Career Point International Journal of Research (CPIJR)
©2022 CPIJR | Volume 4 | Issue 3 | ISSN : 2583-1895
December-2024 | DOI: https://doi.org/10.5281/zenodo.15054398

Role of the Assignment Problem in Resource Optimization: A Case Study of a Clothing manufacturing company

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Abstract:
Mathematics, particularly optimization techniques, plays a crucial role in management, helping to allocate resources efficiently. This paper explores the use of the Assignment Problem in operations management, where products or tasks must be assigned to resources such as workers, machines, or locations. Through a case study of a clothing manufacturing company, we demonstrate how the Assignment Problem can optimize production assignments for different machines to minimize overall production costs. The Hungarian algorithm is applied to solve the problem.

Keywords: Assignment Problem, Hungarian algorithm, Case study, Optimization Techniques, Production Costs

Introduction:

In management, decision-makers often face problems where they need to allocate tasks or resources to different agents (workers, machines, etc.) to optimize efficiency or minimize costs. The Assignment Problem is a special type of optimization problem that aims to find the best one-to-one assignment between tasks and agents while minimizing costs or maximizing productivity.
In this paper, we will focus on the application of the Assignment Problem in operations management, using a case study of a clothing manufacturing company that wants to assign different types of garments to different machines to minimize production costs.

Assignment Problem in Operations Management

The **Assignment Problem** involves assigning a set of tasks to a set of agents such that each task is assigned to one agent, and each agent is assigned exactly one task. The objective is to minimize the total cost or time of completing all tasks.
Mathematically, the Assignment Problem can be formulated as follows:

- Let C_{ij} represent the cost of assigning task i to agent j
- Let x_{ij} be a binary decision variable that equals 1 if task i is assigned to agent j, and 0 otherwise.

The objective is to minimize the total cost:

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$$\text{Minimize } Z = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} x_{ij}$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \forall i \quad \text{(each task is assigned to one agent)}$$

$$\sum_{i=1}^{n} x_{j} = 1 \quad \forall j \quad \text{(each agent is assigned exactly one task)}$$

$$x_{ij} \in \{0, 1\} \quad \forall i, j$$

The **Hungarian algorithm** is a commonly used method for solving Assignment Problems optimally in polynomial time.

Case Study: Production Assignment at Elite Wear Clothing

Company Background

Elite Wear is a mid-sized clothing manufacturer that produces four different types of garments: jackets, trousers, shirts, and skirts. The company has four sewing machines, each capable of producing all garment types but with different production costs. The management wants to assign each type of garment to exactly one machine to minimize total production costs.

Problem Data

The following table shows the production costs (in Rupees) for each garment type on each machine:

Garment/Machine	Machine A	Machine B	Machine C	Machine D
Jackets	11	14	10	15
Trousers	9	12	8	11
Shirts	12	9	11	13
Skirts	10	11	10	9

Objective

The objective is to assign each garment type (Jackets, Trousers, Shirts, Skirts) to one of the four machines (A, B, C, D) in such a way that the total production cost is minimized.

Solving the Problem Using the Hungarian Algorithm

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Step 1: Subtract Row Minimum

To start, we subtract the smallest value in each row from all other values in that row. This step reduces each row to have at least one zero, ensuring a feasible assignment.

Garment/Machine	Machine A	Machine B	Machine C	Machine D
Jackets	$11 - 10 = 1$	$14 - 10 = 4$	$10 - 10 = 0$	$15 - 10 = 5$
Trousers	$9 - 8 = 1$	$12 - 8 = 4$	$8 - 8 = 0$	$11 - 8 = 3$
Shirts	$12 - 9 = 3$	$9 - 9 = 0$	$11 - 9 = 2$	$13 - 9 = 4$
Skirts	$10 - 9 = 1$	$11 - 9 = 2$	$10 - 9 = 1$	$9 - 9 = 0$

Step 2: Subtract Column Minimum

Now, subtract the minimum value from each column. This step ensures each column contains at least one zero.

Garment/Machine	Machine A	Machine B	Machine C	Machine D
Jackets	$1 - 1 = 0$	$4 - 0 = 4$	$0 - 0 = 0$	$5 - 0 = 5$
Trousers	$1 - 1 = 0$	$4 - 0 = 4$	$0 - 0 = 0$	$3 - 0 = 3$
Shirts	$3 - 1 = 2$	$0 - 0 = 0$	$2 - 0 = 2$	$4 - 0 = 4$
Skirts	$1 - 1 = 0$	$2 - 0 = 2$	$1 - 0 = 1$	$0 - 0 = 0$

Step 3: Cover Zeros with Minimum Number of Lines

We attempt to cover all zeros in the matrix using the minimum number of horizontal and vertical lines. If the number of lines equals the size of the matrix (4 in this case), we have an optimal assignment. If not, we adjust the matrix further.

After analyzing the matrix, we can cover all zeros with 3 lines, which is less than 4. Therefore, adjustments are necessary.

Step 4: Adjust the Matrix

We find the smallest uncovered element, which is 1. We subtract 1 from all uncovered elements and add 1 to elements where lines intersect.

The new matrix after adjustment:

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Garment/Machine	Machine A	Machine B	Machine C	Machine D
Jackets	0	3	0	6
Trousers	0	3	0	2
Shirts	1	0	1	4
Skirts	0	1	0	0

Step 5: Find Optimal Assignment

Now, all zeros can be covered with 4 lines, indicating an optimal solution is ready to be extracted. We assign tasks to machines based on uncovered zeros:

- Jackets: Machine C
- Trousers: Machine A
- Shirts: Machine B
- Skirts: Machine D

Results and Analysis

The optimal assignment and the corresponding production costs are:

- **Jackets → Machine C**: Rs10
- **Trousers → Machine A**: Rs. 9
- **Shirts → Machine B**: Rs. 9
- **Skirts → Machine D**: Rs. 9

The total minimum production cost is:

Total Cost=10+9+9+9=37 Rs.

Thus, by optimally assigning each garment type to the most cost-effective machine, Elite Wear reduces its total production cost to Rs.37, minimizing the company's expenses.

Conclusion

The Assignment Problem is a powerful tool in resource optimization, especially in operations management. In this case study, we applied the Hungarian algorithm to assign garment types to machines at Elite Wear in a way that minimizes production costs. The resulting assignment demonstrates how mathematical techniques can improve operational efficiency and cost-effectiveness in manufacturing processes.

The Assignment Problem can be extended to other areas of management, such as assigning employees to projects, machines to tasks, or even delivery routes to vehicles. Future research could involve more complex assignment problems with additional constraints, such as time windows or skill requirements.

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