# OPTIMISATION OF WATER FILTERS IN NITC DEPARTMENT BLOCK

**A COURSE PROJECT REPORT**

*Submitted by*

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*in partial fulfilment of the award of the degree*

*of*

**MASTER OF TECHNOLOGY**

*in*

**INDUSTRIAL ENGINEERING AND MANAGEMENT**

**Under the Guidance of**

**Dr. Ratna Kumar**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**NATIONAL INSTITUTE OF TECHNOLOGY CALICUT**

# ACKNOWLEDGEMENT

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We also take the opportunity to acknowledge the contribution of **Dr. M.L. Joy, Head of Department** (Mechanical Engineering), for his full support and assistance during the development of the project.

We also do not like to miss the opportunity to acknowledge the contribution of all faculty members of the department for their kind assistance and cooperation during the course of my project. Last but not the least, We acknowledge my friends and seniors for their contribution in the completion of the project.

## CERTIFICATE

This is to certify that the report entitled (**OPTIMISATION OF WATER FILTERS IN NITC DEPARTMENT BLOCK )** is a bonafide record of the project done by **Ashik N R(M240987ME) Aswin (M240790ME) Chandrakanth(M240797ME) Mohammed Fahim(M241288ME)** under my supervision as a part of the Course Project .

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# ABSTRACT

This decision modeling project employs a Decision Model to address the optimization of water distribution in a three-floor department block, focusing on determining the minimum number of water filters required. The department comprises 13 rooms on each floor, each room accommodating 30 students with a daily water demand of at least 4 liters per student. Water supply is facilitated by filters, each with a daily capacity of 150 liters. The primary objective is to strategically allocate water resources while minimizing the usage of filters. The problem is formulated as a Set Covering Model, a type of Integer Linear Programming (ILP) problem. Decision variables are introduced to represent the selection of filters in a binary manner. This binary decision-making process reflects whether a filter is chosen to fulfill the water demand of a particular room. The objective function is structured to minimize the total number of filters utilized across the department block. The model incorporates constraints to ensure that the capacity of each filter is not exceeded and that the daily water demand for each room is met. The solution to this Set Covering Model provides an optimal configuration of filters to efficiently distribute water throughout the department. The outcomes of this project offer valuable insights into decision-making for water resource management in multi-room facilities. The Set Covering Model provides a practical and effective tool for administrators and facility managers, enabling them to make informed decisions to optimize water distribution, enhance sustainability, and promote resource efficiency within the college environment.

## 1. Introduction to the Set Covering Model

The set covering problem is a pivotal NP-hard problem in combinatorial optimization, applicable in various practical fields. This decision modeling project addresses the optimization of water distribution within a three-floor department block, aiming to determine the minimum number of water filters required. Each floor consists of 13 rooms, each accommodating 30 students with a daily water demand of at least 4 liters per student. Water is supplied via filters with a daily capacity of 150 liters. The primary objective is to strategically allocate these resources while minimizing the number of filters used.

The problem is formulated as a Set Covering Model, a type of Integer Linear Programming (ILP) problem. Binary decision variables indicate whether a filter is chosen to meet a room's water demand. The objective function minimizes the total number of filters, while constraints ensure that the capacity of each filter is not exceeded and that each room's daily water demand is satisfied. By employing this model, the project aims to provide an optimal configuration of filters, ensuring efficient water distribution throughout the department.

This model provides practical insights into resource management for multi-room facilities. It proves to be a valuable tool for administrators and facility managers, enabling informed decisions to optimize water distribution, enhance sustainability, and promote resource efficiency within the college environment. Furthermore, the project underscores the importance of approximation algorithms in solving NP-hard problems, serving as an educational example for teaching computational algorithms. Through this combinatorial approach, valuable insights into water resource management are gained, highlighting the utility and effectiveness of the Set Covering Model.

**Model:**

An integer linear program (ILP) model can be formulated for the minimum set covering problem as follows:

**Decision Variables:**

1. Xi: Number of water filters installed on floor 1.
2. Yij: Binary variable indicating whether water from filter I serves room j (1 if yes, 0 if no).

**Objective Function:**

Minimize the total number of water filters used.

Minimize Z=$\sum_{i=1}^{5} Xi$

- The objective function$\sum ciyi\ n\ i$=1 is defined to minimize the number of subset Si that cover all elements in the universe by minimizing their total cost. The first constraint implies that every element in i the universe ∪ must be be covered and the second constraint yi ∈ {0,1} indicates that the decision variables are binary which means that every set is either in the set cover or not.
- Set covering problems are significant NP-hard optimization problems, which implies that as the size of the problem increases, the computational time to solve it increases exponentially. Therefore, there exist approximation algorithms that can solve large scale problems in polynomial time with optimal or near-optimal solutions.

**Constraints:**

1. **Room Coverage:**

$$\sum_{i=1}^{6} Yij = 1 \ \ \forall j \ \in \{\, 1,\ 2,\ \ldots 13\}$$

Each room should be served by exactly one water filter

2. **Filter Distribution:**

$$\sum_{j=1}^{13} yij \leq Xi \, \forall i \in \{1,2,3,4,5,\}$$

The number of water filters on a floor must be sufficient to cover all rooms on that floor

3. **Distance Constraint:**

$$\sum_{j=1}^{13} Dij \cdot Yij \leq D \cdot Xi \quad \forall i \in \{1,2,3,4,5\}$$

Ensure that the total distance covered by water pipes from a filter on floor does not excess a certain limit (D).

4. **Total Students:**

$$\sum_{i=1}^{5} \sum_{j}^{13} Sij \cdot Yij \leq C$$

Consider the total number of students in the rooms served by the water filter on a floor does not to exceed a certain capacity (C).

5. **Budget Constraint:**

$$\sum_{i=1}^{5} Ci \cdot Xi \leq B$$

Ensure that the cost of installing water filters does not exceed a specified budget (B).

6. **Binary Variable Constraint:**

$$Yij \in \{0,1\} \; \forall i \in \{1,2,3,4,5\}, \; \forall j \in \{1,2, \ldots .,13\}$$

Binary variables must be 0 or 1

## 2. Problem Statement

In Department block of NIT Calicut, students are facing problems regarding water filter i.e. the present water filter are not sufficient and students have to travel a long distance to drink water. Now there is a need to find the minimum number of WATER FILTER for each floor of the department so the students will have to travel only a small distance to drink water.

**Assumption:**

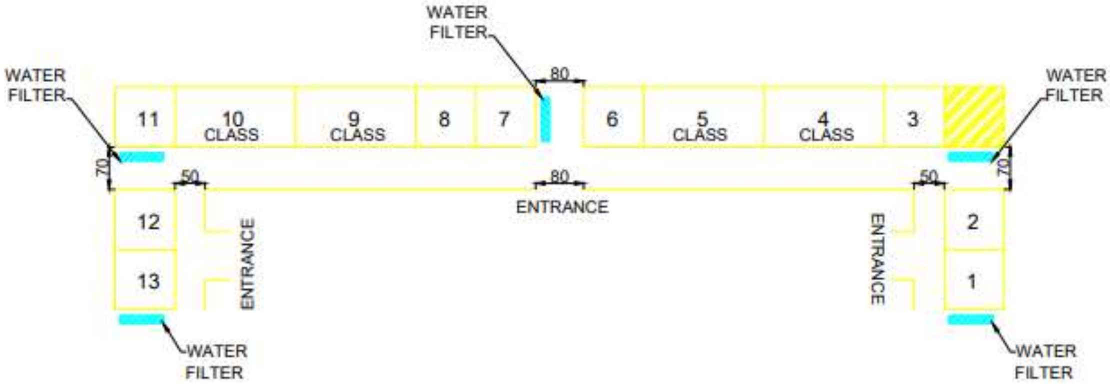
One Water Filter can fulfil the need of at most 4 rooms irrespective of distance between them.

Each room has 30 Students.

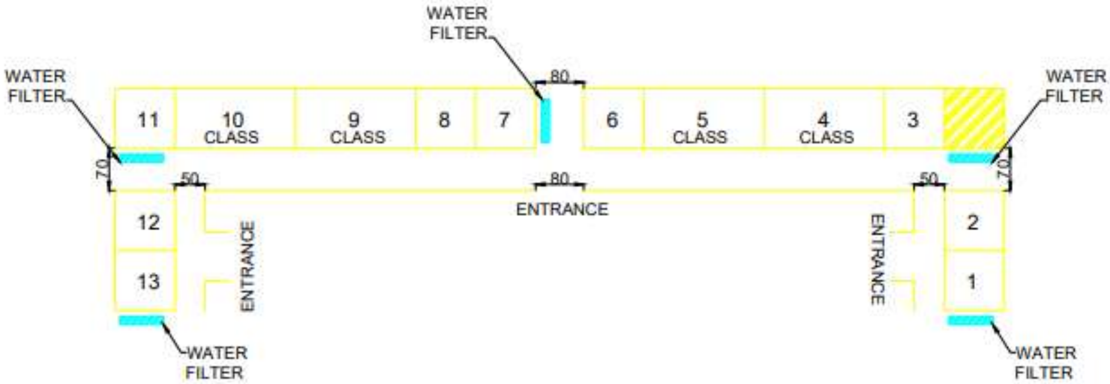
All the Water Filters are having similar specification (Filtering Capacity).

Four cabins are considered as single room

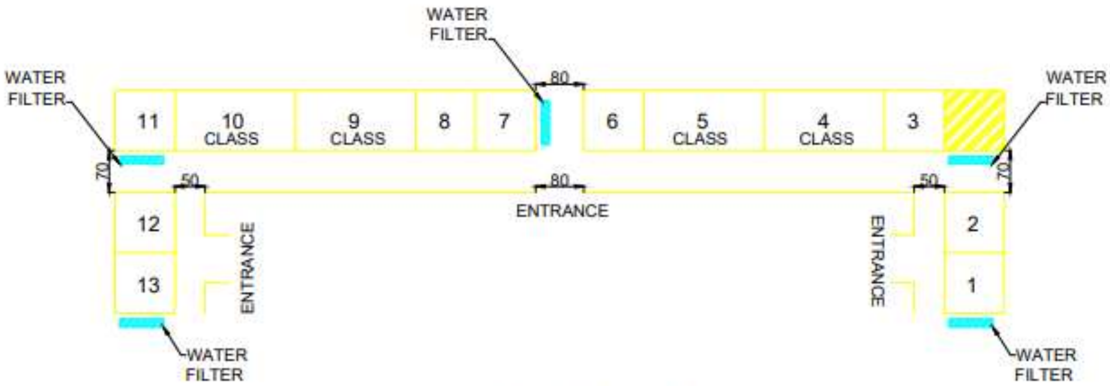
# 3. Layout (Before Optimization)




DWG 3: SECOND FLOOR




DWG 2: FIRST FLOOR




DWG 1: GROUND FLOOR

BEFORE OPTIMIZATION

Xi: Number of water filters installed on floor 1.

Yij: Binary variable indicating whether water from filter I serves room j (1 if yes, 0 if no).

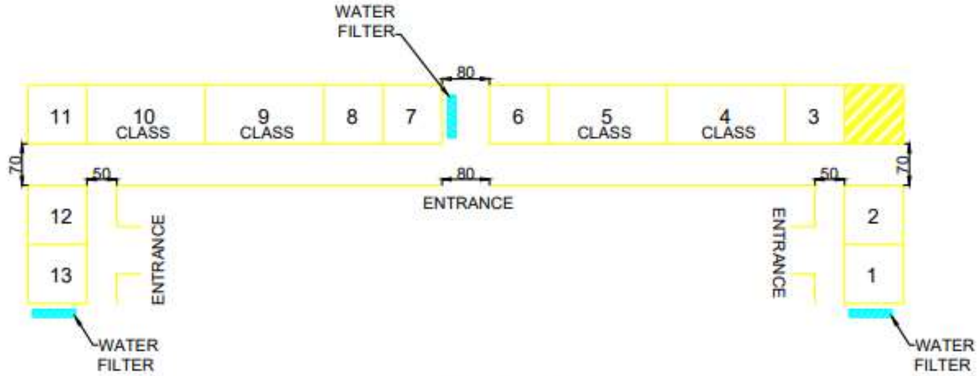
**4. Objective Function:**

**Minimize** $$Z = \sum_{i=1}^{5} X_i = X_1 + X_2 + X_3 + X_4 + X_5$$

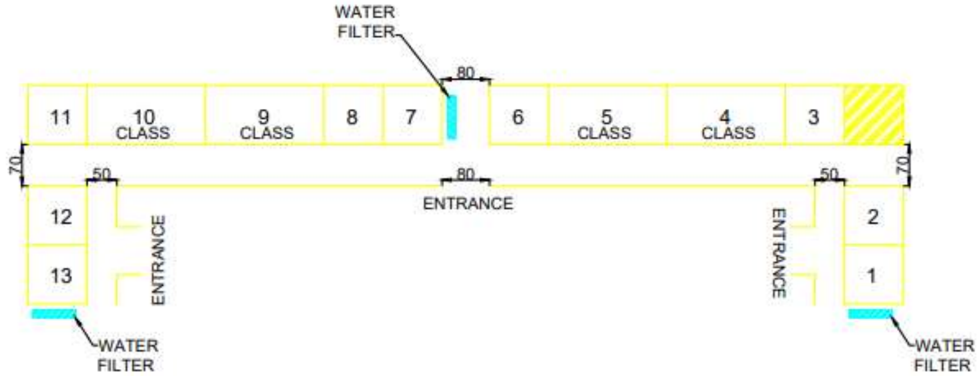
**Subject to:**

| | |
|---|---|
| $X1 \geq 1$ | Room No. 1 |
| $X1 + X2 \geq 1$ | Room No. 2 |
| $X1 + X2 \geq 1$ | Room No. 3 |
| $X2 + X3 \geq 1$ | Room No. 4 |
| $X2 + X3 \geq 1$ | Room No. 5 |
| $X3 \geq 1$ | Room No. 6 |
| $X3 \geq 1$ | Room No. 7 |
| $X3 + X4 \geq 1$ | Room No. 8 |
| $X3 + X4 \geq 1$ | Room No. 9 |
| $X4 + X5 \geq 1$ | Room No. 10 |
| $X4 + X5 \geq 1$ | Room No. 11 |
| $X4 + X5 \geq 1$ | Room No. 12 |
| $X5 \geq 1$ | Room No. 13 |

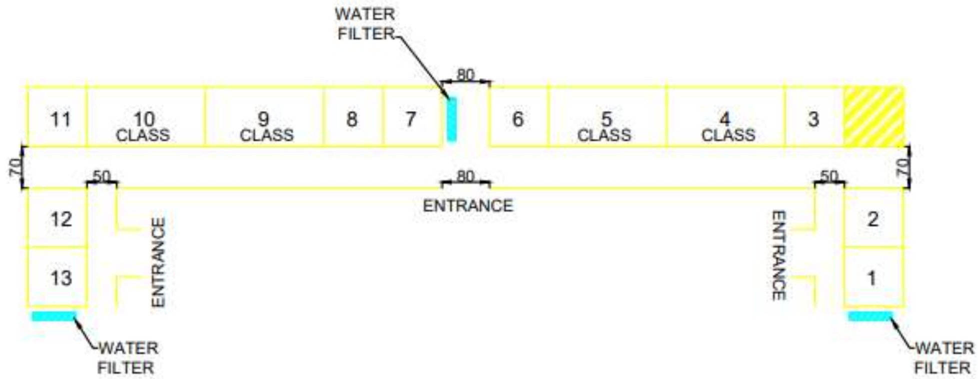
# 5.Layout (After Optimization)




DWG 3: SECOND FLOOR



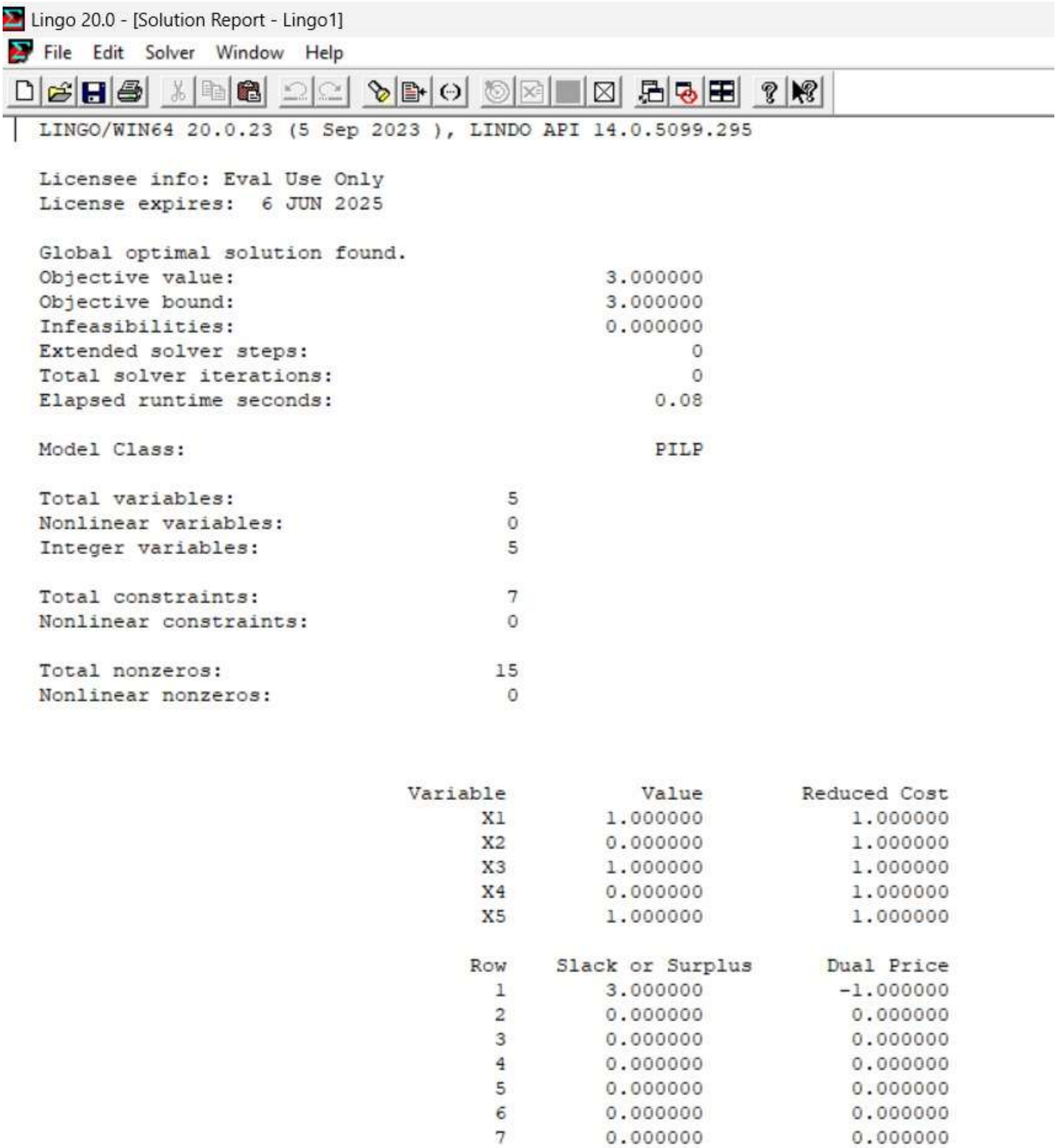

DWG 2: FIRST FLOOR




DWG 1: GROUND FLOOR

AFTER OPTIMIZATION

# 6 . Solution with LINGO



Lingo 20.0 - [Solution Report - Lingo1]

File Edit Solver Window Help

```
LINGO/WIN64 20.0.23 (5 Sep 2023 ), LINDO API 14.0.5099.295

Licensee info: Eval Use Only
License expires:  6 JUN 2025

Global optimal solution found.
Objective value:                              3.000000
Objective bound:                              3.000000
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             0
Elapsed runtime seconds:                          0.08

Model Class:                                      PILP

Total variables:                      5
Nonlinear variables:                  0
Integer variables:                    5

Total constraints:                    7
Nonlinear constraints:                0

Total nonzeros:                      15
Nonlinear nonzeros:                   0


                        Variable           Value        Reduced Cost
                              X1        1.000000            1.000000
                              X2        0.000000            1.000000
                              X3        1.000000            1.000000
                              X4        0.000000            1.000000
                              X5        1.000000            1.000000

                             Row    Slack or Surplus      Dual Price
                               1        3.000000           -1.000000
                               2        0.000000            0.000000
                               3        0.000000            0.000000
                               4        0.000000            0.000000
                               5        0.000000            0.000000
                               6        0.000000            0.000000
                               7        0.000000            0.000000
```

## 7. Inference

The solution has shown that the minimum number of water filters required for a single floor of the department block is three. This finding ensures that the water demands of all 13 rooms, each housing 30 students, are efficiently met without unnecessary excess. By minimizing the number of filters, the institution benefits from significant cost savings, reducing initial purchase and installation expenses as well as ongoing maintenance costs. Additionally, this optimized use of filters contributes to sustainability efforts by lowering energy consumption and reducing waste from filter maintenance and replacement, aligning with the institution’s environmental goals. The solution provides a practical strategy for administrators and facility managers, enabling efficient and effective water distribution while ensuring student needs are met. Furthermore, this project underscores the educational value of applying the Set Covering Model and approximation algorithms, serving as a robust example for teaching computational algorithms and decision-making processes in resource management

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## 8. Reference


- H. A. Taha, Operation Research: An Introduction, 10th ed., Harlow, England: Pearson, 2017.