



Optimization of Investment Banker–Dual Assignments Using the Hungarian Method

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Applications of Operations Research in Real-Life Scenarios: A Literature-Based Analytical Study

Operations Research | Assignment Problems

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Abstract

Investment banks routinely win several mandates at once and must decide which available banker should lead which deal. Each banker has a different expertise, seniority and workload, so each banker–deal pairing carries a different cost in staff hours and opportunity cost. This report treats that decision as a classical **assignment problem** from Operations Research (OR) and solves it with the **Hungarian method** (Kuhn, 1955). A literature-based analysis is combined with a fully worked example of five bankers and five deals, using illustrative cost data in Rs lakh.

The Hungarian method finds a minimum total cost of **Rs 82 lakh**. Staffing the deals in simple sequential order costs Rs 103 lakh, and a greedy rule costs Rs 97 lakh, so the optimal assignment saves 20.4% and 15.5% respectively. The result is certified optimal in two independent ways: a dual (lower-bound) check and complete enumeration of all 120 possible assignments. The report closes with a critical analysis of the model's strengths and limitations, and with extensions needed for real-world use.

1. OperationsTMcsearch and the Assignment Problem

1.1 What is OperationsTMcsearch?

Operations Research is the scientific, quantitative approach to making better decisions under limited resources. It builds mathematical models of a decision situation, solves them with exact or heuristic algorithms, and translates the results back into recommendations. Typical OR problem classes include linear programming, transportation, network flow, scheduling and assignment.

1.2 The assignment problem

In an assignment problem, n people (or machines, vehicles, teams) are matched to n tasks, one-to-one, so that the total cost, time or distance is minimised. Each person does exactly one task, and each task is done by exactly one person.

The problem addressed in this report is:

- **Balanced:** the number of bankers equals the number of deals.
- **A minimisation problem:** the objective is to minimise total cost.
- **A binary linear program:** decisions are yes/no assignments.
- **A special case of the transportation problem,** in which every supply and every demand equals 1.



2. The TMcal-Lific Problem: Staffing Deals in Investment Banking

2.1 The problem

A bank wins five new deal mandates and has five bankers free to take them on. Each banker would incur a different cost, made up of estimated staff hours plus the opportunity cost of not being available for other work, on each deal. The question is: **who should lead which deal?**

2.2 The domain

The domain is investment banking and financial services, covering M&A advisory, equity (IPO) and debt capital markets, leveraged finance and restructuring mandates. Staffing decisions in this industry are made repeatedly, are expensive when wrong, and are usually made informally by senior judgement.

2.3 Why Operations TMcsearch fiits

The situation has exactly the structure of an assignment problem: one banker per deal, one deal per banker, and a clear numerical cost measure. The scale of the problem also justifies a formal method. With only five bankers there are $5! = 120$ possible matchings, which can be checked by brute force. With 20 deals there are $20!$ (about 2.4 quintillion) matchings, which cannot. The Hungarian method nevertheless solves such a problem exactly in moments, because its effort grows only polynomially with n .

3. Literature TMcviewcd

Two published studies form the core of the literature base: the foundational paper that introduced the algorithm, and an applied case study of personnel assignment in a different industry.

3.1 Kuhn (1955): The Hungarian method for the assignment problem

Naval Research Logistics Quarterly, 2(1–2), 83–97.

- **Context:** Kuhn sets out the mathematical foundation for assigning n persons to n jobs using numerical performance scores.
- **Technique:** The method combines ideas of two Hungarian mathematicians, König and Egerváry, into a new solution procedure. This origin gives the algorithm its name.
- **Relevance to this study:** It is the source of the algorithm applied here to banker–deal matching.

3.2 Nahar et al. (2018): Personnel assignment based on traveling time

Optimization of Personnel Assignment Problem Based on Traveling Time by Using Hungarian Methods. IOP Conference Series: Materials Science and Engineering, vol. 300.

- **Context:** Postal logistics. Workers of the Central Post Office Bandung delivered packages to different destinations.
- **Technique:** The Hungarian method was used to minimise the total traveling time of the workers.
- **Relevance to this study:** The people-to-task structure is the same as in banker–deal staffing. The study shows that the model transfers from logistics to staffing decisions in general.



3.3 Supporting literature

Two further sources appear in the reference list as background to the wider assignment-problem literature: Pentico (2007), a survey of assignment problems marking the field's golden anniversary, and Boah, Adu and Gyebil (2015), a study of an assignment problem at a legal firm in Kumasi, Ghana. The legal-firm study is the closest professional-services analogue to the banking setting examined here.

3.4 Common thread

All of these sources share one structure: **people $\leftrightarrow$ tasks, a cost matrix, one-to-one matching, and minimisation of the total**. The literature therefore supports applying the same method to banker–deal staffing.

4. Mathematical Model

4.1 Formulation

Decision variable

$x_{ij} = 1$ if banker i leads deal j , and 0 otherwise.

Parameter

c_{ij} = cost of banker i executing deal j , for $i, j = 1 \dots n$.

Objective

Minimise $Z = \sum_i \sum_j c_{ij} \cdot x_{ij}$

Constraints

Constraint	Meaning
$\sum_j x_{ij} = 1$ for every banker i	Each banker leads exactly one deal
$\sum_i x_{ij} = 1$ for every deal j	Each deal has exactly one lead banker
$x_{ij} \in \{0, 1\}$	Assignments are all-or-nothing

This is a binary linear program. Because the constraint matrix is totally unimodular, the linear-programming relaxation already returns 0/1 solutions, which is why efficient exact algorithms exist.

4.2 Assumptions

1. The number of bankers equals the number of deals.
2. Costs are known and fixed in advance.
3. Each banker leads exactly one deal.
4. Each deal has exactly one lead banker.
5. The cost of one pairing does not depend on the other assignments.



5. The Hungarian Method

The method rests on one observation: subtracting a constant from every entry of a row or column does not change which assignment is optimal. The algorithm therefore creates zeros in the matrix and looks for a complete matching made entirely of zeros.

Step	Name	Action
1	Row reduction	Subtract the smallest entry of each row from that row.
2	Column reduction	Subtract the smallest entry of each column from that column.
3	Cover the zeros	Draw the minimum number of lines through rows and columns that cover all zeros.
Step	Name	Action
4	Test and adjust	If the number of lines equals n , go to step 5. Otherwise subtract the smallest uncovered value from all uncovered cells, add it to cells where two lines cross, and repeat step 3.
5	Assign	Select one zero in each row and column. Their original costs give the minimum total cost.

Variants. A maximisation problem is converted by subtracting every entry from the largest value in the matrix. An unbalanced problem is balanced by adding dummy rows or columns of zero cost.

Complexity. The method runs in $O(n^3)$ steps. By hand it is practical up to roughly 10×10 problems; software handles far larger ones.

6. Worked Example: Five Bankers, Five Deals

6.1 Data

The cost matrix gives the estimated execution cost, in Rs lakh, of banker i leading deal j , being the estimated staff hours plus the opportunity cost. **The data are illustrative and were created for this project.** The bankers differ in sector expertise, seniority and current workload, which is why their costs differ across deals.

Deals on offer

- D1: Cross-border M&A
- D2: Pharma IPO
- D3: Infrastructure bond issue
- D4: LBO financing
- D5: Debt restructuring



Original cost matrix (Rs lakh)

Banker	D1	D2	D3	D4	D5
B1	25	14	35	32	13
B2	29	33	17	38	35
B3	24	33	18	35	24
B4	20	36	18	17	16
B5	14	26	17	22	10

6.2 Step 1: TMow reduction

The smallest entry in each row is subtracted from that row. The row minima are 13, 17, 18, 16 and 10, which sum to 74.

Banker	D1	D2	D3	D4	D5	Row min
B1	12	1	22	19	0	-13
B2	12	16	0	21	18	-17
B3	6	15	0	17	6	-18
B4	4	20	2	1	0	-16
B5	4	16	7	12	0	-10

6.3 Step 2: Column reduction

The smallest entry in each column of the row-reduced matrix is then subtracted. The column minima are 4, 1, 0, 1 and 0, which sum to 6.

Banker	D1	D2	D3	D4	D5
B1	8	0	22	18	0
B2	8	15	0	20	18
B3	2	14	0	16	6
B4	0	19	2	0	0
B5	0	15	7	11	0
Col min	-4	-1	0	-1	0

The total reduction so far is $74 + 6 = 80$. Every row and column now contains a zero, but it is still necessary to check whether a complete zero-cost matching exists.

6.4 Step 3: Cover all zeros

The minimum number of lines needed to cover every zero in the matrix above is **four**: rows B1, B4 and B5, plus column D3. Because $4 < 5$, a complete zero-cost assignment is not yet possible, so the matrix must be adjusted.



6.5 Step 4: Adjust the matrix

The smallest uncovered value is **2** (cell B3, D1). The adjustment rules are:

- subtract 2 from every uncovered cell;
- add 2 to every double-covered cell, which are the intersections (B1, D3), (B4, D3) and (B5, D3);
- leave all other cells unchanged.

Banker	D1	D2	D3	D4	D5
B1	8	0	24	18	0
B2	6	13	0	18	16
B3	0	12	0	14	4
B4	0	19	4	0	0
B5	0	15	9	11	0

Now five lines are required to cover all zeros, so lines (5) = n and an optimal matching exists.

6.6 Step 5: Select the assignment

Zeros are chosen starting with rows or columns that contain only one zero:

1. B2 has a single zero, in D3, so **B2 → D3**.
2. D3 is now taken, so B3 must use its other zero: **B3 → D1**.
3. D1 is taken, so B5 uses **B5 → D5**.
4. D5 is taken, so B4 uses **B4 → D4**.
5. The only banker and deal left are B1 and D2: **B1 → D2**.

The cost of each assignment is read from the **original** matrix, not from the reduced one.

Banker	Deal	Deal description	Cost (Rs lakh)
B1	D2	Pharma IPO	14
B2	D3	Infrastructure bond issue	17
Banker	Deal	Deal description	Cost (Rs lakh)
B3	D1	Cross-border M&A	24
B4	D4	LBO financing	17
B5	D5	Debt restructuring	10
Total			82



The minimum total cost is Rs 82 lakh.

7. TMcsults: Hungarian Method versus Simple Staffing TMulcs

Two plausible rules of thumb were compared with the optimal solution.

- **Sequential order** (B1→D1, B2→D2, and so on): $25 + 33 + 18 + 17 + 10 = 103$.
- **Greedy picks** (each banker in turn takes the cheapest deal still free): B1→D5 (13), B2→D3 (17), B3→D1 (24), B4→D4 (17), B5→D2 (26) = **97**.
- **Hungarian method: 82.**

Method	Total cost (Rs lakh)	Saving from the Hungarian result
Sequential order	103	21 lakh (−20.4%)
Greedy picks	97	15 lakh (−15.5%)
Hungarian method	82	Optimal

The greedy rule performs better than sequential staffing but is still 15 lakh above the optimum. It looks attractive because each local choice is cheap, yet it forces the last banker, B5, onto an expensive deal (D2 at 26) that a global view avoids. This illustrates why an exact method is needed rather than intuition.

8. Solution Tools and Validation

8.1 Accounting for the optimum

The optimal cost can be reconstructed from the reductions made along the way:

Component	Value
Row reductions	74
Component	Value
Column reductions	6
Adjustment: $2 \times (5 - 4)$	2
Optimal cost	82

8.2 Tools

- **By hand:** the Hungarian method itself, with $O(n^3)$ steps and practical up to about 10×10 .
- **Excel Solver:** use binary variables $x(i,j)$, constrain every row sum and column sum to 1, and minimise total cost.
- **Python:** `scipy.optimize.linear_sum_assignment`, as sketched below.



- **Specialist solvers:** LINGO or CPLEX, which become useful if side constraints are added.

```
import numpy as np
from scipy.optimize import linear_sum_assignment

cost = np.array([25, 14, 35, 13],
                [29, 33, 17, 38, 35],
                [24, 33, 18, 35, 24],
                [20, 36, 18, 17, 16],
                [14, 26, 17, 22, 10],
                ])
rows, cols = linear_sum_assignment(cost)
print(cost[rows, cols].sum())    # 82
```

8.3 Validation

The result was validated in three ways:

1. **Dual check.** The total reductions ($74 + 6$) plus the adjustment of $2 \times (5 - 4) = 2$ give 82. This lower bound equals the cost actually achieved, which certifies that 82 is optimal.
2. **Exhaustive enumeration.** All $5! = 120$ possible assignments were enumerated, and 82 is the **unique** minimum.
3. **Independent software.** SciPy's assignment solver returned the same value, 82. Sensitivity can be tested by re-running the model after changing any single cost.

9. Critical Analysis

9.1 Strengths

- It gives an **exact optimum**, not a heuristic approximation.
- It runs in **polynomial time**, so it scales to large n .
- It needs **only a cost matrix** as input.
- Its steps are **transparent and easy to audit**, which matters in regulated financial institutions.

9.2 Limitations

- Costs are **estimates** and may be subjective; the optimum is only as good as the numbers behind it.
- The model assumes **one banker per deal**, whereas real deals are run by teams.
- It ignores **banker preferences, conflicts of interest and compliance walls** (information barriers between advisory and other activities).
- It is a **static, single-period** decision, while deal pipelines and workloads change continually.
- The worked example uses **illustrative data**, so the Rs 82 lakh figure demonstrates the method and is not an empirical finding.



9.3 Extensions

- **Unbalanced cases:** add dummy rows or columns of zero cost when bankers and deals differ in number.
- **Teams:** use the generalised assignment problem or a linear/integer program in which each deal needs several people.
- **Multiple objectives:** weigh cost against client fit and banker development.
- **Dynamic use:** re-run assignments on a rolling basis as new mandates arrive, and treat uncertain costs with robust or stochastic formulations.
- **Side constraints:** conflicts and compliance restrictions can be modelled by assigning a prohibitively large cost to forbidden pairings, or by moving to LINGO or CPLEX.

10. Conclusion

Banker–deal staffing is a balanced, minimisation assignment problem. The Hungarian method solves it exactly through reduction, covering and adjustment. In the worked example it reduces the total cost to **Rs 82 lakh**, compared with Rs 103 lakh under sequential staffing and Rs 97 lakh under greedy picks. The optimum is certified by a dual bound and by full enumeration. The literature, from Kuhn's original algorithm to the Nahar et al. personnel-assignment study, confirms that the method transfers across domains.

Real use in an investment bank would require richer models that handle teams, preferences, compliance constraints and changing costs, but the assignment model is a sound and transparent starting point.

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