

Experiment-1:

Study of Optimization in Engineering Problems

Aim: To study optimization problems in different engineering fields and identify objective functions, decision variables, and constraints.

Theoretical Background

Optimization is the process of finding the **best possible solution** to a problem under given conditions.

An optimization problem generally consists of:

1. Decision Variables

Variables whose values are to be determined (e.g., dimensions, quantities, time).

2. Objective Function

A mathematical function representing the goal of optimization (minimization or maximization).

3. Constraints

Restrictions or limitations on decision variables (equality or inequality constraints).

General Mathematical Form

General Mathematical Form

Optimize $f(x_1, x_2, \dots, x_n)$

subject to

$$g_i(x_1, x_2, \dots, x_n) \leq / = / \geq b_i$$

Engineering optimization problems arise in:

- Mechanical engineering (minimum weight design)
- Electrical engineering (minimum power loss)
- Civil engineering (minimum construction cost)
- Production engineering (maximum profit)

Example 1: Mechanical Engineering

R Code

```
1 - #####  
2 # Experiment 1: Study of Optimization Problems in Engineering  
3 # Identification of decision variables, objective function  
4 # and constraints for real-life engineering problems  
5 - #####  
6  
7 cat("EXPERIMENT 1: STUDY OF OPTIMIZATION PROBLEMS IN ENGINEERING\n\n")  
8  
9 - #####  
10 # 1. Mechanical Engineering Problem  
11 # Minimize weight of a beam  
12 - #####  
13  
14 cat("1. Mechanical Engineering Problem: Beam Design\n")  
15  
16 # Decision Variables  
17 length <- 5          # meters  
18 area <- 0.02        # m^2  
19 density <- 7850      # kg/m^3 (steel)  
20  
21 # Constraint variables (define FIRST)  
22 stress <- 200        # MPa  
23 stress_limit <- 250   # MPa  
24  
25 # Objective Function  
26 weight <- density * area * length  
27  
28 cat("Decision Variables: length, area\n")  
29 cat("Objective Function: Minimize Weight\n")  
30 cat("Weight of Beam =", weight, "kg\n")  
31  
32 cat("Constraint: Stress <=", stress_limit, "MPa\n")  
33 cat("Stress Satisfied:", stress <= stress_limit, "\n\n")  
34
```

Output

```
Console Terminal x Background Jobs x
R - R 4.4.1 · ~/ 
> cat("1. Mechanical Engineering Problem: Beam Design\n")
1. Mechanical Engineering Problem: Beam Design
>
> # Decision Variables
> length <- 5          # meters
> area <- 0.02         # m^2
> density <- 7850       # kg/m^3 (steel)
>
> # Constraint variables (define FIRST)
> stress <- 200         # MPa
> stress_limit <- 250   # MPa
>
> # Objective Function
> weight <- density * area * length
>
> cat("Decision Variables: length, area\n")
Decision Variables: length, area
> cat("Objective Function: Minimize Weight\n")
Objective Function: Minimize Weight
> cat("Weight of Beam =", weight, "kg\n")
Weight of Beam = 785 kg
>
> cat("Constraint: Stress <=", stress_limit, "MPa\n")
Constraint: Stress <= 250 MPa
> cat("Stress Satisfied:", stress <= stress_limit, "\n\n")
Stress Satisfied: TRUE
```

Example 2: Electrical Engineering

R Code

```
#####
# 2. Electrical Engineering Problem
# Minimize power loss in transmission line
#####

cat("2. Electrical Engineering Problem: Power Loss Minimization\n")

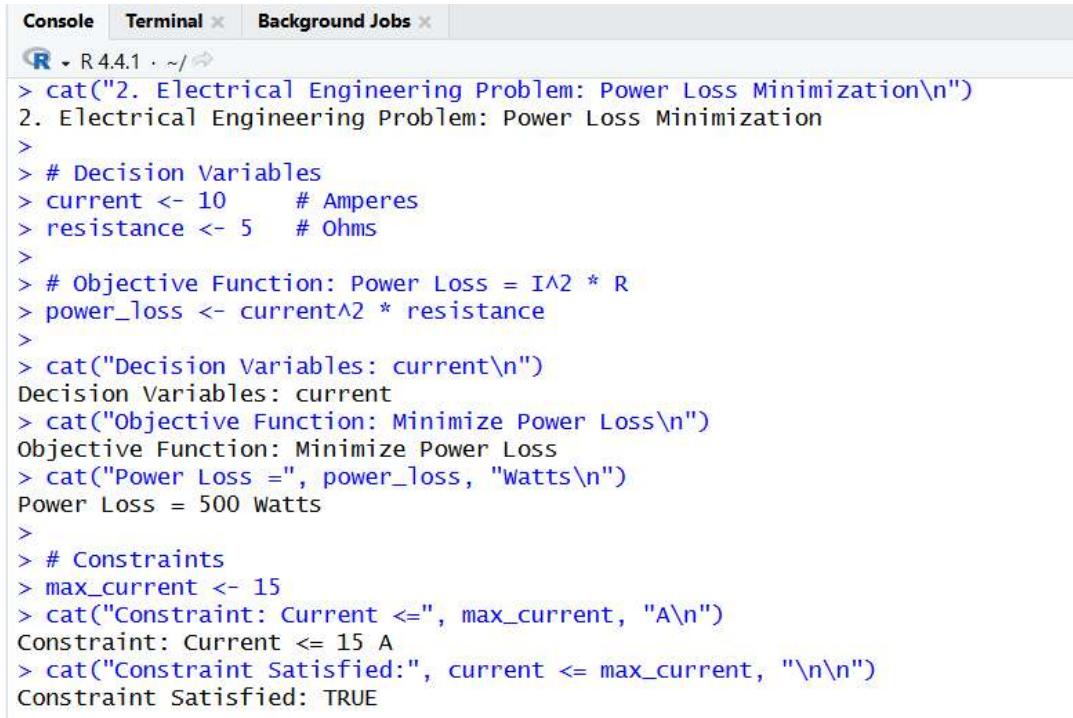
# Decision Variables
current <- 10      # Amperes
resistance <- 5    # Ohms

# Objective Function: Power Loss = I^2 * R
power_loss <- current^2 * resistance

cat("Decision Variables: current\n")
cat("Objective Function: Minimize Power Loss\n")
cat("Power Loss =", power_loss, "Watts\n")

# Constraints
max_current <- 15
cat("Constraint: Current <=", max_current, "A\n")
cat("Constraint Satisfied:", current <= max_current, "\n\n")
```

Output



The screenshot shows an R console window with three tabs: Console, Terminal, and Background Jobs. The Console tab is active, displaying the output of the R code. The output includes the problem statement, variable definitions, objective function calculation, and constraint check.

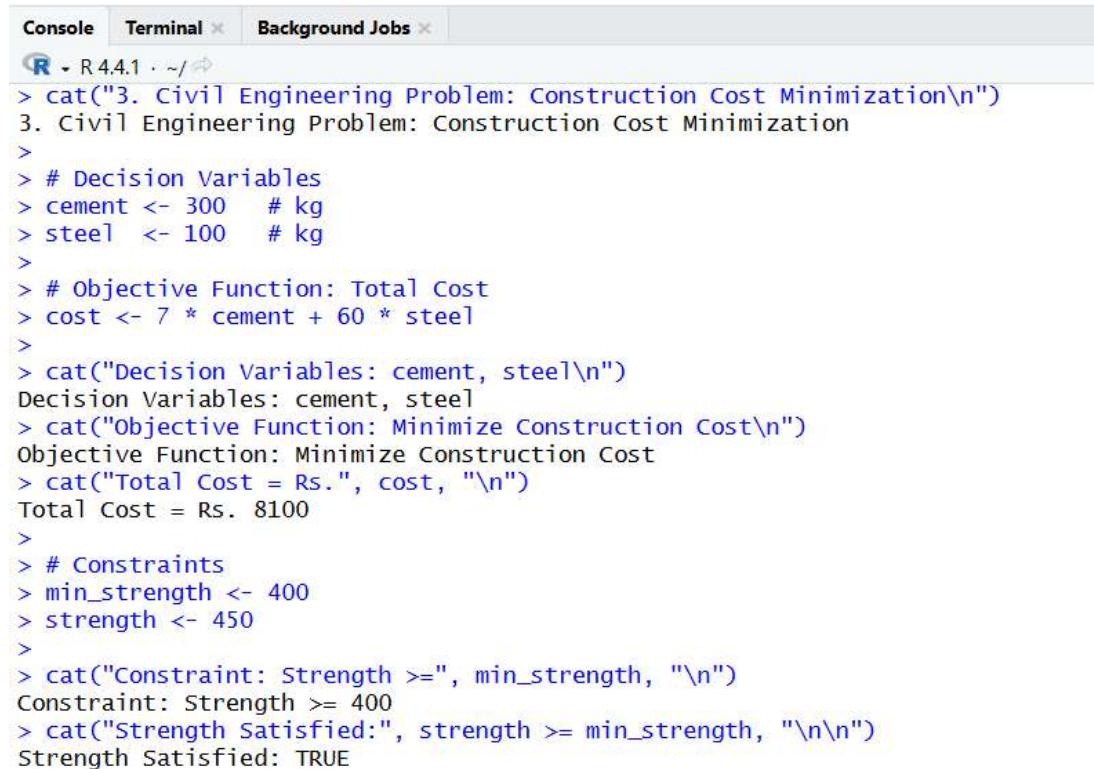
```
Console Terminal × Background Jobs ×
R 4.4.1 · ~/🔗
> cat("2. Electrical Engineering Problem: Power Loss Minimization\n")
2. Electrical Engineering Problem: Power Loss Minimization
>
> # Decision Variables
> current <- 10      # Amperes
> resistance <- 5    # Ohms
>
> # Objective Function: Power Loss = I^2 * R
> power_loss <- current^2 * resistance
>
> cat("Decision Variables: current")
Decision Variables: current
> cat("Objective Function: Minimize Power Loss\n")
Objective Function: Minimize Power Loss
> cat("Power Loss =", power_loss, "Watts\n")
Power Loss = 500 Watts
>
> # Constraints
> max_current <- 15
> cat("Constraint: Current <=", max_current, "A\n")
Constraint: Current <= 15 A
> cat("Constraint Satisfied:", current <= max_current, "\n\n")
Constraint Satisfied: TRUE
```

Example 3: Civil Engineering

R Code

```
58 #####  
59 # 3. Civil Engineering Problem  
60 # Minimize construction cost  
61 #####  
62  
63 cat("3. Civil Engineering Problem: Construction Cost Minimization\n")  
64  
65 # Decision Variables|  
66 cement <- 300 # kg  
67 steel <- 100 # kg  
68  
69 # Objective Function: Total Cost  
70 cost <- 7 * cement + 60 * steel  
71  
72 cat("Decision Variables: cement, steel\n")  
73 cat("Objective Function: Minimize Construction Cost\n")  
74 cat("Total Cost = Rs.", cost, "\n")  
75  
76 # Constraints  
77 min_strength <- 400  
78 strength <- 450  
79  
80 cat("Constraint: Strength >=", min_strength, "\n")  
81 cat("Strength Satisfied:", strength >= min_strength, "\n\n")  
82
```

Output



```
Console Terminal × Background Jobs ×  
R 4.4.1 · ~/  
> cat("3. Civil Engineering Problem: Construction Cost Minimization\n")  
3. Civil Engineering Problem: Construction Cost Minimization  
>  
> # Decision Variables  
> cement <- 300 # kg  
> steel <- 100 # kg  
>  
> # Objective Function: Total Cost  
> cost <- 7 * cement + 60 * steel  
>  
> cat("Decision Variables: cement, steel\n")  
Decision Variables: cement, steel  
> cat("Objective Function: Minimize Construction Cost\n")  
Objective Function: Minimize Construction Cost  
> cat("Total Cost = Rs.", cost, "\n")  
Total Cost = Rs. 8100  
>  
> # Constraints  
> min_strength <- 400  
> strength <- 450  
>  
> cat("Constraint: Strength >=", min_strength, "\n")  
Constraint: Strength >= 400  
> cat("Strength Satisfied:", strength >= min_strength, "\n\n")  
Strength Satisfied: TRUE
```

Example 4: Industrial Engineering

R Code

```
83 #####  
84 # 4. Production / Industrial Engineering Problem  
85 # Maximize profit  
86 #####  
87  
88 cat("4. Production Engineering Problem: Profit Maximization\n")  
89  
90 # Decision Variables  
91 x <- 40 # units of product A  
92 y <- 30 # units of product B  
93  
94 # Objective Function: Profit  
95 profit <- 50 * x + 40 * y  
96  
97 cat("Decision Variables: x (Product A), y (Product B)\n")  
98 cat("Objective Function: Maximize Profit\n")  
99 cat("Total Profit = Rs.", profit, "\n")  
.00 |  
.01 # Constraints  
.02 machine_hours <- 120  
.03 used_hours <- 2 * x + y  
.04  
.05 cat("Constraint: Machine Hours <=", machine_hours, "\n")  
.06 cat("Used Hours =", used_hours, "\n")  
.07 cat("Constraint Satisfied:", used_hours <= machine_hours, "\n")  
.08  
.09 cat("\nExperiment 1 completed successfully.\n")
```

Output

```
Console Terminal ✘ Background Jobs ✘
R - R 4.4.1 · ~/ ⌂
> cat("4. Production Engineering Problem: Profit Maximization\n")
4. Production Engineering Problem: Profit Maximization
>
> # Decision Variables
> x <- 40    # units of product A
> y <- 30    # units of product B
>
> # Objective Function: Profit
> profit <- 50 * x + 40 * y
>
> cat("Decision Variables: x (Product A), y (Product B)\n")
Decision Variables: x (Product A), y (Product B)
> cat("Objective Function: Maximize Profit\n")
Objective Function: Maximize Profit
> cat("Total Profit = Rs.", profit, "\n")
Total Profit = Rs. 3200
>
> # Constraints
> machine_hours <- 120
> used_hours <- 2 * x + y
>
> cat("Constraint: Machine Hours <=", machine_hours, "\n")
Constraint: Machine Hours <= 120
> cat("Used Hours =", used_hours, "\n")
Used Hours = 110
> cat("Constraint Satisfied:", used_hours <= machine_hours, "\n")
Constraint Satisfied: TRUE
>
> cat("\nExperiment 1 completed successfully.\n")

Experiment 1 completed successfully.
```

Practice Questions

1. Modify the beam design code to include an additional constraint on the maximum length.

R Code

```

1 ######
2 # Practical Q1: Beam Design with Maximum Length Constraint
3 #####
4
5 cat("Practical 1: Beam Design with Maximum Length Constraint\n")
6
7 # Decision Variables
8 length <- 5           # meters
9 area <- 0.02          # m^2
10 density <- 7850        # kg/m^3
11
12 # Constraints
13 stress <- 200         # MPa
14 stress_limit <- 250    # MPa
15 max_length <- 6        # meters
16
17 # Objective Function
18 weight <- density * area * length
19
20 # Output
21 cat("Objective Function: Minimize Weight\n")
22 cat("Weight of Beam =", weight, "kg\n")
23
24 cat("Constraint 1: Stress <=", stress_limit, "MPa\n")
25 cat("Stress Satisfied:", stress <= stress_limit, "\n")
26
27 cat("Constraint 2: Length <=", max_length, "m\n")
28 cat("Length Satisfied:", length <= max_length, "\n")
29

```

Output

```

> #####
> # Practical Q1: Beam Design with Maximum Length Constraint
> #####
>
> cat("Practical 1: Beam Design with Maximum Length Constraint\n")
Practical 1: Beam Design with Maximum Length Constraint
>
> # Decision Variables
> length <- 5           # meters
> area <- 0.02          # m^2
> density <- 7850        # kg/m^3
>
> # Constraints
> stress <- 200         # MPa
> stress_limit <- 250    # MPa
> max_length <- 6        # meters
>
> # Objective Function
> weight <- density * area * length
>
> # Output
> cat("Objective Function: Minimize Weight\n")
Objective Function: Minimize Weight
> cat("Weight of Beam =", weight, "kg\n")
Weight of Beam = 785 kg
>
> cat("Constraint 1: Stress <=", stress_limit, "MPa\n")
Constraint 1: Stress <= 250 MPa
> cat("Stress Satisfied:", stress <= stress_limit, "\n")
Stress Satisfied: TRUE

```

```

>
> cat("Constraint 2: Length <=", max_length, "m\n")
Constraint 2: Length <= 6 m
> cat("Length Satisfied:", length <= max_length, "\n")
Length Satisfied: TRUE
>

```

2. Change the objective from minimizing weight to minimizing cost by including material cost per kg.

R Code

```

1 ##### Practical Q2: Beam Cost Minimization #####
2 # Practical Q2: Beam Cost Minimization
3 #####
4
5 cat("Practical 2: Beam Cost Minimization\n")
6
7 # Decision Variables
8 length <- 5          # meters
9 area <- 0.02          # m^2
10 density <- 7850        # kg/m^3
11 cost_per_kg <- 60      # Rs per kg
12
13 # Objective Function
14 weight <- density * area * length
15 cost <- weight * cost_per_kg
16
17 # Constraint
18 stress <- 200
19 stress_limit <- 250
20
21 # Output
22 cat("Objective Function: Minimize Cost\n")
23 cat("Total Weight =", weight, "kg\n")
24 cat("Total Cost = Rs.", cost, "\n")
25
26 cat("Stress Constraint Satisfied:", stress <= stress_limit, "\n")
27

```

Output

```

> # Practical Q2: Beam Cost Minimization
> #####
>
> cat("Practical 2: Beam Cost Minimization\n")
Practical 2: Beam Cost Minimization
>
> # Decision Variables
> length <- 5           # meters
> area <- 0.02          # m^2
> density <- 7850        # kg/m^3
> cost_per_kg <- 60      # Rs per kg
>
> # Objective Function
> weight <- density * area * length
> cost <- weight * cost_per_kg
>
> # Constraint
> stress <- 200
> stress_limit <- 250
>
> # Output
> cat("Objective Function: Minimize Cost\n")
Objective Function: Minimize Cost
> cat("Total Weight =", weight, "kg\n")
Total Weight = 785 kg
> cat("Total Cost = Rs.", cost, "\n")
Total Cost = Rs. 47100
>
> cat("Stress Constraint Satisfied:", stress <= stress_limit, "\n")
Stress Constraint Satisfied: TRUE

```

3. Create an R program that models an electrical power loss minimization problem.

R Code

```

1 ######
2 # Practical Q3: Electrical Power Loss Minimization
3 #####
4
5 cat("Practical 3: Electrical Power Loss Minimization\n")
6
7 # Decision Variables
8 current <- 10          # Amperes
9 resistance <- 5         # Ohms
10
11 # Objective Function
12 power_loss <- current^2 * resistance
13
14 # Constraint|
15 max_current <- 15
16
17 # Output
18 cat("Objective Function: Minimize Power Loss\n")
19 cat("Power Loss =", power_loss, "Watts\n")
20
21 cat("Constraint: Current <=", max_current, "A\n")
22 cat("Constraint Satisfied:", current <= max_current, "\n")
23

```

Output

```
> #####  
> # Practical Q3: Electrical Power Loss Minimization  
> #####  
>  
> cat("Practical 3: Electrical Power Loss Minimization\n")  
Practical 3: Electrical Power Loss Minimization  
>  
> # Decision Variables  
> current <- 10      # Amperes  
> resistance <- 5     # Ohms  
>  
> # Objective Function  
> power_loss <- current^2 * resistance  
>  
> # Constraint  
> max_current <- 15  
>  
> # Output  
> cat("Objective Function: Minimize Power Loss\n")  
Objective Function: Minimize Power Loss  
> cat("Power Loss =", power_loss, "Watts\n")  
Power Loss = 500 Watts  
>  
> cat("Constraint: Current <=", max_current, "A\n")  
Constraint: Current <= 15 A  
> cat("Constraint Satisfied:", current <= max_current, "\n")  
Constraint Satisfied: TRUE
```