



# Hungarian maximization model approach for optimizing human resource assignment in multi-site projects

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## Abstract

Digital transformation in project management demands the implementation of computational models that are able to handle the complexity of human resource (HR) allocation efficiently and objectively. This study examines the application of the Hungarian algorithm in the form of maximization as a computer science-based optimization solution to the HR assignment problem in multi-location projects. By constructing a benefit matrix calculated from weighted attributes such as technical expertise, experience, and location preference, this study implements linear transformations and matrix processing procedures using a numerical approach in Python. This digitalization process allows the system to perform assignment evaluation and allocation automatically and with high precision. Simulation results on a case study of five workers and five project locations show that the model produces optimal assignments with a total benefit score of 420. This model proves its effectiveness in solving polynomial assignment problems, while expanding the use of the Hungarian algorithm in the domain of applied computer science to support data-driven decision making. This study emphasizes the role of classical algorithms in supporting scalable and replicable digital solutions for modern HR management systems.

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## 1. Introduction

In an era of increasingly complex globalization and digitalization, organizations are required to be able to manage resources adaptively and efficiently, especially in the context of multi-location projects involving cross-regional coordination. Assigning human resources (HR) in such projects is a strategic challenge because it must consider variables such as individual expertise, geographic location, relocation costs, and project deadlines [1]. Inefficiency in HR placement can lead to waste of resources, schedule conflicts, and delays in achieving project targets [2]. Complexity increases with the growth of large-scale projects spread across multiple locations, where organizations must make assignment decisions in a short time but remain accurate. In practice, many organizations still use conventional

approaches that are subjective or intuition-based in assigning personnel, which often do not result in optimal labor allocation [3]. This issue underscores the need for a systematic, data-driven approach to support efficient and sustainable HR assignment decisions [4]. Although the challenges in HR assignment have long been identified, quantitative approaches to optimize workforce distribution in multi-location projects are still rarely implemented systematically. Most organizations still rely on subjective assessments or manual systems in allocating personnel, which tend to ignore the maximum potential of each individual based on competence, productivity, and suitability of the task location. In today's digital era, one of the models that can be utilized for HR management is the operations research technique [5][6][7].

Operations Research (OR) techniques are a scientific approach to decision making that aims to help organizations solve complex problems using quantitative and mathematical methods.[8][9][10]. Operations research techniques aim to assist in scientific, objective and optimal decision making in complex situations that are limited by various constraints [11]. In the context of operations research, the assignment problem model offers a mathematical approach to solving this problem, and one algorithm that has proven to be efficient is the Hungarian algorithm [12]. The Hungarian algorithm is a mathematical method used to solve assignment problems optimally [13][14][15][16]. The Hungarian method is generally divided into two main forms of approach, namely Hungarian for minimization and Hungarian for maximization [17][18]. Most previous studies have focused more on cost minimization applications in the context of manufacturing or transportation [19][20][21], while the use of the Hungarian model in benefit maximization scenarios, especially for HR assignments across project locations, is still very limited. This gap indicates a lack of exploration of the application of the Hungarian maximization model as a strategic solution in supporting data-driven project management decisions [22][23]. Therefore, research is needed that not only adapts the algorithm to the needs of HR assignment, but also tests it in the context of complex and dynamic multi-location projects.

Based on these problems, this study aims to implement the Hungarian model in the form of maximization to optimize human resource assignments on multi-location projects efficiently. The main focus of this study is to maximize the fit between individuals and tasks based on contribution or fit scores, which are calculated through indicators such as technical expertise, project experience, and work location preferences. This approach differs from traditional models that tend to prioritize cost minimization alone, because it considers the strategic value of individual productivity in the context of distributed projects. This study also provides theoretical contributions by extending the application of the Hungarian algorithm to relevant maximization scenarios in modern project management—an area that is still underexplored in the academic literature. In addition, the practical contribution of this study lies in the development of a decision-making framework that can be used by project managers to distribute labor objectively and based on data, thereby improving operational efficiency while supporting the achievement of project targets more holistically.

To answer the research objectives, this study uses a quantitative approach with a case-based modeling method, where individual qualification data, project locations, and task fit scores are converted into a benefit matrix. This matrix is then used as input in the application of the Hungarian maximization model, which is modified to suit the context of inter-location HR assignment. The algorithm is implemented using Python programming with the `scipy.optimize` library, and the optimal assignment results are analyzed using efficiency and task consistency metrics. A case study was conducted on an organization running a project in three different locations, to demonstrate the validity and scalability of the model in real situations. In terms of significance, this study not only contributes to the development of Hungarian algorithm applications outside the manufacturing context, but also offers a data-driven framework to assist project managers in making objective, fair,

and measurable assignment decisions. In the long term, the application of this method has the potential to increase project productivity and organizational efficiency in managing workforces in complex and geographically dispersed project environments.

## 2. Methods

This study uses a quantitative approach based on case studies, with the application of the Hungarian maximization algorithm to solve the problem of human resource assignment in multi-location projects. The main objective of this method is to obtain an optimal assignment configuration that maximizes the fit between individuals and task locations based on the constructed benefit matrix. The research process is carried out through four main stages:

1. Identification and Data Collection: Primary data was collected from the organizations running the project in three different locations. The information collected includes:
  - a. Employee profile (technical skills, experience, location preferences),
  - b. Human resource needs for each location (number, type of expertise),
  - c. Employee-location match matrix, normalized to a value between 0–100.
2. Benefit Matrix Construction: A two-dimensional matrix is formed with rows representing individuals and columns representing task locations. Each cell contains a match score based on weighted weights of criteria such as competence, experience, and location.
3. Hungarian Maximization Model Implementation: The Hungarian algorithm is used to solve assignment problems optimally. Since the standard version is minimization [24], the benefit matrix is transformed through a linear transformation to conform to the maximization form [25]. The implementation of the Hungarian maximization method is carried out following the model stages, namely:
  - a. *Forming a Profit Matrix*  
Construct a two-dimensional matrix where rows represent agents (e.g., HR) and columns represent tasks (e.g., project locations). Each element of the matrix is a benefit value or match score between agents and tasks.
  - b. *Maximization Matrix Transformation*  
Since the Hungarian algorithm only works for minimization, perform the following transformation:
    - a) Find the maximum value across all elements of the benefit matrix.  $M$
    - b) Create a new matrix with the equation:

$$c_{ij} = M - a_{ij} \quad (1)$$

where  $a_{ij}$  is the original element of the benefit matrix. This matrix becomes the cost matrix for minimization.

- c. *Row Reduction*  
Subtract each element in a row from the smallest value in that row so that each row has at least one zero element.
- d. *Column Reduction*  
After row subtraction, subtract each element in a column from the smallest value in that column so that each column has at least one zero element.
- e. *Covering Zeros*  
Mark the zeros in the matrix with the minimum number of horizontal and/or vertical lines that cover all zeros. If the number of lines is equal to the number of rows (or columns), then the optimal solution can be found in the next step.

- f. *Matrix Adjustment If Solution Is Not Optimal*  
If the number of lines covering zero is less than the number of rows, find the smallest element that is not covered by any line.*k*
- Subtract from all uncovered elements.*k*
  - Add to the elements that lie at the intersection of the horizontal and vertical lines. Repeat the zero-closing process until the optimal solution is reached.*k*
- g. *Determining Optimal Assignment*  
Once the number of zero-covering lines is equal to the number of rows, determine the assignment that maximizes the original value by choosing non-overlapping zero elements (one per row and one per column).
- h. *Returning Maximization Solution*  
Due to the initial transformation, the results of the assignments to the cost matrix can be used to determine the assignments to the original benefit matrix so that the maximum total score is achieved [26].
4. **Analysis and Evaluation of Results:** The final solution is analyzed based on the metrics of assignment efficiency, HR utilization rate, and comparison to conventional methods (manual/manual decision-based). Evaluation is done using quantitative analysis of the assignment results generated by the algorithm.

The Hungarian algorithm was chosen because of its ability to optimally solve linear assignment problems with polynomial time complexity, making it suitable for applications with medium to large data scales [27]. Modifications are made only on the transformation of values in the benefit matrix to suit the maximization context, without changing the structure of the basic algorithm. The results of the analysis will be tested using Python software that uses the NumPy and SciPy libraries.

### 3. Results and Discussions

This study uses data from a construction company that runs six projects in different locations: Location A, Location B, Location C, Location D and Location E. There are six workforces with different skill profiles and location preferences. A benefit matrix representing the level of benefit obtained by the company for individual assignments with each project location is built based on the parameters of technical competence, field experience, and personal preferences, with nominal values in millions.

Table 1.  
Profit Matrix

HR	Location A	Location B	Location C	Location D	Location E
SDM <sub>1</sub>	85	70	60	75	75
HR <sub>2</sub>	75	90	65	60	80
SDM <sub>3</sub>	60	55	80	70	75
SDM <sub>4</sub>	70	85	75	85	90
SDM <sub>5</sub>	80	60	70	75	55

The transformation of a matrix maximizes a row by finding the maximum value in the row and subtracting each value in the row from the selected maximum value.

Maximum value on each line:

$$c_1 = 85$$

$$c_2 = 90$$

$$c_3 = 80$$

$$c_4 = 90$$

$$c_5 = 80$$

From the results of row maximization, a matrix is obtained as in the following table:

Table 2.  
Row Redaction Matrix

HR	Location A	Location B	Location C	Location D	Location E
SDM1	0	15	25	10	10
HR2	15	0	25	30	10
SDM3	20	25	0	10	5
SDM4	20	5	15	5	0
SDM5	0	20	10	5	25

Form a change matrix in a column by subtracting each value in the column from the lowest value in each column. The lowest value in each column produces the following results:

$$j_1 = 0$$

$$j_2 = 0$$

$$j_3 = 10$$

From the results of column minimization, a matrix is obtained as in the following table:

Table 3.  
Column Redaction Matrix

HR	Location A	Location B	Location C	Location D	Location E
SDM1	0	15	25	5	10
HR2	15	0	25	25	10
SDM3	20	25	0	5	5
SDM4	20	5	15	0	0
SDM5	0	20	10	0	25

Perform covering zeros or closing 0 values on rows and columns to test the optimal value, covering zeros are made with horizontal and/or vertical lines that cover all zeros. Horizontal lines to cover 0 values on columns and vertical lines to cover 0 values on rows.

Table 4.  
Covering Zeros

HR	Location A	Location B	Location C	Location D	Location E
SDM1	0	15	25	5	10
HR2	15	0	25	25	10
SDM3	20	25	0	5	5
SDM4	20	5	15	0	0
SDM5	0	20	10	0	25

Table 4 shows the optimality testing stage in the Hungarian algorithm process on the HR assignment maximization model to the project. This table is a matrix resulting from the transformation of the benefit matrix (profit matrix) into a minimization form.

The red triangle mark on each zero value (0) indicates the location of the zero value that has been identified as an optimal assignment candidate. At this stage, covering zeros is performed by:

1. Vertical line: marks the zero closure on a row — meaning a row can only have one active zero assignment (a single assignment for each HR).

2. Horizontal line: marks a zero closure on a column — meaning that one column (project location) can only be assigned to one HR.

Each zero value marked with a triangle is the result of subtracting rows and columns in the cost matrix, and represents the points of possible optimal assignments between HR and project locations. These points are later selected to produce the final solution that maximizes the total benefit score. This step is important in the Hungarian algorithm because the number of cover lines needed to cover all zeros determines whether the optimal solution has been achieved. If the number of lines is equal to the number of rows or columns, then the optimal solution has been found and the assignment can be determined. Table 4 shows that the solution has reached the optimal condition, indicated by the number of zero cover lines (5) which is equal to the number of rows (5) and equal to the number of columns (5), so that the assignment can be determined without the need for further iterations.

From Table 4 it is known that the allocation of HR assignments at the project location is:

HR 1 => Location A : 85

SMD 2 => Location B : 90

HR 3 => Location C : 80

HR 4 => Location E : 90

HR 5 => Location D : 75

And the profit obtained from the assignment allocation is:

$Profit = 85 + 90 + 80 + 90 + 75$

$Profit = 420$ (value in millions)

To test the accuracy of the manual calculation results, data analysis was carried out using Python software using NumPy and SciPy libraries for the Hungarian maximization model. From the test results with Python software, the results are as shown in Figure 1.

```

import numpy as np
from scipy.optimize import linear_sum_assignment

profit_matrix = np.array([
    [85, 70, 60, 75, 75], # SDM1
    [75, 90, 65, 60, 80], # SDM2
    [60, 55, 80, 70, 75], # SDM3
    [70, 85, 75, 85, 90], # SDM4
    [80, 60, 70, 75, 55], # SDM5
])

max_value = np.max(profit_matrix)
cost_matrix = max_value - profit_matrix

row_ind, col_ind = linear_sum_assignment(cost_matrix)

print("Penugasan Optimal (SDM -> Lokasi):")
total_profit = 0
for i in range(len(row_ind)):
    sdm = f"SDM{row_ind[i] + 1}"
    lokasi = f"Lokasi {chr(ord('A') + col_ind[i])}"
    nilai = profit_matrix[row_ind[i], col_ind[i]]
    print(f"{sdm} -> {lokasi} (Nilai: {nilai})")
    total_profit += nilai

print(f"\nTotal Profit Maksimum: {total_profit}")

```

Penugasan Optimal (SDM -> Lokasi):  
 SDM1 -> Lokasi A (Nilai: 85)  
 SDM2 -> Lokasi B (Nilai: 90)  
 SDM3 -> Lokasi C (Nilai: 80)  
 SDM4 -> Lokasi E (Nilai: 90)  
 SDM5 -> Lokasi D (Nilai: 75)  
 Total Profit Maksimum: 420

Figure 1. Testing with Python software

Figure 1 shows the results of the Hungarian algorithm implementation for the HR assignment maximization model to project locations using the Python programming language. A profit matrix consisting of five HRs and five project locations is used as input. Since the `linear_sum_assignment` algorithm from the `scipy.optimize` library works for minimization by default, a matrix transformation is performed by subtracting all values from the maximum value of the matrix (`max_value - profit_matrix`), so that it can be adjusted for the maximization case. After the transformation process, the algorithm produces an optimal assignment by placing each HR to the location that provides the highest contribution value without any assignment conflicts. The final result shows that HR<sub>1</sub> is assigned to Location A with a value of 85, HR<sub>2</sub> to Location B with a value of 90, HR<sub>3</sub> to Location C with a value of 80, HR<sub>4</sub> to Location E with a value of 90, and HR<sub>5</sub> to Location D with a value of 75. The total maximum profit obtained from this assignment configuration is 420, indicating that the optimal solution has been successfully achieved by the algorithm. This output also validates the effectiveness of the Hungarian method in solving data-based assignment problems accurately and efficiently.

The implementation of the Hungarian model in the form of maximization in this study is proven to be able to produce optimal human resource (HR) assignment configurations on multi-location projects. With a data-based approach through a profit matrix that represents the match score between individuals and task locations, this system provides an objective alternative to conventional methods that still rely on intuition or subjective managerial preferences.

The final results of the assignment show that each worker was placed at the project location with the highest relative benefit value, which is reflected in the contribution score, namely SDM<sub>1</sub> to Location A (85), SDM<sub>2</sub> to Location B (90), SDM<sub>3</sub> to Location C (80), SDM<sub>4</sub> to Location E (90), SDM<sub>5</sub> to Location D (75).

Thus, the total benefit score obtained is 420 points, which reflects the highest allocation efficiency that can be achieved from all available combinations. This achievement shows that the transformation of the maximization matrix into the minimization form—which is the operational prerequisite of the Hungarian algorithm—is successfully implemented correctly. The systematic procedure involving row and column reduction, as well as the covering zeros mechanism, demonstrates the algorithmic power in optimizing assignments based on quantitative values representing multidimensional matches.

Furthermore, the success of this model in solving problems with five workers and five project locations demonstrates the scalability of the approach to more complex real-world contexts. This model can be extended and integrated into digital-based project management decision-making systems, especially in organizations that manage simultaneous projects across multiple geographic locations. The effectiveness of the algorithm is also strengthened by the low computation time and the stability of the results despite variations in the input benefit matrix.

Compared to conventional methods, such as manual allocation that tends to be suboptimal and prone to decision bias, the Hungarian maximization model offers a transparent, replicable, and evidence-based approach. This becomes important in the context of an organization's digital transformation, where accountability and traceability of decisions are key prerequisites for modern HR governance [28][29][30].

Theoretically, these results broaden the scope of applications of the Hungarian algorithm, which has so far been used more in the context of cost minimization in the logistics or manufacturing sectors [31]. This study confirms that the algorithm is not only compatible for maximization problems in the HR domain, but also adaptive to complex parameters such as location preferences, work experience, and competency fit.

In practice, these findings provide significant contributions for project managers and HR strategists in developing a more strategic and measurable HR assignment system. Thus, this study not

only offers mathematical solutions, but also encourages a paradigm shift in organizational decision making—from intuition-based to efficient and adaptive data-driven decision making.

#### 4. Conclusion

This study successfully demonstrates that the implementation of the Hungarian model in the form of maximization can be used effectively to optimize human resource (HR) assignments on multi-location projects. By building a benefit matrix based on quantitative parameters such as technical competence, work experience, and location preferences, this model is able to provide objective, efficient, and appropriate assignment solutions to the maximum potential of each individual. The results of the analysis show that all workers can be optimally placed at project locations that provide the highest contribution to organizational performance, with a total benefit score of 420. The matrix transformation process and algorithmic stages carried out, such as row/column reduction and zero closing, prove the accuracy and stability of the model in handling complex assignment problems. This study expands the scope of the Hungarian algorithm application from the context of cost minimization in the industrial sector to strategic applications in project HR management. In practice, this model provides an alternative data-based decision-making that can be integrated into a modern project management system to improve efficiency, transparency, and accountability in workforce allocation. This study not only offers a mathematical solution that is proven to be effective, but also contributes to the digital transformation of organizational HR management in an era of increasingly complex and geographically dispersed projects.

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