

LECTURE 1: INTRODUCTION TO OPERATIONS RESEARCH

1. INTRODUCTION

Hello everyone and welcome to APMA 1210! My name is Peyam and I'll be your instructor this semester

- **Logistics:** All the info is on the syllabus, which can be found on the Course Website
- **Office Hours:** Tu 12:15–1:15 pm, Th & F 1:15–2:15 pm
- **Textbook:** Technically none required, but I really recommend you to read along the recommended textbook in the syllabus
- **Resources:** Here are some resources you can use:
 - ▶ Course Website: for the lecture notes, homework, and study material
 - ▶ Canvas: Announcements and to check your grades
 - ▶ Gradescope: Where you upload your homework
 - ▶ Ed Discussion: A forum-like tool where you can post questions and your classmates can answer them
 - ▶ Dr Peyam: My YouTube channel, where you'll find useful videos related to this course

Date: Thursday, September 8, 2022.

- **Grading:**

- **HW 30%**, due Tuesdays by 11:59 pm on Gradescope. You'll find the assignments on the course website. Lowest HW dropped. Some of them *might* involve some MATLAB programming, but I'll try to keep it at a minimum.
 - **Midterm 1, 15%** On **Tuesday, October 11**, during class
 - **Midterm 2, 20%** On **Tuesday, November 15**, during class
 - **Final 35%** Cumulative, on **Wednesday, December 14**, 2 pm
- **Grades:** You will be graded according to the scale in the syllabus, so everyone can get an A if they work hard. I will try my best to be as generous as I can
 - **Finally:** Sit back, relax, and enjoy the show ☺

Today: Just a historical overview of Operations Research, no math

2. THE HISTORY OF OPERATIONS RESEARCH

Let me share an interesting story I had with my sister's husband: I was surprised to learn that there are some cultures in South America that don't use any numbers or counting (Source: this article). And he replied "Think about it! Why do we even *need* numbers? It's in order to do trading, like "I'm selling you 5 cows so you give me 20 chickens in return." And this, on a larger scale, is the essence behind Operations Research.

What is Operations Research? Since the industrial revolution, the world has seen a remarkable growth in the size and complexity of organizations. Think for instance Amazon (or Wal-Mart), which used to be a small online bookstore, and now is a billion-dollar corporation

giant. One reason for this change has been the increase in the division of labor and segmentation of management responsibilities in those organizations.

With great power comes great responsibility, and this specialization created new problems, problems that are still persisting today. One main issue is the following: Suppose the company has a budget of 10 million dollars. How would they allocate this budget to the various organizations so as to maximize the total profit? This is precisely the emergence of a field called **Operations Research**.

Why “Operations” ? Dates back from World War II, where the US and British military had an urgent need to allocate resources or budget to its various military operations. Because of this, the British and US military called upon a large number of scientists to apply a scientific approach to dealing with this and other strategic and tactical problems. In effect, they had to do *research* on military *operations*. Those operations research (OR) teams were instrumental in winning the Air Battle of Britain, the Battle of the North Atlantic, and the Island Campaign of the Pacific.

From military to business: Because of this success, the field of OR spurred interest of applying OR outside of military as well. As the industrial boom was running its course, the increasing complexity and specialization in organizations were again causing problems. It became apparent to business consultants that these were the same problems that were faced by the military, just in a different context. These people introduced the use of OR to a variety of organizations in business, industry, and government, which induced the rapid spread of OR.

Growth of OR: There are two other factors that played a key role in the rapid growth of OR. One was the substantial progress made in

improving the techniques of OR. Lots of scientists who worked in OR teams at that time were motivated to pursue research relevant in the field, which resulted in important advancements. A prime example is the **simplex method** for solving linear programming problems, developed by **George Dantzig** in 1947, which we'll talk about a lot in this course

Fun Fact: (Source: Wikipedia) George Dantzig did his PhD in Math at UC Berkeley (my alma mater ☺), under the supervision of Jerzy Neyman. Near the beginning of a class, Neyman wrote two problems on the blackboard. Dantzig arrived late and assumed that they were a homework assignment. According to Dantzig, they “seemed to be a little harder than usual,” but a few days later he handed in completed solutions for both problems, still believing that they were an assignment that was overdue. Six weeks later, an excited Neyman eagerly told him that the “homework” problems he had solved were two of the most famous unsolved problems in Statistics. And in fact, this story served as an introductory scene in the movie “Good Will Hunting”

Computer Revolution: The second factor to play a role in the success of OR is the computer revolution. A large amount of computation is usually required to solve the problems from OR, which makes sense because we're dealing with huge companies. Doing this by hand would be practically impossible, but the development of electronic digital computers, which do computations a *a million* times faster than human beings, made OR a tremendous success. For example, Microsoft Excel has a built-in solver that will solve a variety of OR problems. We will use MATLAB.

3. WHAT IS OPERATIONS RESEARCH?

Definition: In short, OR is the science of formulating and using mathematical and computational tools for solving problems of

- Choice
- Scheduling
- Allocation

in order to optimize the goal

Applications: As its name implies, operations research involves “research on operations.” So OR is applied to problems that concern how to conduct and coordinate the operations/activities within an organization. It is a very versatile and has been applied to very diverse areas such as

- (1) Manufacturing
- (2) Transportation
- (3) Construction
- (4) Telecommunications
- (5) Financial Planning
- (6) Health Care
- (7) Military
- (8) Public Services
- (9) University

Scientific Method OR uses an approach that is similar to research conducted in scientific fields. In particular, the **scientific method** is considerably used to investigate the problem of concern. In fact, OR is sometimes also called **management science**.

Here are the typical steps used to solve an OR problem:

STEP 1: Carefully formulate the problem and gather the data

STEP 2: Construct a mathematical model that abstracts the essence of the real problem and formulate a hypothesis

STEP 3: Model Validation: Conduct experiments to test the hypothesis

However, OR is more than science! Since we're dealing with an organization, we also need to see if the model actually helps the company in question.

Optimal Solution: We will often look for optimal solutions (which might not be unique). So instead of just saying "We will improve the current situation," the goal is to be bold and to identify the **best** possible course of action. For example, if you're a C student, "improving the situation" would be like getting a B , but we will try to get you an A . Of course there will also be **constraints** because the company doesn't have an infinite amount of resources

4. EXAMPLE

To give you a small taste of what we'll do in this class, a typical example will have the following form:

Suppose you're an ice cream company with two flavors x_1 (chocolate) and x_2 (vanilla), priced at \$4 and \$6 each, then a typical problem will be to maximize

$$\text{Maximize } z = 4x_1 + 6x_2$$

Subject to the **constraint**

$$\begin{aligned}x_1 &\leq 30 \\x_1 - x_2 &\leq 6 \\3x_1 + x_2 &\leq 17 \\&\vdots \\x_1 &\geq 0 \\x_2 &\geq 0\end{aligned}$$

This is an **algebra model** and we'll be able to transform this then into a **geometric model** (see picture in class)

5. ANALYTICS AND DATA SCIENCE

A big buzzword you are hearing a lot those days is the term “analytics.” It's basically OR but with a different name. Analytics fully recognizes that we have entered the era of **big data** where massive amounts of data are available to many businesses and organizations to help guide managerial decision making.

Definition: **Analytics** is the scientific process of transforming data into insight for making better decisions

Compare this with OR, which studies the company to make better decisions (almost the same thing)

There are three applications of Analytics:

Descriptive Analytics: Using innovative techniques to identify interesting patterns in data in order to describe and understand what is going on. People who specialize in descriptive analytics are called ... **data scientists!**

Predictive Analytics: Using the data to predict what will happen in the future, using statistical forecasting methods and simulations

Prescriptive Analytics: Using Data to describe what should be done in the future

OR is basically the second and the third part combined.

Applications to Politics: Analytics played a huge role in the 2012 Obama campaign. Back then, President Obama hired a huge team of statisticians, predictive modelers, data-mining experts, mathematicians, and OR analysts, five times as large as his 2008 campaign. They all gathered data from various sources to target voters and political donors. Initially, the election was expected to be a close one, but because of this, he was able to win by a landslide. In fact analytics was used more extensively by both parties in future elections as well

Applications to Sports: Described in the movie *Moneyball*, which is based on the true story of how the Oakland Athletics baseball team achieve a great success, despite having one of the smallest budgets in the major leagues, by using various kinds of data to evaluate the potential of players available through a trade or draft. Analytics were

used to identify overlooked players who could greatly help the team. After witnessing the impact of analytics, many major league baseball teams now have hired analytics professionals.

6. THE SUCCESS OF OPERATIONS RESEARCH

OR has had a tremendous impact on improving the efficiency of numerous organizations around the world.

Company	Impact	Annual Savings
Taco Bell	Plan employee schedules	\$13 million
Merryl Lynch	Pricing Analysis financial services	\$50 million
Hewlett-Packard (HP)	Production and distribution redesign	\$180 million
Samsung	Reduced manufacturing times	\$200 million
Inter Continental Hotels	Revenue management	\$400 million
Deere & Co	Inventory management	\$1 billion