# The art of solving real-world problems: Operations Research (OR)

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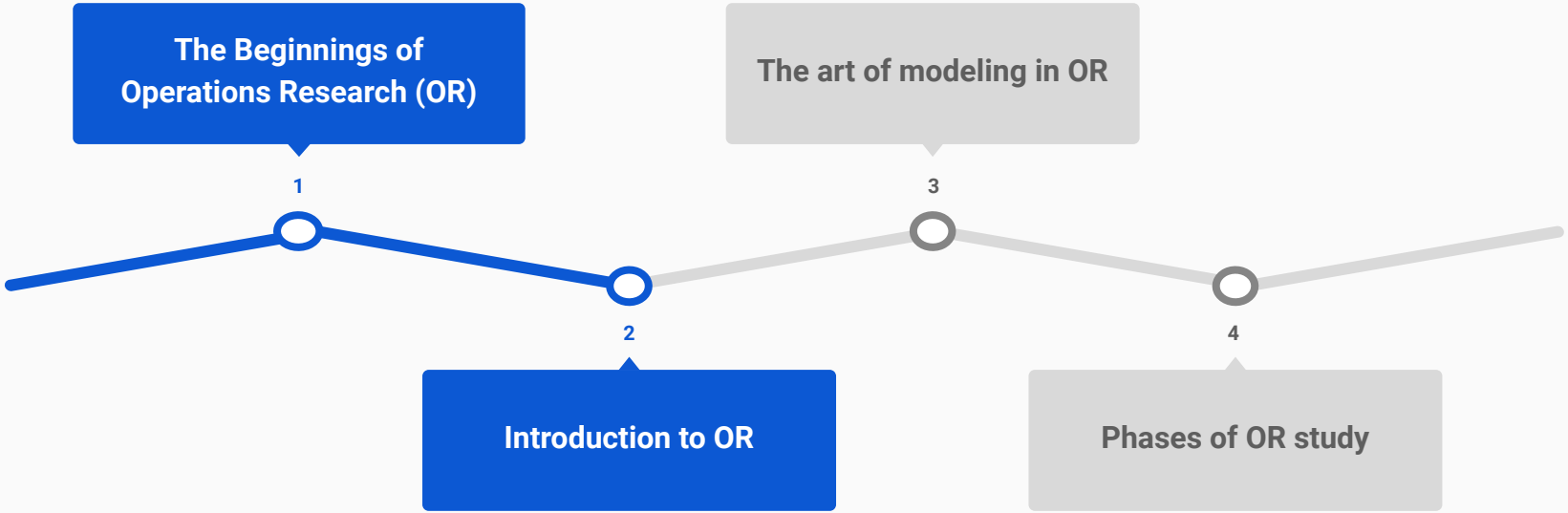
# Agenda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# The Beginnings of Operations Research (OR)

# Origine of Operations Research (OR)

## Who were the first Operations Research teams?



***The scientists became the first operations research (OR) teams***

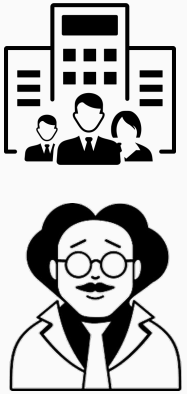
***During World War II***

# Origine of Operations Research (OR)

- Large number of scientists are called to apply a scientific approach to address strategic and tactical problems
- Results
  - Scarce resources allocation to military operations
  - Deployment of radar
  - Convoy management
  - ...

**The origins of operations research (OR) is the a time of war, when highly intelligent scientists came together to tackle *crucial problems*.**

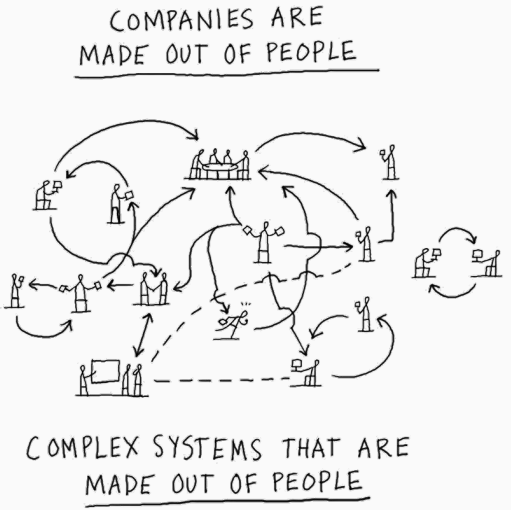
# OR from War to Business and Research



- OR Teams during War spur Adoption and Advancements in 1950s
  - Business consultants introduced OR to various organizations in the early 1950s
  - Scientists motivated to pursue OR research, leading to significant advancements in the field
- Simplex Method revolutionizes Linear Programming in 1947
- OR Advances in 1950s: LP, DP, Queuing, Inventory Theory

# OR and organizational Growth Challenges

- Growth of organizations
- Emergence of components with separate goals
- Conflict between components
- Difficulty in resource allocation




**Emergence of Operations Research (OR) to solve these problems**

# OR and computer revolution

- The computer revolution was a major boost to OR's development
- The continued acceleration of computer power has contributed to the growth of OR

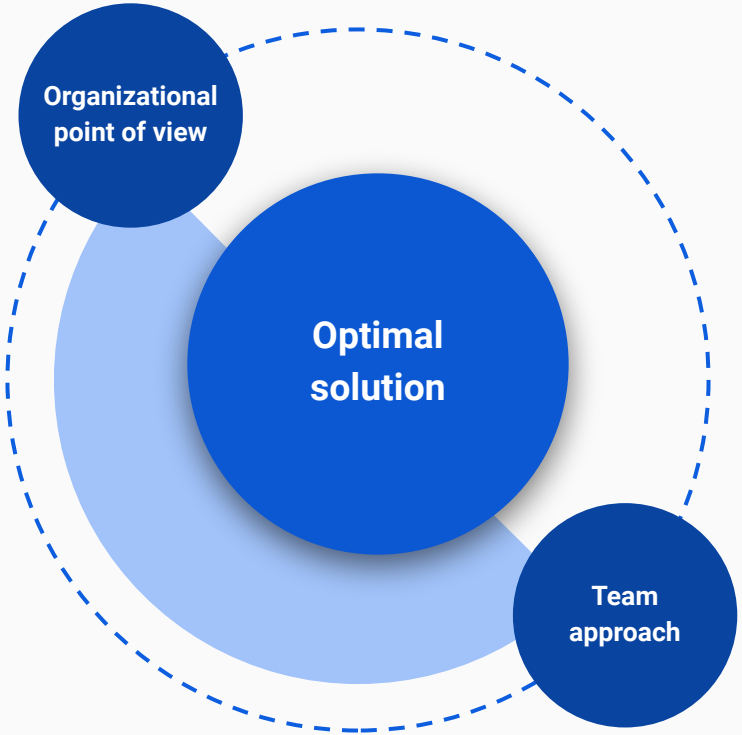
# Introduction to Operations Research (OR)

# Operations Research

- **Operations :** problems related to operations within organizations
- **Research :** scientific method to investigate the problem
  - Observation and formulation
  - Building a mathematical model
  - Testing the model.

# Nature of Operations Research (OR)

- OR adopts an **organizational point of view** and considers the best for the organization as a whole
- OR searches for the **best possible solution (optimal)** not only an acceptable solution
- OR requires a **team approach**, as no single individual can have expertise in all aspects of OR

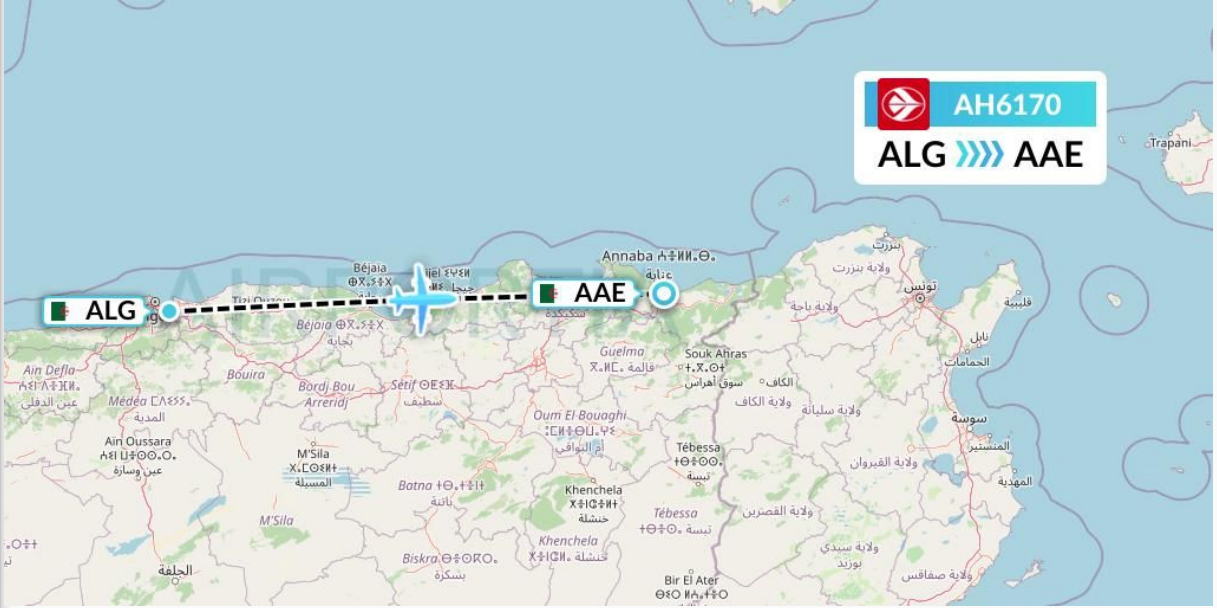


# Impact of Operations Research (OR)

| Organization | Use case | Annual Savings |
|---|---|---|
| **Samsung Electronics** | Reduce manufacturing time and the amount of stocked raw material | **$200 million more revenue** |
| **Hewlett-Packard (HP)** | Product portfolio management | **$180 million** |
| **Netherlands Railways** | Optimize operation of a railway network | **$105 million** |
| **Waste Management** | Develop a route management system for trash collection and disposal | **$100 million** |
| **Syngenta** | Increase the productivity of crops | **$57 million** |

# Example: Tickets purchasing problem

- A businessperson has a 5-week commitment traveling between Annaba (AAE) and Algiers (ALG)
- Weekly departure from Annaba (AAE) is on Mondays and returns on Wednesdays
- A regular round trip ticket costs $400
- A 20% discount is granted if the roundtrip dates span a weekend.
- A one-way ticket costs 75% of the regular roundtrip ticket price.




**Determine the best way to purchase tickets for the 5-week period**

# Tickets purchasing problem

**Alternatives** — What are the decision alternatives ?

**Constraints** — What are the restrictions for making the decision?

**Objective** — What is an appropriate objective criterion for evaluating the alternatives ?

# What are the decision alternatives ?

a. Buy five regular AAE-ALG-AAE for departure on Monday and return on Wednesday of the same week.

b. Buy one AAE-ALG, four ALG-AAE-ALG that span weekends, and one ALG-AAE.

c. Buy one AAE-ALG-AAE to cover Monday of the first week and Wednesday of the last week and four ALG-AAE-ALG to cover the remaining legs. All tickets in this alternative span at least one weekend.

# Tickets purchasing problem

**What are the restrictions for making the decision?**

The businessperson must leave AAE on Monday and return on Wednesday of the same week.

**Objective criterion**

The cheapest ticket price.

**Alternatives costs**

a. Alternative a : Cost: $2000 (5 * $400)
b. Alternative b : Cost: $1880 (0.75 * $400 + 4 * 0.8 * $400 + 0.75 * $400)
**c. Alternative c : Cost: $1600 (5 * 0.8 * $400)**

**The best alternative is the one with the smallest cost**

# Challenge : what are the decision alternatives ?

- How many alternatives exist?
- Is there a cheaper alternative to the options offered ?
- What is the cost of this alternative?

## Example: Garden problem

- A homeowner is starting a backyard vegetable garden
- The garden must be rectangular and fenced to keep critters out
- The owner has enough material to build a fence of length **L = 100 ft**

**Fence the largest possible rectangular area**

# Garden problem

**Alternatives** — What are the decision alternatives ?

**Constraints** — What are the restrictions for making the decision?

**Objective** — What is an appropriate objective criterion for evaluating the alternatives ?

# Garden problem

## What are the restrictions for making the decision?

- We control the **width (w)** and **height (h)** of the rectangle
- Width, height are continuous variables between 0 and L.
- Perimeter of the garden <= 100

## Objective criterion

Maximize the area of the garden

## Alternatives costs

Impossible to test all the possibilities because we have continuous variables

# Garden problem

Maximize **z = wh**

subject to

**2(w + h) = 100**

**w, h >= 0**

## Operations Research problem formulation

**Decision variables:** variables that we can control to optimize the objective function

**Feasible solution :** solution satisfies all constraints

**Optimal solution :** It yields the best (maximum or minimum) value of the objective function

Maximize or minimize

**Objective Function**

Subject to

**Constraints**

# The art of modeling in Operations Research (OR)

## Example: Wozac production process

- Eli Daisy produces Wozac by heating a chemical mixture in a pressurized container
- The production process results in different amounts of Wozac produced each time
- The amount produced is called the process yield, measured in pounds

**Understand the factors that influence the yield.**

# Wozac Production Process

- **Model-building** process should be used

- **Decision variables:** factors influencing Wozac production yield:
  - Container volume (V), Container pressure (P), Container temperature (T)
  - A, B, and C be percentage of mixture made up of chemicals A, B, and C

- **Model:** descriptive model that describes behavior of actual yield
  - Regression methods used to determine influence
  - Find the model parameters based on the data

$$yield = 300 + 0.8V + 0.01P + 0.06T + 0.001T * P - 0.01T^2 - 0.001P^2$$
$$+11.7A + 9.4B + 16.4C + 19A * B + 11.4A * C - 9.6B * C$$

# Constraints in Wozac Production Process

What are the restrictions for making the decision on Wozak Production Process ?

- Volume (V)  between **1 and 5 liters**
- Pressure between **200 and 400 milliliters**
- Temperature between **100 and 200 degrees Celsius**
- Mixture must be made of A, B, and C
- Maximum half of mixture can be product A for proper performance of the drug

# Wozac Production Process

$$\text{Maximize } z = 300 + .8V + .01P + .06T + .001T{*}P - .01T^2 - .001P^2 + 11.7A + 9.4B + 16.4C + 19A{*}B + 11.4A{*}C - 9.6B{*}C$$

Subject to (s.t.)

$$V \leq 5$$
$$V \geq 1$$
$$P \leq 400$$
$$P \geq 200$$
$$T \leq 200$$
$$T \geq 100$$
$$A \geq 0$$
$$B \geq 0$$
$$C \geq 0$$
$$A + B + C = 1$$
$$A \leq 5$$

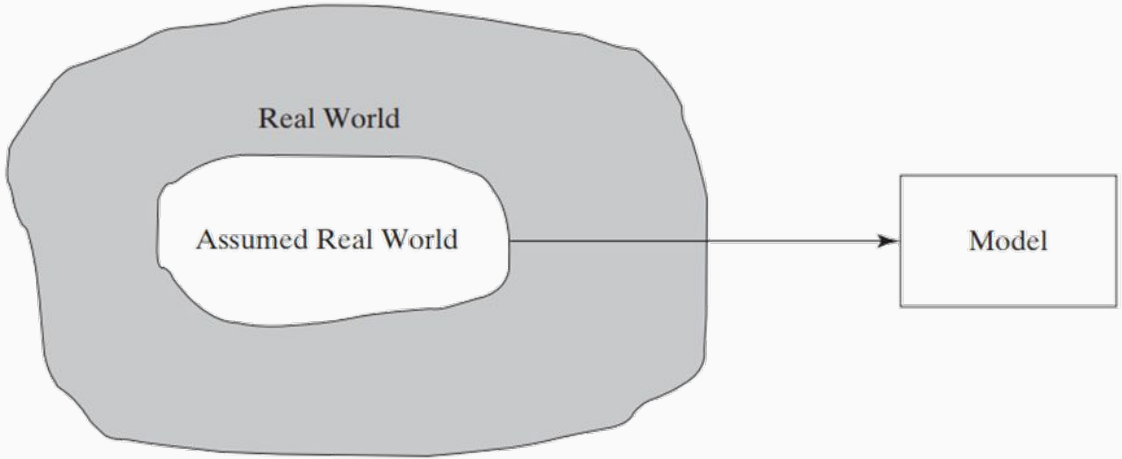
# Wozac Production Process

- Any values of decision variables that meet constraints is in **feasible region**
- **Optimal solution** is a point in feasible region that optimizes objective function
- Use an OR method  to determine the optimal solution for the model

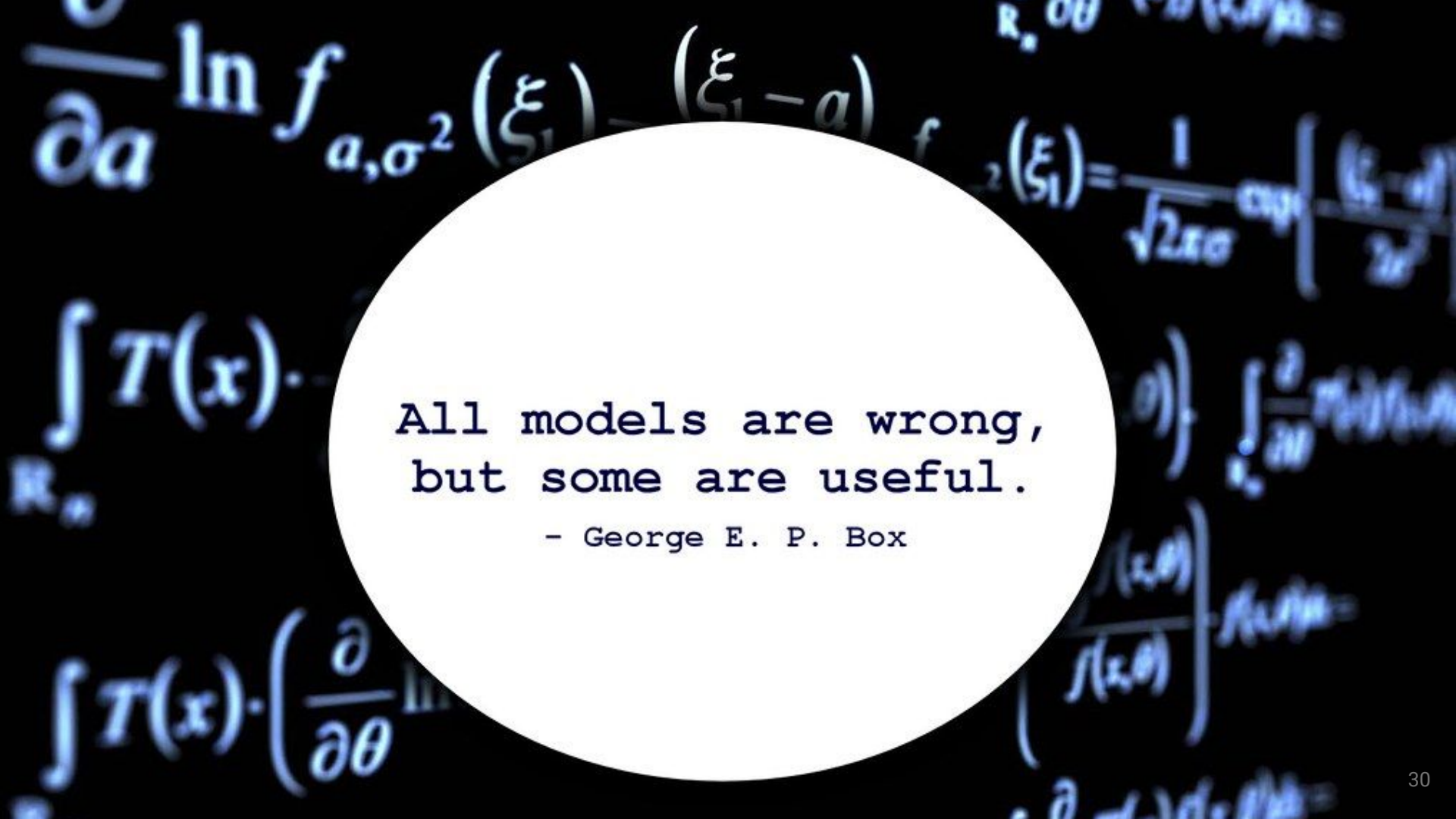
- **Optimal solution:**
  - 5-liter container, 200 milliliters pressure, 100 degrees Celsius temperature, 29% A and 71% C
  - Maximum yield of **183.38 pounds** can be obtained with the **optimal solution**

# Modeling in OR

- Model expresses the behavior in an easily understandable manner
- Dominant variables are concentrated
- Mathematical functions representing the behavior of the assumed real world

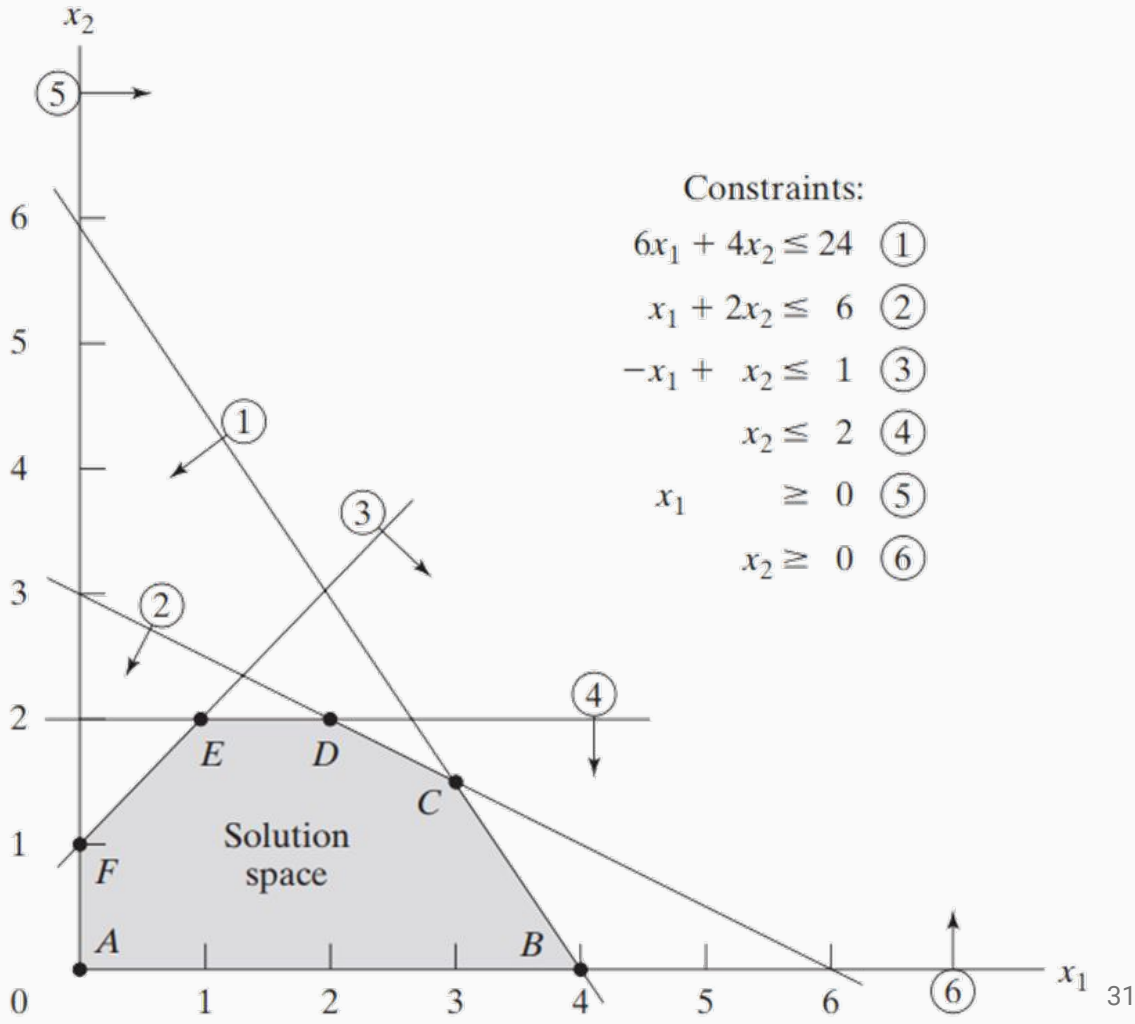



**Model is a simplified representation of reality, not reality itself**


All models are wrong,
but some are useful.
- George E. P. Box

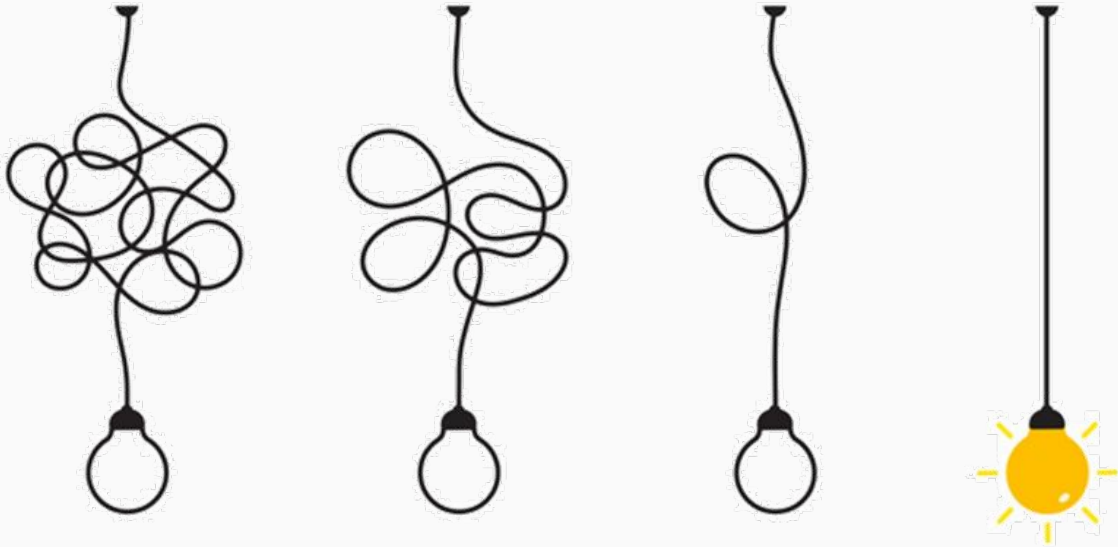
# Solving OR model

- OR Technique
  - Linear Programming is the most prominent one (next week)
- Other OR Techniques
  - Integer Programming
  - Dynamic Programming
  - Network Programming
  - Nonlinear Programming
- ...



## Modeling is more than Just Mathematics

- OR models rely on mathematical analysis
- Start Simple, Then Progress to Complex Models
- Human elements play a crucial role in decision making
- Understanding psychology is important



**Avoid Mathematical Bias,**

**Prioritize Understanding & Simple Solutions**

# Example: UPS- Optimize delivery itineraries


**Problem:**

- UPS introduced ORION software to provide tailored delivery itineraries
- The software proposed shorter routes, leading to potential savings
- **Drivers didn't like the idea of a machine "beating" them**

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**Problem:**

- UPS introduced ORION software to provide tailored delivery itineraries
- The software proposed shorter routes, leading to potential savings
- **Drivers didn't like the idea of a machine "beating" them**

**Solution:**

- ORION developers added a button "**Beat the Computer**"
- Drivers took the challenge, some beat computer-suggested routes
- Perception of ORION changed from a **threat** to a **complement to drivers' experience**

# Example: Solving the Airport Baggage Delay

**Problem:**

- Long baggage wait complained about by Houston Intercontinental Airport travelers
- **Increasing the number of baggage handlers did not alleviate the problem**

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**Problem:**

- Long baggage wait complained about by Houston Intercontinental Airport travelers
- **Increasing the number of baggage handlers did not alleviate the problem**

**Solution:**

- **Arrival gates were moved farther away from baggage claim**
- **Extra walking allowed ample time for luggage to be delivered to the carousel**
- **Complaints disappeared**

# Example: Elevator Wait Time Issues

**Problem:**

- Complaints of slow elevator service in a large office building
- **Waiting-line problem requiring mathematical queuing analysis**

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**Problem:**

- Complaints of slow elevator service in a large office building
- **Waiting-line problem requiring mathematical queuing analysis**

**Solution proposed with psychologist:**

- **Installation of full-length mirrors at the entrance to the elevators**
- **People were kept occupied watching themselves and complaints disappeared**

# Example: Solving the Long Wait for Truck Transport

**Problem:**

- A number of departments share  three trucks to transport material
- Departments complained of long wait and demanded adding a fourth truck
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**Solution:**

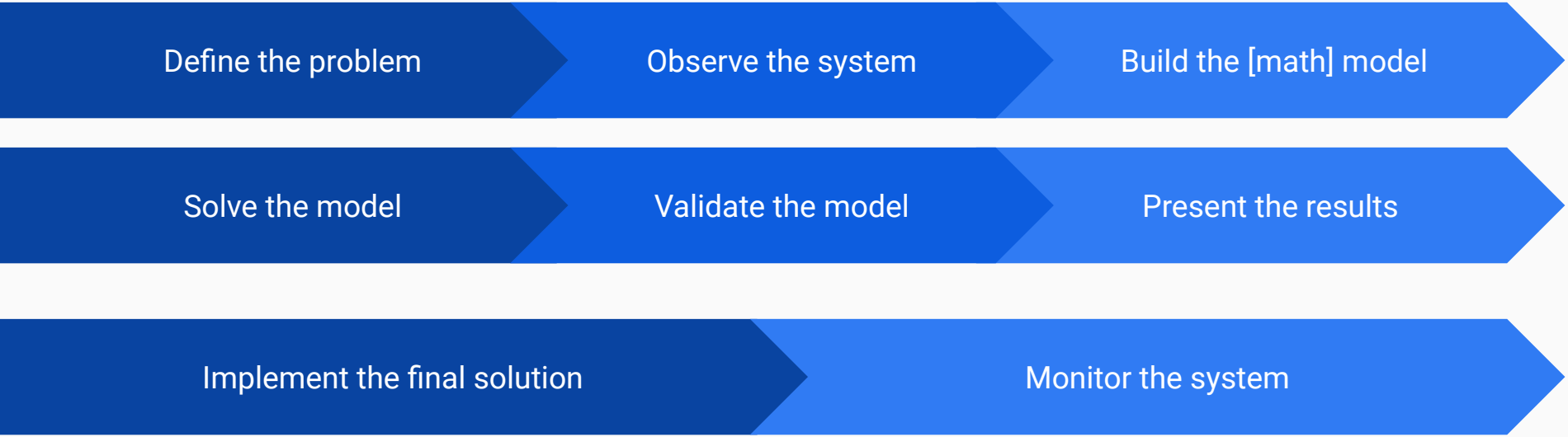
- Low truck utilization due to obscure parking and lack of visibility for supervisors
- Two-way radio communication was installed to solve the problem
- **Moving trucks to a more visible location to increase visibility and encourage usage**

# Lessons Learned from these examples

1. Consider diverse ideas, seek social **science/psychology expertise**
2. Adopt a bird's eye view to **uncover nontechnical reasons for the problem**
3. **Avoid bias to use mathematical tools**, use simplest technique to analyze data
4. **Consider human behavior in solutions**, root in people not just technology

# Phases of an Operations Research (OR) Study

# Phases of an OR Study (1)



# Phases of an OR Study (2)

| Define the problem | Observe the system | Build the [math] model |
| --- | --- | --- |
| • Define the problem<br>  ○ Objectives<br>  ○ Decision alternatives<br>  ○ Constraints<br>• Determine the study scope<br>  ○ Organization parts | • Collect data<br>• Data tells story about the problem.<br>• Determine the variables affecting problem | • Translate problem to a math model<br>• Model may fit standard math models (e.g. linear programming) |

# Phases of an OR Study (3)

## Solve the model

- Use well-defined methods if possible
- Heuristics or simulation if not
- Sensitivity analysis (to be covered)

## Validate the model

- Validate the model's output with historical data or simulations
- Ensure the solution is intuitively acceptable

## Present the results

- Present model and recommendation to decision maker
- Discuss feasibility
- Revisit earlier phases if recommendations are not approved

# Phases of an OR Study (4)

Implement the final solution

- Assistance in implementing the recommendations
- Translating the results into clear and understandable operating instructions

Monitor the system

**Monitor the system and update it regularly to meet organization's objectives**

# Example: CITGO Petroleum


- CITGO is an oil-refining and marketing company
- Klingman et al. (1987) applied management-science techniques to CITGO Petroleum
- The work saved the company an estimated $70 million per year
- CITGO was purchased by Southland Corporation (the owners of 7-Eleven stores)

# Phases of an OR Study (1)

| Define the problem | Observe the system | Build the [math] model |
| --- | --- | --- |
| • The goal : Minimize the cost of operating CITGO's refineries | • Observe Lake Charles Refinery<br>• Estimate key relationships (cost of producing each product, energy needed to produce each product, yield, etc.)<br>• Install Accurate Data Collection Systems | • Develop Linear programming (LP) model to optimize operations |

# Phases of an OR Study (2)

Solve the model

- Solve the Linear programming problem using a software package

Validate the model

- Validate model with actual inputs and outputs from the refinery

Present the results

- Show Benefits of $50M+ Annually to Decision Makers

# Phases of an OR Study (2)

## Implement the final solution

- Use the model to guide day-to-day operations

## Monitor the system

**Monitor the system and update it regularly to meet organization's objectives**

# Conclusion

- OR **rationalizes complex** organizational management using scientific methodology
- OR involves **collaboration across multiple fields** to solve problems
- OR is about **understanding problems** and **proposing solutions** that **lead to cost savings and profits**

# Conclusion

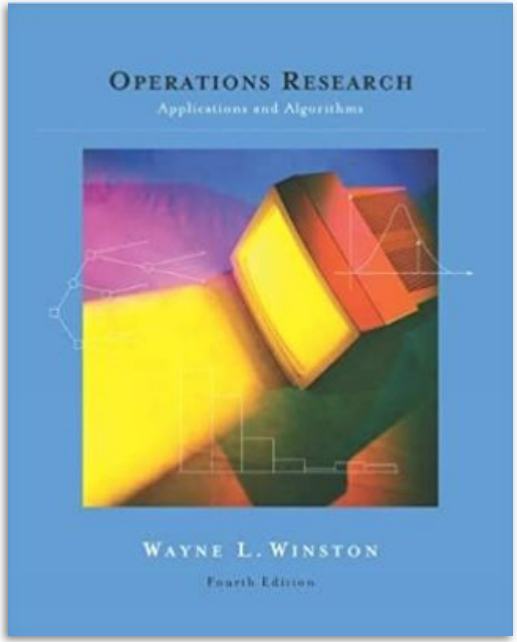
***Real-world problem***

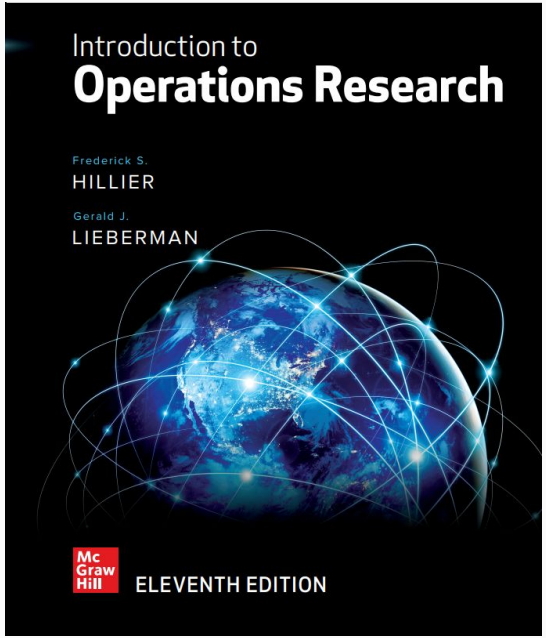
***Abstract Model***

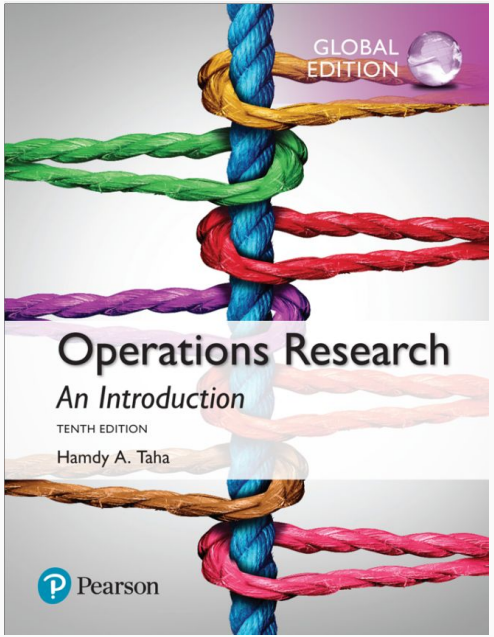
***Solve the model***

***Improve the reality***

# Used Books for Lecture Preparation



# Open discussion