IE 400

Principles of Engineering Management

Engineering and Management

Today's Learning Objectives

- See some definitions of the concepts central to the course content
- Have a glimpse at the history of Operations Research discipline
- Learn about the mathematical modeling process and its successful applications
- Formulate a mathematical model for a toy example problem

Engineering and Management

Definitions by ABET (Accrediting Board for Engineering and Technology)

- **Engineering:**

  *The profession in which a **knowledge of the mathematical and natural sciences** gained by study, experience, and practice is applied with judgement to develop ways to **utilize, economically, the materials** and forces of the nature for the benefit of humankind.*

- **Engineer:**

  A person applying her/his mathematical and science knowledge properly for humankind

- **Any idea what is the root of the word "muhendis"?**

Engineering and Management

*What is **Management**?*

- Directing the actions of a group to achieve a goal in the most efficient manner
- Getting things done through people
- Process of achieving organizational goals by working with and through people and organizational resources

Engineering and Management

***Functions** of Managers:*

- ***Planning:*** Selecting missions and objectives. Requires **decision making.**
- ***Organizing:*** Establishing the structure for the objective
- ***Staffing:*** Keeping filled the organization structure
- ***Leading:*** Influencing people to achieve the objective
- ***Controlling:*** Measuring and correcting the activities

Engineering and Management

- **Engineering management** is a specialized form of **management** that is concerned with the application of **engineering** principles to business practice.

- Engineering management is a career that brings together the technological **problem-solving** savvy of engineering and the **organizational**, **administrative**, and **planning** abilities of management in order to oversee complex enterprises from conception to completion

Operations Research
(Management Science)

What is Operations Research (OR)?

OR is a **decision-making tool(box)** based on mathematical modeling and analysis to aid in determining **how best to design and operate a system** usually under the conditions requiring **allocation of scarce resources.**

www.scienceofbetter.org

Brief History of OR

The main origin of Operations Research was during the **Second World War** in Britain.

At the time of World War II, the military management in England invited a team of scientists to study the **strategic** and **tactical problems** related to air and land defense of the country.

Brief History of OR

At that time, the resources available in England was very limited and the objective was to win the war with available **scarce resources.**

The resources such as food, medicines, ammunition, manpower etc., were required to manage war and for the use of the population of the country.

It was necessary to decide upon the most **effective utilization** of the **available resources** to **achieve the objective**.

It was also necessary to utilize the military resources cautiously.

Brief History of OR

British military leaders asked an interdisciplinary team of scientists, engineers, psychologists, and sociologists to analyze some problems arising in military operations and find the optimum allocation of limited resources.

These specialists had a brain-storming session and came up with a method of solving the problem, which they named **“Linear Programming”**.

Brief History of OR

As the name suggests:

Operations is used to refer to the problems of military,

Research is used for inventing new method.

As this method of solving the problem was invented during the war period, the subject is given the name **'OPERATIONS RESEARCH'** and abbreviated as **'OR'**

Brief History of OR

After the World War II, there was a scarcity of industrial material and industrial productivity reached the lowest level.

Soon after, it was discovered that OR techniques could also be applicable in various settings.

Today, OR techniques are heavily used to solve industrial, civil and military problems.

Three Main Properties of OR

Systems Approach

Interdisciplinary Action Based

Scientific Methodology

Some Applications of OR

Manufacturing (facility layout, machine scheduling, workforce scheduling, cost minimization, profit maximization, inventory allocation, etc.)

Finance (portfolio optimization, risk minimization, etc.)

Statistics (data fitting, error minimization, etc.)

Networks (design problems, shortest path, routing, etc.)

Transportation
Communication/computer
Physical (oil, gas, etc.)
Supply chain

OR Delivers Significant Value

Today, organizations and the world in which they operate continue to become more complex.

Organizations worldwide in business, the military, health care, and the public sector are realizing powerful benefits from O.R., including:

OR Delivers Significant Value

Business insight: Providing quantitative and business insight into complex problems.

Business performance: Improving business performance by embedding model-driven intelligence into an organization's information systems to improve decision-making.

Cost reduction: Finding new opportunities to decrease cost or investment.

Forecasting: Providing a better basis for more accurate forecasting and planning

OR Delivers Significant Value

Improved scheduling: Efficiently scheduling staff, equipment, events, and more.

Pricing: Dynamically pricing products and services.

Productivity: Helping organizations find ways to make processes and people more productive.

Profits: Increasing revenue or return on investment; increasing market share.

OR Delivers Significant Value

Quality: Improving quality as well as quantifying and balancing qualitative considerations.

Resources: Gaining greater utilization from limited equipment, facilities, money, and personnel.

Risk: Measuring risk quantitatively and uncovering factors critical to managing and reducing risk.

Throughput: Increasing speed or throughput and decreasing delays.

Operations Research Over the Years

1947

Project SCOOP (Scientific Computation of Optimum Programs) with George Dantzig and others developed the Simplex method for linear programs

1950s

Lot of excitement, mathematical developments, queueing theory, mathematical programming

1960s

More excitement, more development, and grand plans

1970s

Disappointment and a settling down. NP-completeness. More realistic expectations.

1980s

Widespread availability of personal computers. Increasingly easy access to data. Widespread willingness of managers to use models

1990-2000s

Improved use of O.R. systems. Further inroads of O.R. technology, e.g., optimization and simulation add-ins to spreadsheets, modeling languages, large-scale optimization. More intermixing of AI and O.R.

Operations Research in the 2000s

- Lots of opportunities for O.R. as a field
- Data, data, data
  - e-business data (click stream, purchases, other transactional data, e-mail and more)
  - Sensor data
  - The human genome project and its outgrowth (e.g., the human connectome project)
- Need for more automated decision-making
- Need for increased coordination for efficient use of resources (Supply chain management)

OR Modeling

Despite the fundamental differences among several settings, many problems share similar characteristics. E.g.:

- A physical network vs. a computer network.
- Parallel computing vs. queuing systems in a bank (scheduling, queuing).
- Air traffic control vs. local area network (routing).

OR Modeling

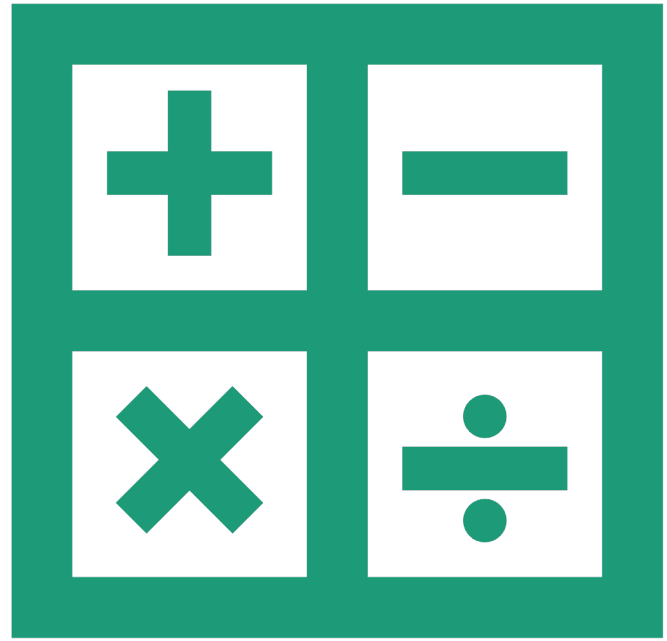
It is the OR modeler's responsibility to observe and understand the inner workings of a system (usually in conjunction with the experts in the setting in which the problem arises).

Model: A structure which has been built purposely to exhibit features and characteristics of some other object. E.g.:

- road maps
- model airplanes
- simulation model
- mathematical model, etc.

Mathematical Model

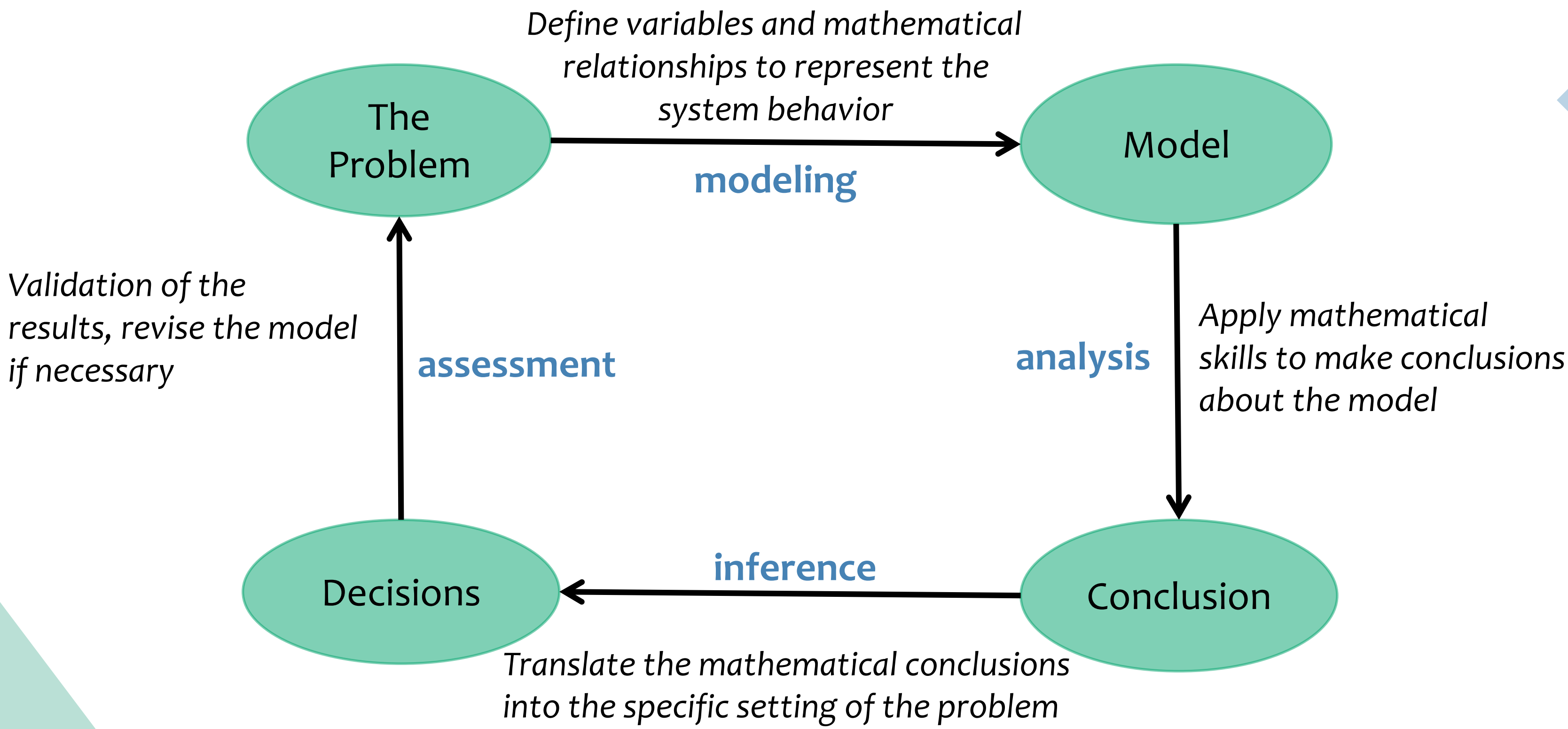
The **essential feature of a mathematical model** in OR is that it involves a set of mathematical relationships (such as **equations, inequalities, logical dependencies,** etc.) which correspond to the characterization of the relationships in the real world.



Why do we need mathematical modeling?

- To have a greater understanding of the object/system being modeled
- To analyze it mathematically to help suggest courses that are not apparent otherwise
- To simplify the inner workings of a complex system by using the universally understandable language of algebra and math

The Modeling Process



Success Stories

- **Optimal crew scheduling saves American Airlines $20 million/yr**
- Improved shipment routing saves Yellow Freight over $17.3 million/yr
- Improved truck dispatching at Reynolds Metals improves on-time delivery and reduces freight cost by $7 million/yr
- Optimizing global supply chains saves Digital Equipment over $300 million
- Restructuring North America Operations, Proctor and Gamble reduces plants by 20%, saving $200 million/yr
- **Optimal traffic control of Hanshin Expressway in Osaka saves 17 million driver-hours/yr**

Success Stories

- Better scheduling of hydro and thermal generating units saves southern company $140 million
- Improved production planning at Sadia (Brazil) saves $50 million over three years
- **Production Optimization at Harris Corporation improves on-time deliveries from 75% to 90%**
- Tata Steel (India) optimizes response to power shortage contributing $73 million
- **Optimizing police patrol officer scheduling saves police department $11 million/yr**
- Gasoline blending at Texaco results in saving of over $30 million/yr

Decision-making Problem

What are the decision alternatives?

Under what restrictions is the decision made?

What is an appropriate objective criterion for evaluating the alternatives?

Modeling Examples

Milk Production

- There are **two** machines needed to process milk to produce **low-fat** and **regular** milk. The processing times are:

	(Pasteurization) **Machine 1**	(Homogenization) **Machine 2**
Low-fat	3 minutes/liter	1 min/lt
Regular	2 min/lt	2 min/lt

- In a day, machine 1 can be used for 12 hours and machine 2 can be used for 6 hours
- The sales price of low-fat milk is 2.5 TL/lt and that of regular milk is 1.5 TL/lt.
- Find how much low-fat and regular milk should be produced in a day to maximize total revenue.

Milk Production

1. What are the unknowns that should be determined by decision maker?
   - **X_1** : amount in liters of low-fat milk produced in a day
   - **X_2** : amount in liters of regular milk produced in a day

- These are the **decision variables** (controllable variables)

Milk Production

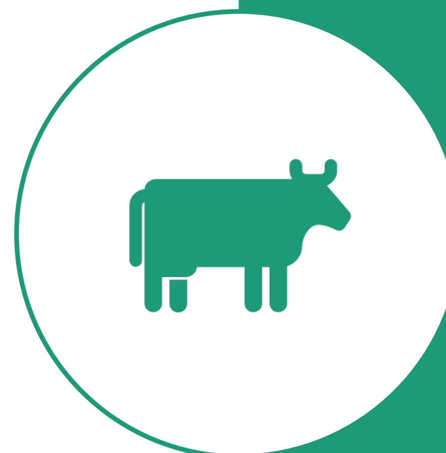
2. What are the technical factors which are not under control of the decision-maker?

- Available machine hours
- Required machine hours/product
- Revenue per unit of each product

These are the **parameters** (uncontrollable variables)

Milk Production

3. What are the physical limitations?
    - Total production time on each machine cannot exceed the available machine hours.
    - Production amounts should be nonnegative



These are the **constraints**

Milk Production

4. What is the measure used to compare different decisions?
    - Total revenue

This is the **objective function**

Mathematical Model for Milk Production

maximize (max) total revenue

subject to (s.t.)

- Total production time on Machine 1 ≤ 12 hours
- Total production time on Machine 2 ≤ 6 hours
- Production amounts ≥ 0

Mathematical Model for Milk Production

max $2.5X_1 + 1.5X_2$

s.t.

- Total production time on Machine 1 $\leq$ 12 hours
- Total production time on Machine 2 $\leq$ 6 hours
- Production amounts $\geq$ 0

Mathematical Model for Milk Production

max $2.5X_1 + 1.5X_2$

s.t.

- $3X_1 + 2X_2 \leq 12x60$
- Total production time on Machine 2 $\leq$ 6 hours
- Production amounts $\geq$ 0

Mathematical Model for Milk Production

max $2.5X_1 + 1.5X_2$

s.t.

- $3X_1 + 2X_2 \leq 720$
- $X_1 + 2X_2 \leq 360$
- Production amounts ≥ 0

Mathematical Model for Milk Production

max $2.5X_1 + 1.5X_2$

s.t.

- $3X_1 + 2X_2 \leq 720$
- $X_1 + 2X_2 \leq 360$
- $X_1 \geq 0$
- $X_2 \geq 0$

Mathematical Model for Milk Production

max $2.5X_1 + 1.5X_2$ (1) objective function

s.t.

- $3X_1 + 2X_2 \leq 720$ (2)
- $X_1 + 2X_2 \leq 360$ (3)
- $X_1 \geq 0$ (4)
- $X_2 \geq 0$ (5)

$\left.\begin{array}{l} (2) \\ (3) \\ (4) \\ (5) \end{array}\right\}$ constraints

The Milk Production Problem

*This is an example of a **Linear Programming (LP)** model.*

- Any values of decision variables X_1 and X_2 that satisfy all of the constraints (2)-(5) simultaneously is called a feasible solution.
- The set of all feasible solutions is called the feasible set or the feasible region.
- The objective is to find a feasible solution that yields the best objective function value (value of objective function (1) evaluated at the feasible solution).
- If there exists such a feasible solution, it is called an optimal solution.
- The objective function value evaluated at an optimal solution is called the optimal value (objective function value).

The Linear Programming (LP) Problem

An LP problem is an optimization problem in which

- The objective function is given by a linear combination of the decision variables.

i.e. min (or max) $c_1x_1 + c_2x_2 + \ldots + c_nx_n$

where $c_1,\ldots,c_n \in \mathbb{R}$ are given parameters and $x_1,\ldots,x_n$ are the decision variables.

- The constraints are linear inequalities or linear equations.

i.e. $a_1x_1 + a_2x_2 + \ldots + a_nx_n \begin{Bmatrix} \leq \\ = \\ \geq \end{Bmatrix} b$

where $a_1,\ldots,a_n \in \mathbb{R}$, $b \in \mathbb{R}$ and $x_1,\ldots,x_n$ are the decision variables.

General Form of an LP Problem

max (min) $c_1x_1 + c_2x_2 + \ldots + c_nx_n$

$x_1,\ldots,x_n$ are the decision variables.

s.t.

L "≤" constraints $a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n \leq b_i \quad ,\forall i = 1, 2, \ldots, L$

P "≥" constraints $a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n \geq b_j \quad ,\forall j = (L+1), (L+2), \ldots, (L+P)$

Q "=" constraints $a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n = b_k \quad ,\forall k = (L+P+1), (L+P+2), \ldots, (L+P+Q)$

The sign restrictions, i.e.,

$x_1, x_2, \ldots, x_m \geq 0$

$x_{m+1}, x_{m+2}, \ldots, x_{m+s}$ u.r.s.

$x_{m+s+1}, x_{m+s+2}, \ldots, x_n \leq 0$

c_j's, a_{ij}'s, b_j's $\in \mathbb{R}$ and given. They are the parameters.

Assumptions of an LP Problem

Proportionality & Additivity:

- The contribution of each decision variable to the objective function or to each constraint is proportional to the value of that variable.
- The contribution from decision variables are independent from one another and the total contribution is the sum of the individual contributions.

Divisibility:

- Each decision variable is allowed to take fractional values.

Certainty:

- All input parameters (coefficients of the objective function and of the constraints) are known with certainty.

Next Class

- Modeling different problems inspired by real-life applications
- We will be doing exercises together, so bring pen&paper/tablets

Announcements

- Set 1 Lecture Notes will be posted later this week (when we cover all slides)
- Exam dates are announced:
  - Quiz 1: October 5, 18:00-19:00
  - Quiz 2: October 24, 20:30 – 21:30
  - Midterm: November 11, 19:30-21:30
  - Quiz 3: December 2, 19:30-20:30
  - Quiz 4: December 21, 18:00-19:00

Recap

- Definitions of *Engineering*, *Management*, *Operations Research (OR)*, *Linear Programming (LP)*, *Mathematical Modeling*
- History of Operations Research and some successful applications in real life problems
- *(the iterative)* Modeling Process
- Main components of Decision-making problems
  1. Decision alternatives **(decision variables)**
  2. Restrictions of the system **(parameters & constraints)**
  3. Criteria for evaluation **(objective function)**
- Modeling a toy example with LP
- General form and assumptions of an LP problem

This Week's Learning Objectives

- Apply the first iteration of modeling process to multiple real-life-inspired examples
- Identify decision variables in a given example
- Identify parameters and express the constraints of the problem from verbal explanations with linear expressions
- Learn how to linearize some of the non-linear constraints

Blending Problem - 1

An oil refinery distills crude oil from Saudi Arabia and Venezuela into gasoline, jet fuel and lubricants. The crude differ in chemical composition and yields.

1 ton of S.A crude oil	0.3 tons of gasoline 0.4 tons of jet fuel 0.2 tons of lubricants
1 ton of. Ven. Crude oil	0.4 tons of gasoline 0.2 tons of jet fuel 0.3 tons of lubricants

Remaining 0.1 tons is lost in refining

Blending Problem - 1

- At most 90 tons can be purchased daily from S.A. at a cost of \$600/ton

- At most 60 tons can be purchased daily from Ven. at a cost of \$550/ton

- The daily demand is 20 tons of gasoline, 15 tons of jet fuel, and 5 tons of lubricants

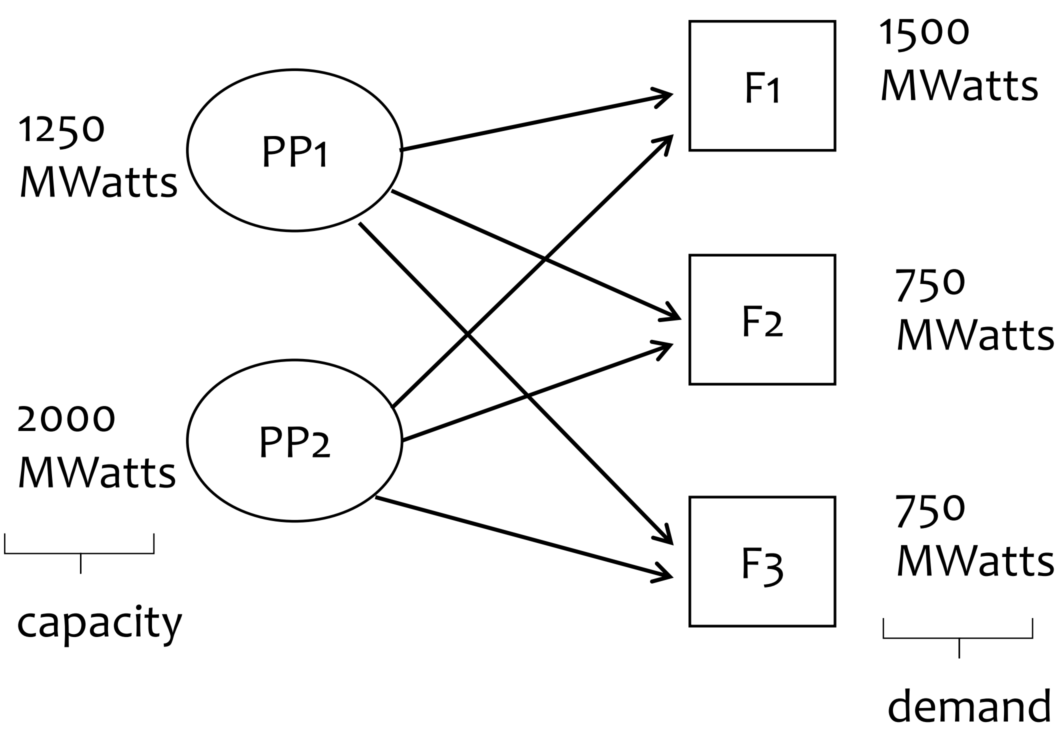
How should the demand be met at a minimum cost?

LP Model for Blending Problem - 1

Decision Variables	Model

Transportation Problem

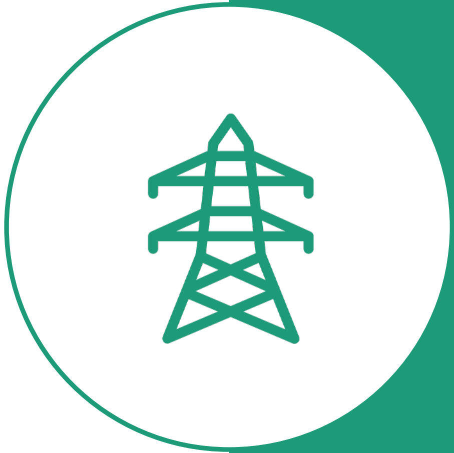
There are **two power** plants generating electricity, and **three factories** that need electricity in their production.



Transportation Problem

Transmission costs per MWatt (in USD):

	F1	F2	F3
PP1	50	100	60
PP2	30	20	35



How to satisfy the demand of each factory from the two power plants with minimum total cost?

LP Model for Transportation Problem

Decision Variables	Model

General Transportation Problem

Say there are m warehouses and n stores.

- Let a_i denote the amount of stock at warehouse i for $i=1, \ldots, m$
- Let d_j denote the demand of store j for $j=1, \ldots, n$
- Let c_{ij} denote the cost of transporting a unit of product from warehouse i to store j, for $i=1, \ldots, m$ and $j=1, \ldots, n$

How should the demands of stores be met at a minimum total transportation cost while respecting the stock limitations of the warehouses?

LP Model for General Transportation Problem

Decision Variables	Model

Blending Problem - 2

- OJ Inc. produces orange juice from 3 different grades of oranges. Oranges are graded 1(poor), 2(medium), and 3(good) depending on their quality.

Grade	Yield (Juice lt/kg)
1	0.4
2	0.5
3	0.6

- The company currently has:
  - 100 kgs of Grade 1 oranges
  - 150 kgs of Grade 2 oranges
  - 200 kgs of Grade 3 oranges
- OJ Inc produces 3 types of orange juices from these oranges: superior, premium and regular

Blending Problem - 2

- Production Requirements:

Type	Minimum average grade	Profit per liter	Min. daily production
superior	2.4	1.5 TL	45 lt
premium	2.2	1 TL	50 lt
regular	2.0	0.75 TL	100 lt

- Assume the company may sell more than demand at the same prices

How can the company maximize profit profit while satisfying production requirements

LP Model for Blending Problem - 2

Decision Variables	Model

Short-term Investment Planning

You have 12,500 TL at the beginning of year 2021 and would like to invest your money. Your goal is to maximize your total amount of money at the beginning of year 2024. You have the following options:

Option	Duration (years)	Total interest rate	Available (at the beginning of)
1	2	26%	2021, 2022
2	1	12%	2021, 2022, 2023
3	3	38%	2021
4	2	27%	2022

Short-term Investment Planning

Note that, normally:

Cash available at time t = cash invested at time t
+
uninvested cash at time t that is carried over to time t+1

However, since Option 2 is available at each year, we can always invest in this option rather than keeping some money for later better options.

Hence, for this problem, the following holds:

Cash available at time t = cash invested at time t

LP Model for Short-term Investment Planning

Decision Variables	Model

Product Mix Problem

- Milk chocolate is produced with three ingredients. 1 kg of milk chocolate contains:
  - ✓ 0.5 kg of milk,
  - ✓ 0.4 kg of cocoa,
  - ✓ 0.1 kg of sweetener

- Each of these three ingredients must be processed before they can be used in the production of milk chocolate.

Product Mix Problem

- The factory has two departments that can process these ingredients:

Ingredient	Department 1 (hours/kg)	Department 2 (hours/kg)
Milk	0.4	0.6
Cocoa	0.3	0.2
Sweetener	0.5	0.6

- Both departments have 150 hours of available time per week for processing.

Formulate an LP problem that maximizes the total amount of milk chocolate produced in a week

LP Model for Product Mix Problem

Decision Variables	Model

Error Minimization Problem

You estimate that there is a linear relationship between the stock price of a beverage company and the # of beverages sold (in thousands) in a day:

Day	Stock Price	# of Beverages Sold
1	2	10
2	3	12
3	2	8
4	3	11
5	4	14

Error Minimization Problem

You predict the relationship as $\mathbf{s_i=an_i+b}$, where s_i is the stock price and n_i is the # of beverages sold (in thousands) on day i, i=1,…,5.

For a given choice of a and b, your estimation error on day i is $\mathbf{|s_i-an_i-b|}$, i=1,…,5.

Choose the unknown coefficients a and b such that the largest estimation error in any one of the 5 days is as small as possible.

LP Model for Error Minimization Problem

Decision Variables	Model

Production Planning Problem

XYZ Company produces three products A, B, and C and must meet the demand for the next four weeks.

	Weekly Demand			
Product	1	2	3	4
A	25	30	15	22
B	15	16	25	18
C	10	17	12	12

Each unit of:

- Product A requires 3 hours of labor
- Product B requires 2 hours of labor
- Product C requires 4 hours of labor

Production Planning Problem

- During a week, 120 hours of regular-time labor is available at a cost of $10/hour.
- In addition, 25 hours of overtime labor is available weekly at a cost of $15/hour.
- **No shortages are allowed** and XYZ Company has 18 A, 13 B, and 15 C initial stocks for these products.

Provide an LP formulation to determine. a production schedule that minimizes the total labor costs for the next four weeks.

Production Planning Problem

Decision Variables:

- **X_{ij}:** the amount of product i produced during week j, i∈{A,B,C} and j=1,2,3,4.
- **Inv_{ij}:** the amount of inventory of product i at the end of week j after meeting demand. i∈{A,B,C} and j=0,1,2,3,4 *(in this case, Inv_{i0} is the notation for the initial stock)*
- **OT_j:** the amount of overtime hours used in week j, j=1,2,3,4.

Production Planning Problem

Production Constraints

- For any product i=1,2,3 and any week j=1,2,3,4,

$$Inv_{i,j-1} + X_{i,j} - D_{i,j} = Inv_{i,j}$$

(assume $D_{i,j}$ is the parameter that represents the demand of product i in month j)

For Product A:

$$
\begin{aligned}
8 + X_{A,1} - 25 &= Inv_{A,1} \\
Inv_{A,1} + X_{A,2} - 30 &= Inv_{A,2} \\
Inv_{A,2} + X_{A,3} - 25 &= Inv_{A,3} \\
Inv_{A,3} + X_{A,4} - 22 &= Inv_{A,4}
\end{aligned}
$$

Production Planning Problem

Production Constraints

For Product B:

$$13 + X_{B,1} - 15 = Inv_{B,1}$$
$$Inv_{B,1} + X_{B,2} - 16 = Inv_{B,2}$$
$$Inv_{B,2} + X_{B,3} - 25 = Inv_{B,3}$$
$$Inv_{B,3} + X_{B,4} - 18 = Inv_{B,4}$$

For Product C:

$$15 + X_{C,1} - 10 = Inv_{C,1}$$
$$Inv_{C,1} + X_{C,2} - 17 = Inv_{C,2}$$
$$Inv_{C,2} + X_{C,3} - 12 = Inv_{C,3}$$
$$Inv_{C,3} + X_{C,4} - 12 = Inv_{C,4}$$

Production Planning Problem

Demand Constraints:

$Inv_{i,j} \geq 0$ for $i \in \{A,B,C\}$ and $j=1,2,3,4$

Labor Constraints:

$$3X_{A,1} + 2X_{B,1} + 4X_{C,1} \leq 120 + OT_1$$
$$3X_{A,2} + 2X_{B,2} + 4X_{C,2} \leq 120 + OT_2$$
$$3X_{A,3} + 2X_{B,3} + 4X_{C,3} \leq 120 + OT_3$$
$$3X_{A,4} + 2X_{B,4} + 4X_{C,4} \leq 120 + OT_4$$

Overtime Constraints:

$OT_j \leq 25$, $j=1,2,3,4$.

Production Planning Problem

Sign restrictions:

$X_{i,j} \geq 0$, $i \in \{A,B,C\}$ and $j=1,2,3,4$
$OT_j \geq 0$, $j=1,2,3,4$.

Objective Function:

$$\text{Min} \quad 10 \cdot \left(\sum_{j=1}^{4} 3X_{A,j} + 2X_{B,j} + 4X_{C,j} \right) + 5\sum_{j=1}^{4} OT_j$$

Class Exercises - 1

Rylon Corporation manufactures Brute and Channelle perfumes from a raw material costing $3/pound.

- Processing 1 pound of the material takes 1 hour and yields 3 ounces of Regular Brute and 4 ounces of Regular Chanelle. This perfume can be sold directly or can be further processed to make luxury versions of the perfumes.
- One ounce of Regular Brute can be sold for $7, but 3 hours of processing and $4 of cost will convert it into one ounce of Luxury Brute, which sells for $18.
- One ounce of Regular Chanelle can be sold for $6, but 2 hours of processing and $4 of cost will convert it into one ounce of Luxury Chanelle, which sells for $14.
- Rylon has available 4000 pounds of raw material, 6000 hours of processing time, and will sell everything it produces.

Determine how Rylon can maximize its profit.

LP Model for Rylon Corporation

Decision Variables	Model

Class Exercises - 2

Bel Aire Pillow Company needs to manufacture 12,000 pillows in their factory next week. They have two kinds of employees: line workers (who do the actual work) and supervisors (who oversee the line workers). Bel Aire currently has 120 line workers and 20 supervisors. Each line worker can make 300 pillows per week. Supervisors do not engage in actual pillow-making.

A recent study done on Bel Aire's operation concluded that, for proper supervision, there must be at least 1 supervisor for every 5 line-workers. The study also suggested that Bel Aire might be able to cut its costs by doing some or all of the following:

- hiring new employees as line workers (the training cost is $100/worker)
- firing some current line workers (the fired worker is given $240 severance pay)
- promoting some current line workers to supervisors (the training cost is $200/worker)
- demoting some current supervisors to line workers (no cost associated with this)

Pay for a line worker is $400/week. Pay for a supervisor is $700/week. All hiring and firing, and training occur before the upcoming work week, and the costs of those activities will be charged against the upcoming week. Bel Aire wishes to perform the appropriate hiring, firing, promotions and demotions that will minimize its operations cost for next week.

LP Model for Bel Aire Company

Decision Variables	Model

- What is different about this mathematical model?
- Is it a linear programming problem?

Next Class

- Graphical solution to LP problems

- Think about a problem from your discipline where a mathematical modeling similar to we’ve seen so far could be devised.