Petroleum and Gas Refining Engineering Department

Management and economics of petroleum projects

Fourth Class

Lecture (7)

By

Luay Ahmed Khamees

Decision making by project management:

In any project, whether oil or non-oil, the most important function of project management is how to make the appropriate decision that achieves the required goals of the project. The decision-making process requires knowing the optimum and how to achieve it; therefore, decision-makers need to know the principles of optimization and its applications to reach the required goals.

What is mean optimization?

- Optimization is an act, process or methodology of making something (system, design or decision) as fully perfect, functional and effective as possible to achieve optimum solution.
- A collective process of finding the best conditions required to achieve the best results from a given situation.
- It is one of the major quantitive tools in the machinery of decision-making. A wide variety of problems in the design, construction, operation and analysis of petroleum and refinary plants can be resolved by optimization.

Some other important definitions:

- Optimum value: it is a technical term including quantities measurements and mathematical analysis to determine the best setting (maximum or minimum) of a dependent variables.
- Optimization procedure: it is the process of determining the optimum value (maximum or minimum) of some criterion function.
- Optimization problem: is the specification of the variables that need to be optimized.

The optimization is interested for the engineers. Why?

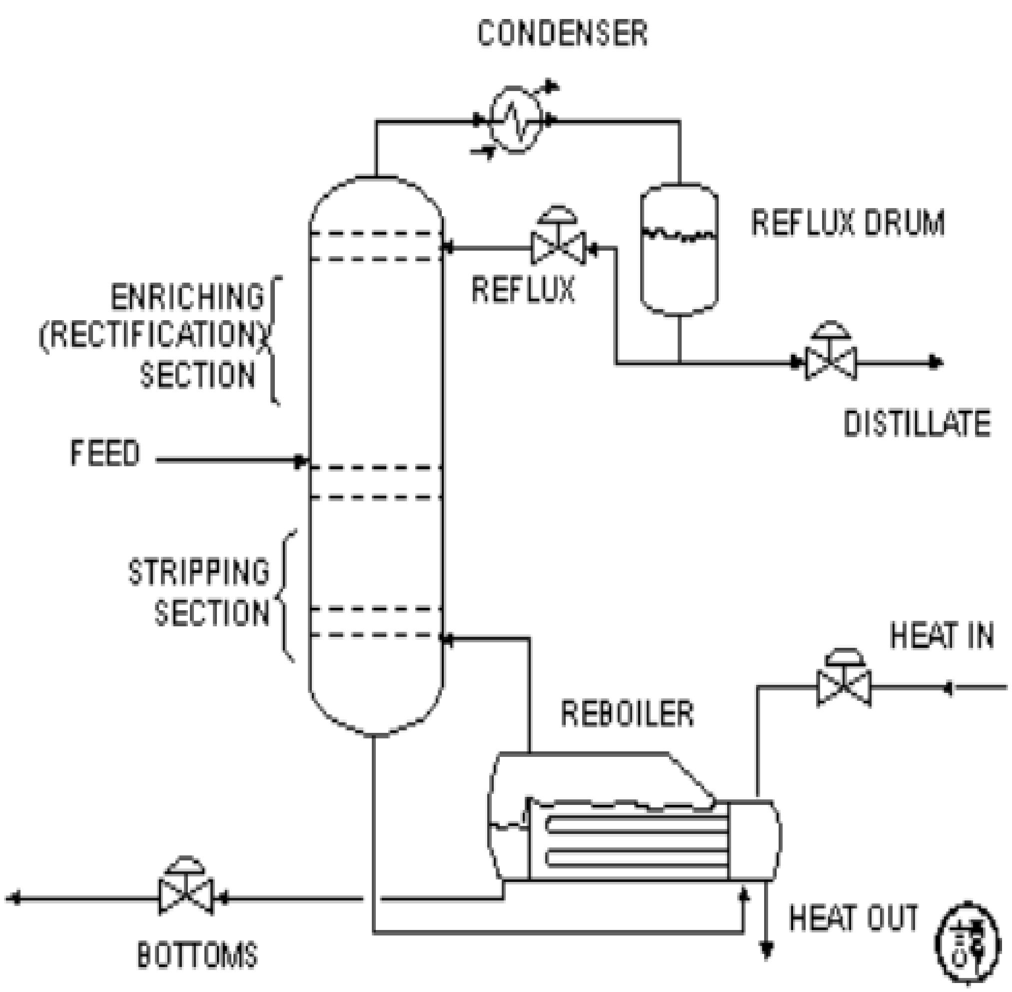
- Engineers work to improve the initial design of process and equipment.
- Engineers strive for enhancements in the operation, in order to realize:

1 Largest production.

2 Greatest profit.

3 Minimum cost (least energy usage)

Distillation column parameters' that could enhance the equipment performance (optimal condition)



- Equipment size.
- Schedule maintenance and equipment replacement.
- Design of heat exchanger network.
- Operation planning scheduling.
- Control system.
- Long time between shutdown.

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In plant operation, benefits arise from improved plant performance such as:

- Improved yields of valuable products or reduced yields of contaminations.
- Reduced energy consumption.
- Higher processing rates.
- Longer times between shutdowns.
- Reduced maintenance costs.
- Less equipment wear.
- Better staff utilization.

Example of applications of optimization:

- Determination of best sites for plant location.
- Routing of tankers for the distribution of crude and refined products.
- Pipeline sizing and layout.
- Equipment and entire plant design.
- Maintenance and equipment replacement scheduling.
- Operation of equipment, such as tubular reactors, columns, exchangers…..etc.
- Evaluation of plant data to construct a model of a process.
- Minimization of inventory charges (these are costs associated with storing and managing good, materials and products within warehouses or storehouses)

- And many other.

Statements of an optimization problem:

All optimization problem are stated in some standard form. You have to identify the essential elements of a given problem and translate them into a prescribed mathematical form.

- Decisions: items that need to be figured out to achieve max. efficiency.
- The ranking function: a method to make different choices of decisions.
- Rules and restrictions: specifying limitations on choices of decision values.
- Parameters: information necessary in specifying ranking function and rules.

Optimization models

Which is the mathematical representation of optimization problem to analyze or solve the optimization problem.

These models have:

1. Objective function: terms of design or decision variable and other problem or process parameters such as cost function. This function could be economical or technical.

   For example: economic objectives, maximize profit, minimize costs of production.
2. constraints: represent limitation on the choice of decision variables, either internal or external imposed by the designer.
3. Parameters: represent the given data.
4. Decision (design) variables: represent items that need to be determined and may involve many design variables.

Important note: there is no scope (room) for optimization, if all the design variable are fixed.

- **Example: 1 (optimal design of a can)**

Design which will hold at least 500 ml of liquid. Height = [7 12] cm, radius [7 3] =cm? what is the dimensions for the cylindrical Can use the least amount? We can minimize the material by minimize the area A.!

So, objective function:

$$A = 2\pi r^2 + 2\pi r h$$

Area of two ends — Lateral Area

Constraint:

$V = \pi r^2 h \geq 500$

Bounds (Decision variables):

$3 \geq r \leq 7$

$7 \geq h \leq 12$

-What is the dimensions for the cylindrical can use the least amount?

-we can minimize the material by reduce the area, A.

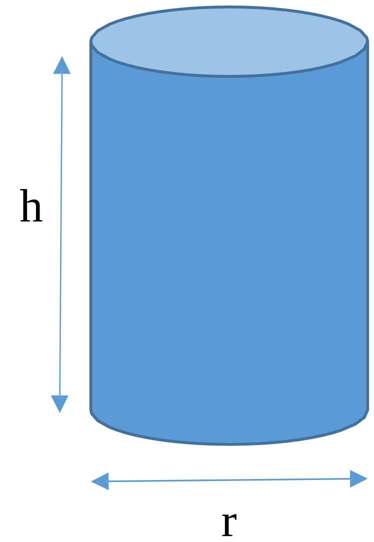

Figure 1. dimensions of can.

Example: 2 (The optimal pipe diameter)

- Determination of optimal pipe diameter that uses for pumping a given amount of fluid from one point to another.

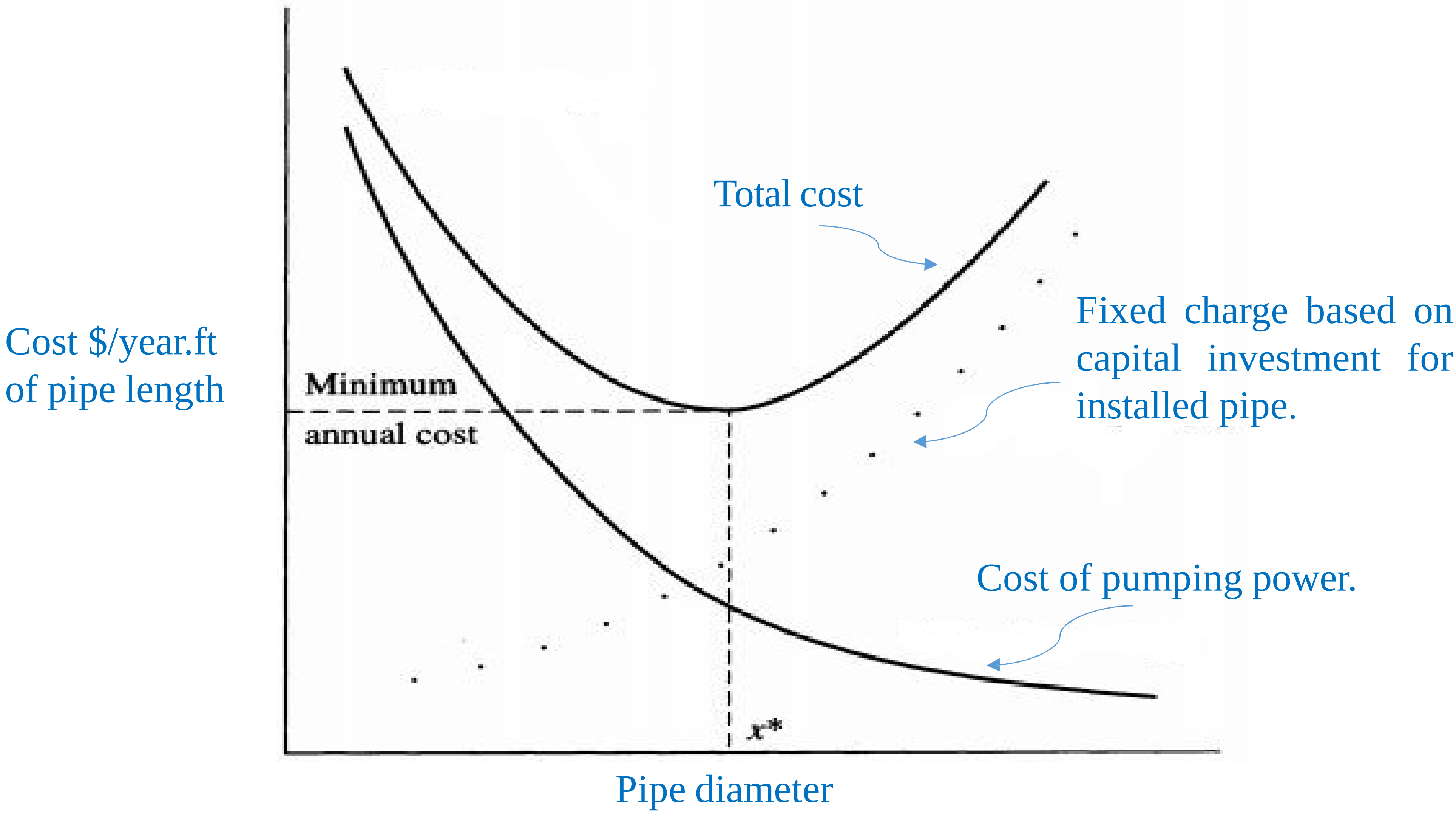

Figure 2. determination of optimum economic pipe diameter for constant mass through rates. (x^* = optimum diameter)

Notes:

- Total cost = pumping cost + fixed cost for the installed piping system.
- Pumping cost increase with decreased size of pipe diameter, why?
- The fixed charges (installed) for the pipeline become lower when smaller pipe diameters are used, why?
- The optimum economic diameter is found where the sum of the pumping costs and fixed costs for the pipeline becomes a minimum.
- Even though, the engineer must chooses the cheapest design by considering the quality of the product and the operation as well as the total cost.

Example#3 (the optimal insulation thickness)

- Additional insulation should save money through reducing heat losses.
- But, the insulation material can be expansive?
- So, we need the optimal amount of insulation.

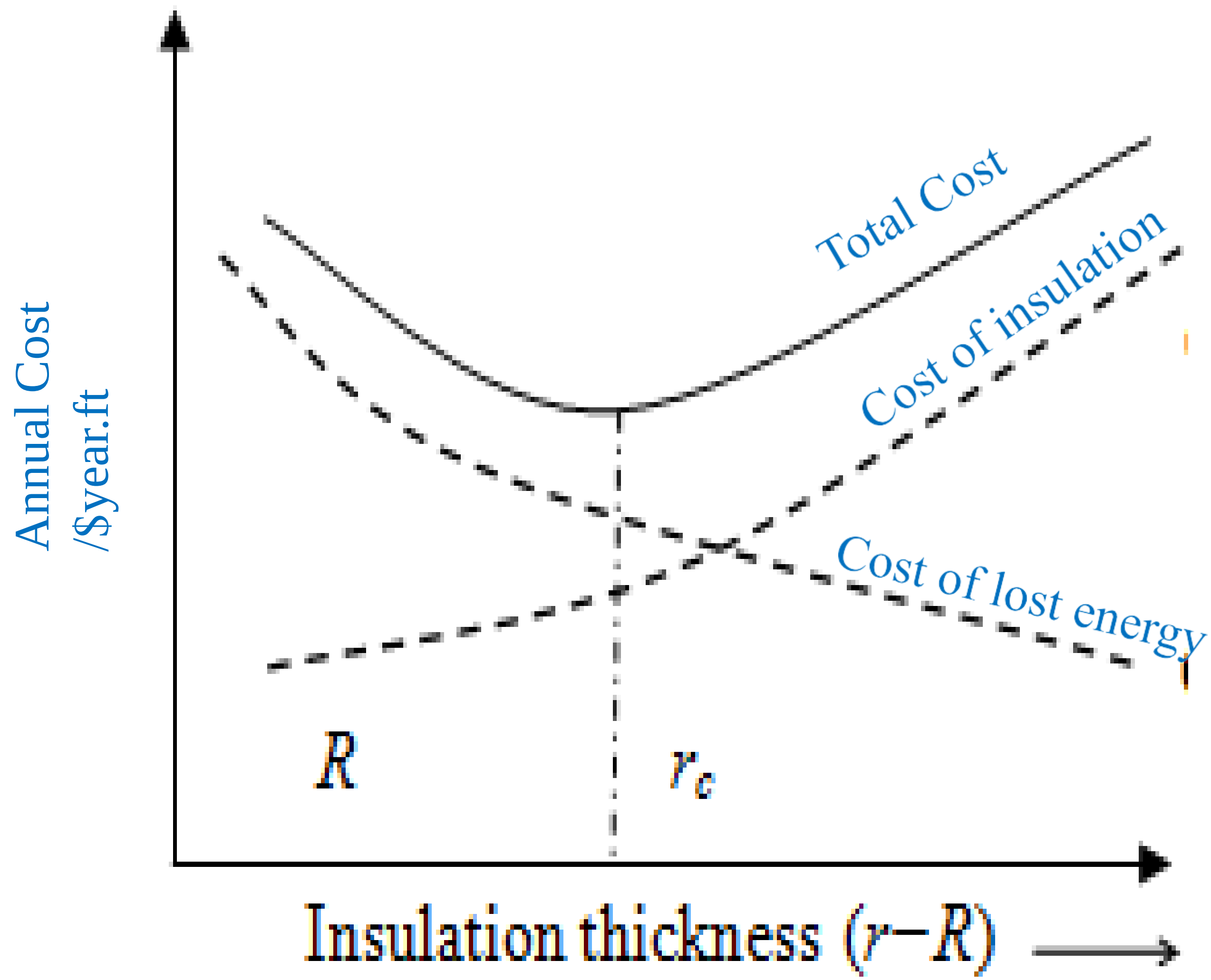

Figure 3. The effect of insulation thickness on total cost (*x = optimum thickness)**

Formulation of optimization model:

.1 Type of variable (Decision variable): these are defined to capture decisions that need to be made. These variables have different types depending on the values they can take.

The basic variable types are:

A- continuous: this can take any real value such as, how much should I change my current investment in stocks?

B- continuous-non-negative: this can take only non negative values x>= 0. Such as, how much milk should I drink every day?

C- Binary : this can take values 0 and 1 only, x ∈ { ,{0,1such as, should I build my new house in Baghdad?

D- Integer: this can take any integer value, x ∈ z, where z is a set of integer. If it is required to be non-negative then x ≥ 0. such as, how many workers should be hired to meet lunch time demand in a café?

E- finite sets: this can take a small set of values x ∈ s, where s is the set of values x can take. Such as, which road should I take to go to collage today?

2 -Objective function: can be defined as a function of decision variables whose output is a number. There are uncountable possible functions of this kind, these are classified into two groups:

A- linear functions:

$$f(x_1, x_2, x_3) = x_1 + x_2 + 5x_3$$

B- non-linear functions:

Polynomials , like, $f(x, y, z) = x^2 + y^2 + z^2$

Cross terms, like, $f(x, y, z) = xy$

Eponentionals, like, $f(x) = e^x$

Maximum, *like*, $f(x, y, z) = \max\{x, y, z\}$

Absolute, like, $f(x) = |x|$

3 constraints or restrictions or limitations:

These represent limitation on the choice of decision variables, either internals or external imposed by the designer. Can be classified into two major types:

A- linear constraints, which is three types ($\leq, \geq, =$), such as:

$$x1 + x2 \geq 5$$

$$\left.\begin{array}{c} 0 <= x1 <= 5 \\ X >= 0 \end{array}\right\} \text{ inequality constraints}$$

$$X1 + x2 + x3 = 12 \quad \text{equality constraints}$$

B- non-linear constrains, such as,

$$x^2 + y^2 \geq 3$$

$$x + e^x \geq 0$$

$$x^2 + y^2 + z^2 = 1$$

4- parameters: represent the given data, or any information necessary in specifying the ranking function and rules.

Two important notes:

1-The constraints are suited to the independent decision variables (x_i).

2-most of the Petroleum Refining engineering problems are constrained because of the physical and economical considerations. So they can be called constrained optimization problems.

If the problem has no limitations or restrictions, it is called unconstrained optimization problems.

Example#:1

A petrochemical company produces two types of polymers P1 and P2, using three types of raw materials R1, R2, and R3, as shown below. Formulate this optimization problem to maximize the company's profits.

Raw material	Raw material needed per ton		Raw material available ton/day
	P1	P2	
R1	2	1	16
R2	1	1	8
R3	0	1	3.5
Net profit $/ton	150	300	

Solution:

A- Decision variables:

X1 =P1 produced per day, ton/day.

X2 =P2 produced per day, ton/day .

B- Objective function:

To maximize the company profit, hence

$$\text{Max} \quad f(x) = 150x1 + 300x2$$

C- constraints:

$2x1+x2 \leq 16$ raw material R1

$x1+x2 \leq 8$ raw material R2

$x2 \leq 3.5$ raw material R3

D- parameters:

All the data available

Homework: 1

In a U.S refinery has two kinds of crude oils that have the yields which shown below with all costs and process, formulate this problem to maximize the refinery profit.

Products	Volume % yield		Selling price $/bbl	Max. allowable product bbl/day
	Crude1	Crude2		
Gasoline	80	44	36	24000
Kerosene	5	10	24	2000
Fuel oil	10	36	21	6000
Residual	5	10	10	No limit
Processing Cost $/bbl	0.5	1		
Raw material Cost $/bbl	24	15		

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Example: 2

A petrochemical plant makes three products E, F, and G, and utilize three raw materials A, B and C in limited supply. Each of the three products is produced in a separate process. The available material of A, B and C do not have to be consumed totally. The reactions are:

Process I A+B → E

Process II A+2B → F

Process III 3A+2B+C → G

Formulate the objective function to maximize the total profit in $/day and satisfy all the constraints for this problem?

The available data are tabulated below:

Table#1

Raw material	Max. available Ib/day	Cost $/Ib
A	40000	1.5
B	30000	2.0
C	25000	2.5

Table#2

Products	Ib react/Ib produced	Process Cost /$Ib	Selling price of product /$Ib
E	(2/3)A, (1/3)B	1.5	4.0
F	(2/3)A) ,2/3B	0.5	3.3
G	(1/2)A, (1/6)B, (1/3)C	1.0	3.8

Solution :

Let A = X1

B= X2

C=X3

X1 + X2 = X4

X1 + 2X2= X5

3X1+2X2+X3 =X6

Objective function: Max. 4X4+ 3.3 X5 + 3.8 X6

Subject to:

Constraint available:

X1 <= 40000 ,

X2 <= 30000 ,

X3 <= 25000 ,

Constraint cost :

X1 <=1.5 ,

X2 <= 2.0 ,

X3 <= 2.5 ,

Solution:

Constraint cost of react product:

$2/3\ X1 + 1/3\ X2 <= 1.5$

$2/3\ X1 + 2/3\ X2 <= 0.5$

$1/2\ X1 + 1/6\ X2 + 1/3\ X3 <= 1.0$

Example: 3

In one of drilling process , there were two types of drilling mud , mud _L1, mud_ L2. Where mud_L1 consisted of mixing 50 volumetric units of water and 3 volumetric units of bentonite , while mud_L2 consisted of mixing 40 volumetric units of water, 7 volumetric units of bentonite and 2 units of polymer and the Available are (280,35,15) volumetric units of water, bentonite, polymer respectively . The distance drilled by a mixture mud _L1 is 30 units in length, and for the mixture ud_L2 , it is drilled 40 units of length. It is required to determine the largest distance to be drilled.

SOLUTION:

Formulation of Linear Problem

Step 1: Identify the decision variables

Assume that :

Total number of using type mud L1 is X

Total number of using type mud L2 is Y

And the maximum distance is Z

Step 2: Write the objective function , **Max Z = 30 X + 40 Y**

Example: 3

Step 3: Writing the constraints

The first constraint for the amount of water.

$50X + 40Y \leq 280$

The second constraint for the amount of bentonite.

$3X + 7Y \leq 35$

The third constraint for the amount of polymer.

$0X + 2Y \leq 15$

Step 4: The non-negativity restriction

The values of X and Y will be greater than or equal to 0.

$X \geq 0, Y \geq 0$

So the final mathematical model will be written in the following form , Max $Z = 30X + 40Y$

Subject to:

$50X + 40Y \leq 280$

$3X + 7Y \leq 35$

$0X + 2Y \leq 15$

$X \geq 0, Y \geq 0$

Homework 2

A refinery must produce 100 gallons of gasoline and 160 gallons of diesel to meet customer demands. The refinery would like to minimize the cost of crude and two crude options exist. The less expensive crude costs $50 per barrel while a more expensive crude costs $63 per barrel. Each barrel of the less expensive crude produces 10 gallons of gasoline and 20 gallons of diesel. Each barrel of the more expensive crude produces 15 gallons of both gasoline and diesel. Find the number of barrels of each crude that will minimize the refinery cost while satisfying the customer demands.