".
  - We hope to let you know how to use OR to help you.
  - We hope to make you be interested in OR.
  - If you want to learn more about OR afterwards, please let me know so that I may give you some advises.
- We will still spend some (a lot of?) time on algorithms and theory.
  - Not just know how to use a tool. Know **why it works**.
  - Then you really know how to adjust your way of using the tool when the environment changes.
- Tentative topics:
  - Making an optimal decision for linear problems.
  - Making an optimal decision for discrete or nonlinear problems.
  - Making an optimal decision when others' decisions affect your payoff.

Before we start...

- If you are an IM student:
  - I will keep teaching this course before you graduate.
- If you are not:
  - Always welcome but think twice!
  - Ask for the codes for enrollment after this three-hour lecture.

Agenda

- Ch. 1: What is Operations Research?
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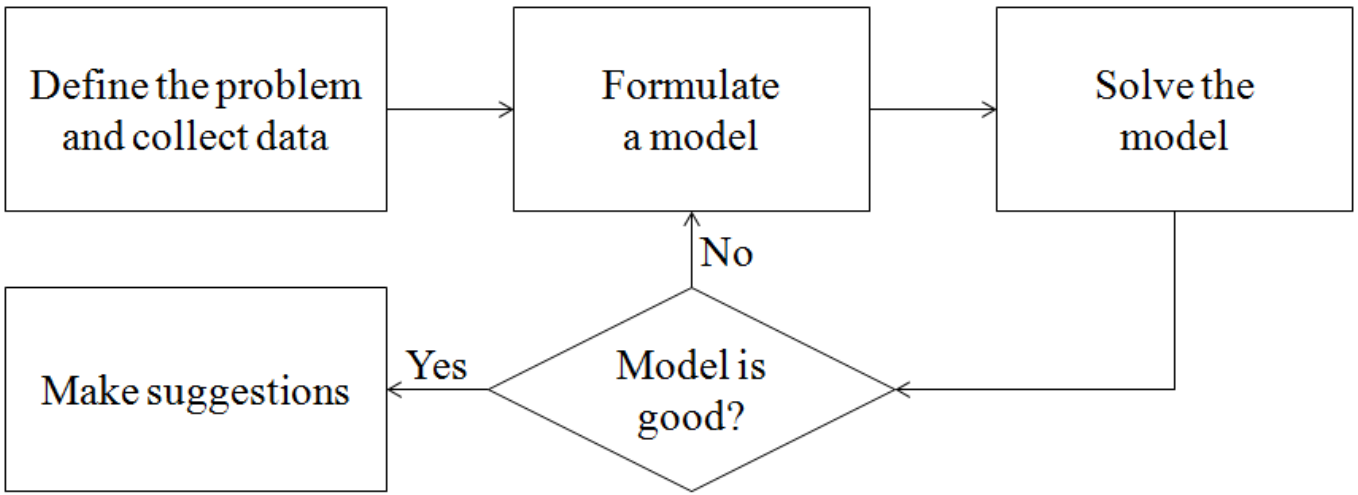
- Syllabus.
- **Ch. 2: Introduction to modeling.**

Five steps of an OR study

- To apply OR to facilitate better decision making, we conduct OR studies in five steps:
  - Define the problem and collect relevant data.
  - Formulate a **mathematical model** to represent the problem.
  - Develop or apply a procedure to derive a solution from the model.
  - Test the model and refine it when needed.
  - Make managerial suggestions.



- One thing should be defined: What is a mathematical model?

Mathematical modeling

- The main "weapon" we will use in OR is **mathematical modeling**.
  - Often a mathematical model is called a **model**, a **formulation**, or a **program** in OR.
- Modeling is a way of **abstracting** a physical problem into a model with **symbols** and **formulas**.
  - Use mathematics to describe a problem.
- Why modeling?
  - We use a model to describe a problem **precisely** and **concisely**.
  - Once an **algorithm** for a type of model is developed, all problems that can be modeled in that way can be solved.

An example: step 1

- Consider the following example.
  - I have three used textbooks to sell in a second-hand market.
  - I need to bring them to the market.
  - But I may carry at most 5 kg.
  - Which book(s) should I bring?
- Step 1: Define the problem and collect relevant data.
  - The problem: To maximize the sales revenue without hurting me.
  - Data:

Book	Title	Price (NT$)	Weight (kg)
1	Calculus	500	4
2	Computer Programming	400	2
3	Operations Research	200	3

Step 2: formulating the problem

- Step 2: Precisely **formulate** (i.e., describe) the problem.
- To describe a problem:
  - **Parameters**: What cannot be controlled by us?
  - **Decision variables**: What may we control?
  - **Objective function**: What do we want?
  - **Constraints**: What are the limitations?
- Parameters:
  - 5 kg and 3 books; 500, 400, and 200 dollars; 4 kg, 2 kg, and 3 kg.
- Decision variables:
  - For each book, we may control whether to bring it. We thus define

$$x_i = \begin{cases} 1 & \text{if I carry book } i \\ 0 & \text{otherwise} \end{cases}, i = 1, ..., 3$$

as our decision variables.

Step 2: formulating the problem

- What do we want? We want to maximize the sales revenue:

$$500x_1 + 400x_2 + 200x_3.$$

- What prevent us from bringing everything? We are not strong enough:

$$4x_1 + 2x_2 + 3x_3 \leq 5.$$

- Our first model:

$$\begin{array}{rrcrcrcl} \max & 500x_1 & + & 400x_2 & + & 200x_3 & & \\ \text{s.t.} & 4x_1 & + & 2x_2 & + & 3x_3 & \leq & 5. \end{array}$$

Step 3: solving the model

- Now we want to solve the model

$$\begin{array}{rrcrcrcl} \max & 500x_1 & + & 400x_2 & + & 200x_3 & & \\ \text{s.t.} & 4x_1 & + & 2x_2 & + & 3x_3 & \leq & 5. \end{array}$$

- Wait... this problem is **unbounded**.
  - $(0, 0, 0)$ is feasible and results in \$0 as my revenue.
  - $(-1, 2, 0)$ is feasible and results in \$300 as my revenue.
  - $(-2, 4, 0)$ is feasible and results in \$600 as my revenue.
  - And so on and so on.
- We will become millionaires! What is wrong here?

Step 4: testing and revising the model

- We cannot bring "negative two" textbooks.
- How about this:

$$\begin{array}{rrcrcrcl} \max & 500x_1 & + & 400x_2 & + & 200x_3 & & \\ \text{s.t.} & 4x_1 & + & 2x_2 & + & 3x_3 & \leq & 5 \\ & x_i \geq 0 & & \forall i = 1, ..., 3. & & & & \end{array}$$

- The best solution is $(0, 2.5, 0)$. Still wrong!
- How about this:

$$\begin{array}{rrcrcrcl} \max & 500x_1 & + & 400x_2 & + & 200x_3 & & \\ \text{s.t.} & 4x_1 & + & 2x_2 & + & 3x_3 & \leq & 5 \\ & x_i \geq 0 & & \forall i = 1, ..., 3. & & & & \\ & x_i \leq 1 & & \forall i = 1, ..., 3. & & & & \end{array}$$

- The best solution is $(0.75, 1, 0)$. Still wrong!

Step 4: testing and revising the model

- What we still need: We cannot split a book:

$$x_i \in \{0, 1\} \quad \forall i = 1, ..., 3.$$

- The final formulation:[5]

$$\begin{array}{rrcrcrcl} \max & 500x_1 & + & 400x_2 & + & 200x_3 & & \\ \text{s.t.} & 4x_1 & + & 2x_2 & + & 3x_3 & \leq & 5 \\ & x_i \in \{0, 1\} & \forall i = 1, ..., 3. & & & & & \end{array}$$

- The best solution is $(0, 1, 1)$. Makes sense!

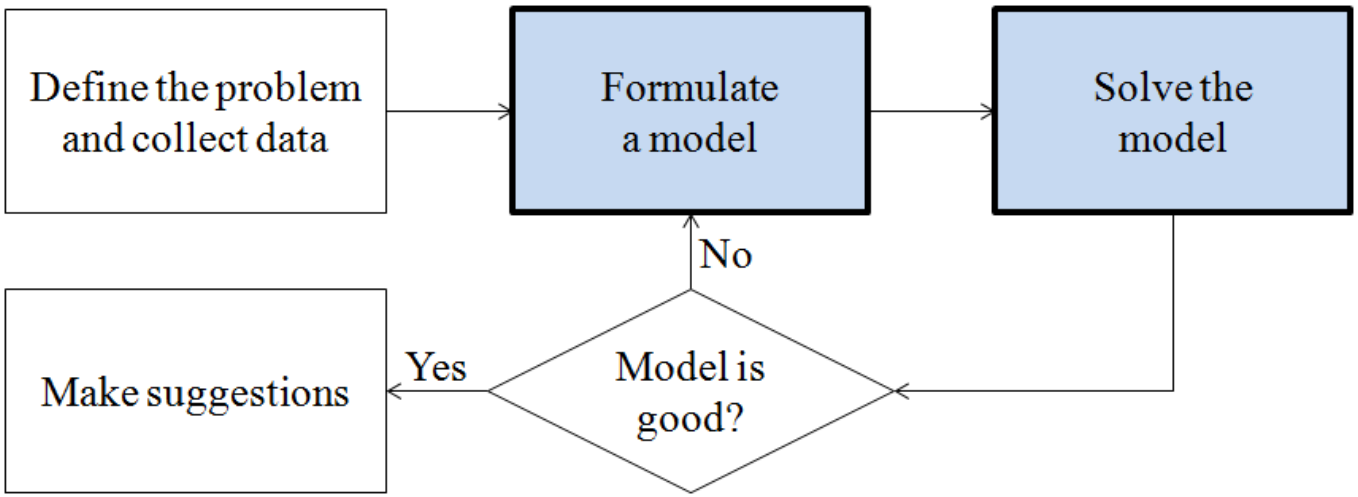
[5] The problem is an example of the **knapsack** problem, one of the most fundamental problem in Computer Science.

Lastly: Making managerial suggestions

- "$(0, 1, 1)$" means nothing to you.
  - It will also mean nothing to your boss or any manager.
  - We need **suggestions** on what to do!
  - We need to **interpret** the solution.
- Step 5: Given our model and the solution we obtain, we suggest you to sell the textbooks of Computer Programming and OR!
  - Please do so at least after you pass these courses.

Summary

- An OR study is conducted in the following five steps:



- In this course, we will focus on Steps 2 and 3.
  - These technical parts require **practices** but no **experience**.
  - You will do Step 4 by yourselves from time to time.
  - You will get a taste on Steps 1 and 5 when doing your final project.

The DFSI principle

- When you are asked to solve a decision problem in this course, you MUST do the following four things:
  - Step 1: **Define** the decision variables (and the notations you use for parameters).
  - Step 2: **Formulate** the problem as a mathematical model by writing down the objective function and constraints.
  - Step 3: **Solve** the model by finding the values for all decision variables in an optimal solution.
  - Step 4: **Interpret** the optimal solution by indicating "what to do".