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Application of Modified Ghadle-Munot Method in Applied Mathematics Learning through Chocolate Production Case Study at CV. Putra Mataram Sedalu

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Abstract

Applied mathematics plays an important role in solving real-world problems, including in the agricultural product processing industry. This study aims to apply the Modified Ghadle-Munot method to solve employee assignment problems in a private company operating in chocolate production and to connect its implementation with applied mathematics learning. The core issue addressed is the imbalance between the number of employees and the number of production stages, which creates an unbalanced assignment problem. This study uses an applied quantitative research approach with assignment optimization as the main variable. Data were collected through interviews and documentation related to the production process and employee task distribution. The results showed that the Modified Ghadle-Munot method was able to reduce the total work time from an initial average of 970 minutes to 660 minutes. The application of this algorithm not only improves operational efficiency but also carries educational value. It can serve as a contextual case study in teaching applied mathematics, particularly in linear programming and optimization. Therefore, this research contributes both to practical problem-solving in small-scale industry settings and to strengthening real-world, problem-based learning in mathematics education.

Keywords: *Applied mathematics, optimization, employee assignment, Modified Ghadle-Munot, contextual education*

1. Introduction

Mathematics is not only an abstract science learned in the classroom, but also an important tool for solving real problems in various fields of life, including industry, economics, and resource management. In the context of education, especially mathematics education, it is important for students to understand how mathematical concepts can be applied directly to everyday problems. Applied mathematics learning encourages students to think critically, analytically, and solve complex real situations. One relevant approach to strengthen this understanding is through case studies in the industrial world.

This research presents a case study from the real world, namely the problem of employee assignment in the chocolate production process at CV. Putra Mataram Sedalu, Polewali Mandar. In the company, the limited number of workers and the many stages of production create an unbalanced assignment problem. This problem can be solved using mathematical concepts in the form of assignment models and optimization algorithms, which have been widely studied in various industries with different constraints such as time windows, resource limitations, and uncertainty (Wang, Liu and Lin, 2022; Gozali, 2024). One of the methods used is the Modified Ghadle-Munot Algorithm, which is not only effective in solving industrial problems, but also relevant as teaching material in applied mathematics education.

In 2017-2021, Indonesia will become the world's third-largest cocoa producer. It is the largest cocoa production center in the world (Associated Press, 2024). The fact that a lot of employment and income is generated by farmers shows how important cocoa is to the Indonesian economy. Cocoa production fell by 10% to 641 thousand tons in 2024 from 648 thousand tons in 2023. According to the Central Bureau of Statistics (BPS), West Sulawesi is the province with the 4th largest cocoa bean producer in all of Sulawesi. It is also the province that produces the most cocoa beans out of the 10 largest provinces in Indonesia (Badan Pusat Statistik, 2023). According to BPS records in 2023, during 2022 Polewali Mandar district has produced as much as 36,428.11 tons of cocoa from all 16 sub-districts in the region (Kementrian Pertanian, 2023). This certainly opens up opportunities for the region to produce cocoa into saleable products. To do this, a cocoa industry is needed that can serve as a production house to produce products such as chocolate. Cocoa from Polewali Mandar, with its superior quality, will be an important asset in the development of a local chocolate processing industry (Badan Pusat Statistik, 2023). However, as the chocolate processing industry develops, there are many problems in terms of operations and human resource management. One of the main problems is how to optimally utilize the resources owned, namely the problem of dividing the workforce into jobs (Abdullah and Patria, 2024). This problem is usually called the assignment problem (Rumetna *et al.*, 2025).

The company must address all of its issues. This includes production issues such as workmanship and readiness of materials and tools, as well as employee issues such as scheduling and organization and placement of employees that do not match their abilities (Mardiani *et al.*, 2020). The linear program model is one of the methods that can be used to solve production problems and employee tasks (Sipni and Rarasati, 2025). Using this model, companies can determine the ideal production capacity, create efficient work schedules, and maximize employee productivity to meet market demand and resource constraints (Erfianti and Muhaijir, 2020).

There are many problems in linear programming, including production optimization problems, distribution problems through transportation models and also resource management problems through assignment models (Riani and Laharjingga, 2024). However, this research discusses the assignment problem. The assignment model itself aims to assign appropriate tasks to workers so as to optimize the total resource expenditure in completing the task (Mardiani *et al.*, 2020). With the employee assignment problem, there are many methods that can be used, such as genetic algorithms (Gozali, 2024), simulation-based models for dual constraints (Fernandes *et al.*, 2022), and fuzzy multi-objective approaches (Kimamporn and Nunkaew, 2025), which show the diversity of strategies to address real-world complexity, but in this problem the author will use the Modified Ghadle-Munot Algorithm method (Anggraini, Pasaribu and Prihandono, 2024). Ressa Anggraini, Meliana Pasaribu and Bayu Prihandono with an article entitled “Solving Unbalanced Assignment Problems Using the Modified Ghadle-Munot Algorithm”. From the results of the study it was found that to solve unbalanced problems we can use one of the modified methods of the Hungarian method, namely the modified Ghandle-Munot algorithm. This is a form of optimization with a matrix that does not use a rectangular matrix, but a matrix with different columns and rows. And in this study can be optimized for problems on unbalanced assignments. The results found in this study are that 1 employee can be assigned to two places (Anggraini, Pasaribu and Prihandono, 2024).

CV. Putra Mataram Sedalu is a private company engaged in the production of chocolate and cocoa-based beverages. Based on initial observation, the company employs three employees who are responsible for ten stages in the chocolate production process, namely fermentation, drying, sorting, roasting, stripping, first grinding, second grinding, tempering, molding, and summarization. However, there is no structured division of tasks between employees. There is no shift work system or assignment based on specific skills. All employees carry out general tasks, so there is often an overlap of work which results in low operational efficiency. The main products produced by the company are couverture chocolate and compound chocolate, both in bar and powder form. Currently, production decisions are still estimative and not based on systematic calculations or optimization approaches. Therefore, the problem in this study is formulated as an assignment model optimization problem, namely how to optimally allocate three employees to ten production stages in order to minimize total work time and improve the company's operational efficiency.

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The linear program model is one method that can be used to solve production and employee assignment problems. Through this model, companies can determine the ideal production capacity, develop efficient work schedules, and maximize employee productivity according to limited resources. One approach in solving the assignment problem is the Modified Ghadle-Munot Algorithm method, which is a development of the Hungarian method. This method is considered capable of handling unbalanced assignment problems, where the number of jobs is greater than the number of employees (Rahmawati *et al.*, 2024).

Thus, this research not only provides solutions to production problems at CV. Putra Mataram Sedalu, but also a means of contextual learning in applied mathematics education. Through this approach, students can understand the relevance and application of mathematical concepts in the real world of work.

2. Metode

This research uses a quantitative approach with the type of applied research. This approach was chosen because it aims to apply mathematical concepts, especially assignment models and optimization algorithms, in solving real problems in the industrial world, as well as integrating them into the context of applied mathematics education (Purba, Sinaga and Sianturi, 2024). By using a case study at CV. Putra Mataram Sedalu, this research also aims to provide contextual teaching materials for college-level mathematics learning, especially in operations research or linear programming courses. The data used consists of primary data and secondary dat a. Primary data was obtained through direct observation, interviews, and documentation of the chocolate production process and the division of employee duties at CV. Putra Mataram Sedalu. Secondary data is obtained from supporting documents such as work reports and production time records of each employee. Data collection was carried out in May 2025. The process of solving the assignment problem was carried out using the Modified Ghadle-Munot Algorithm, which aligns with recent optimization studies involving unbalanced assignment and real-time adaptation in resource-constrained scheduling (Zhao, Sun and Yamamoto, 2024). The stages of applying this algorithm are modeled as part of the problem-based learning process, which can be replicated in classroom mathematics learning.

This research was conducted using the Modified Ghadle-Munot algorithm with the following stages (Munot and Ghadle, 2020):

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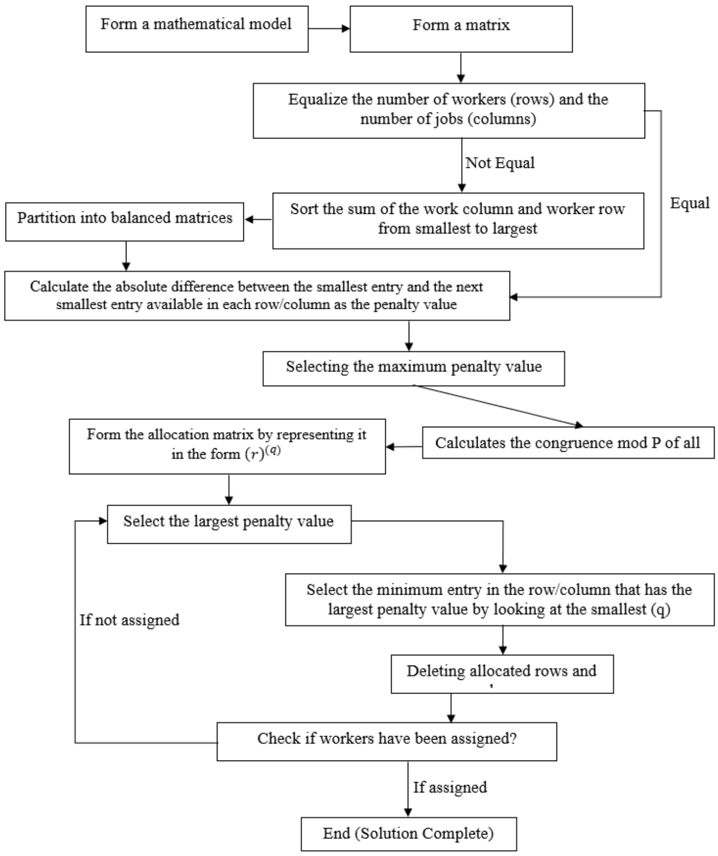

Figure 1 Stages of completion

a) Form a mathematical method of an assignment problem.
b) Form a matrix from the assignment table that has been compiled. The matrix is formed in order to facilitate the solution process at each step.
c) Whether the number of rows of workers is the same as the number of columns of work. If it is the same, then proceed directly to step 6. But if it is not the same, then add up each column of work (Sum Column) and each row of workers (Sum Row). Then the process continues to step 4.
d) Sort the results of the sum of job columns (Sum Column) and the sum of worker rows (Sum Row) from smallest to largest.
e) Partition the assignment matrix into $m \times m$ form and obtained n kth balanced matrix. The next process is to solve the kth matrix with k $k = 1,2, \ldots n$.
f) Calculate the absolute difference between the smallest entry and the next smallest entry available in each row/column as the penalty value.
g) Selecting the maximum penalty value among all penalties. The maximum penalty value is denoted by P.
h) Calculates the congruence $mod\ P$ of all kth matrix entries. Then, form the allocation matrix by representing it in the form $(r)^{(q)}$ where (r) is the remainder of the quotient $mod\ P$ and (q) is the quotient $mod\ P$.
i) Check if the largest penalty value in each row/column is the same? If not then select the available row/column with the largest penalty value and proceed to step 10.
j) Select the minimum entry in the row/column that has the largest penalty value by looking at the smallest (q). Check if the row/column with the largest penalty value has the same smallest (q)? If no then allocate $x_{i,j}$ to the cell in the row/column with the largest penalty value by selecting the smallest (q) result. If yes then allocate $x_{i,j}$ to the cell in the row/column that has the largest penalty value by selecting the minimum (r) among the smallest (q). Then the process continues to step 11.

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k) Deleting allocated rows and columns. The deleted rows and columns are not involved for the next allocation.
l) Have all workers been assigned to each job? If not then the process continues to step 9. If yes then the solution for the kth matrix with $k = 1,2,\dots,n$.

Have all the kth partition matrices with $k = 1,2,\dots,n$ been investigated? If not then the process continues to step 6. If yes then the solution is optimal. This model also illustrates how the process of math-based decision-making can be learned and applied in real terms by students in understanding the role of mathematics in the world of work.

3. Results and Discussion

CV. Putra Mataram Sedalu is one of the chocolate production sites in Polewali Mandar Regency, West Sulawesi. The company was established in 2015 in Wonomulyo sub-district. In addition to producing goods, this company also has a cafe that is directly connected to the production site so that visitors who come to the location can see firsthand the chocolate production process in the company. There are 3 employees in this company in the production section. The company produces 5 kinds of couverture chocolate in the company.

The company was founded by several people namely M. Haritz Satrio, Dheny Frisandi Nur, Muh. Akbar Anar, and M. Taqwin with the motivation that in Polewali Mandar also has a company that produces chocolate. By capitalizing on the old industry that is no longer used, CV. Putra Mataram Sedalu is still operating well today. There are two kinds of chocolate produced in this factory, namely Compound chocolate and Couvertur chocolate. However, the only chocolate produced in this company is Couvertur chocolate, while Compound chocolate used to be produced in this company. However, currently the goods are imported in a semi-finished state and continued at this company for the final touch in the production stage and distributed to various places. So that in this study only performs optimization calculations on products that are overall carried out at CV. Putra Mataram Sedalu.

To solve the assignment problem is done with the following steps:

a. Model the above assignment problem into an amtematics model by determining the decision variables, objective function and constraint function.

Table 1 Total time to complete each stage for each employee (minutes)

Employees	Production Stages										Capacity (Employee)
	I	II	III	IV	V	VI	VII	VIII	IX	X	
1	45 x_{11}	120 x_{12}	60 x_{13}	210 x_{14}	120 x_{15}	45 x_{16}	60 x_{17}	120 x_{18}	60 x_{19}	60 x_{110}	1
2	60 x_{21}	180 x_{22}	180 x_{23}	60 x_{24}	120 x_{25}	60 x_{26}	60 x_{27}	90 x_{28}	30 x_{29}	120 x_{210}	1
3	60 x_{31}	180 x_{32}	180 x_{33}	210 x_{34}	120 x_{35}	60 x_{36}	60 x_{37}	60 x_{38}	60 x_{39}	60 x_{310}	1
Capacity (Production Stages)	1	1	1	1	1	1	1	1	1	1	3 / 10

(*Source : CV. Putra Mataram Sedalu*)

1) Decision Variable

This decision variable is taken by looking at the assignments in CV. Putra Mataram Sedalu. These assignments are taken from the stages involved in the chocolate making process at this company. The assignments and employees in the chocolate making process at this company are as follows:

1) Employees
   a) A
   b) H
   c) HS
2) Tasks
   a) Fermentation
   b) Drying
   c) Sorting
   d) Roast
   e) Stripping

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f) First Mill
g) Second Mill
h) Tempering
i) Print
j) Summarization

The decision variable in this problem is the i-th employee assigned/not assigned to the j-th production stage. The notation of the variable can be seen as follows:

$$x_{i,j} = \begin{cases} 1, & if\ the\ i-th\ employee\ is\ assigned\ to\ the\ j-th\ production\ stage \\ 0, & if\ the\ i-th\ employee\ is\ not\ assigned\ to\ the\ j-th\ production\ stage \end{cases}$$

With $i = 1, 2, 3$ and $j = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10$.

2) Objective Function

$$Minimize\ Z = \sum_{i=1}^{3}\sum_{j=1}^{10} C_{ij}X_{ij}$$

3) Constraint Function

Employee Constraints

$$\sum_{j=1}^{10} x_{ij} \geq 1. \quad for\ i = 1, 2, 3$$

Production Stage Constraints

$$\sum_{i=1}^{3} x_{ij} = 1.\ for\ j = 1.2.3.4.5.6.7.8.9.10$$

b. Organize the table 1. above into a matrix form to facilitate the completion of the next step.

$$\begin{array}{cccccccccccc} & \text{I} & \text{II} & \text{III} & \text{IV} & \text{V} & \text{VI} & \text{VII} & \text{VIII} & \text{IX} & \text{X} \end{array}$$

$$M = \begin{matrix} K_1 \\ K_2 \\ K_3 \end{matrix} \begin{bmatrix} 45 & 120 & 60 & 210 & 120 & 45 & 60 & 120 & 60 & 60 \\ 60 & 180 & 180 & 60 & 120 & 60 & 60 & 90 & 30 & 120 \\ 60 & 180 & 180 & 210 & 120 & 60 & 60 & 60 & 60 & 60 \end{bmatrix}$$

Description:
K_1 = A
K_2 = H
K_3 = HS
I = Fermentation
II = Drying
III = Sorting
IV = Roast
V = Stripping
VI = First Mill
VII = Second Mill
VIII = Tempering
IX = Print
X = Summarization

c. Based on the material above, the assignment matrix is not balanced because the number of employees is less than the number of stages or jobs. So first sort the sum column and sum row which will be used to form a balanced matrix.

Table 2 The sum of each row and each column

Employees	Production Stages										*Sum Row*
	I	II	III	IV	V	VI	VII	VIII	IX	X	
K_1	45	120	60	210	120	45	60	120	60	60	**900**

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K_2	60	180	180	60	120	60	60	90	30	120	**960**
K_3	60	180	180	210	120	60	60	60	60	60	**1050**
Sum Column	**165**	**480**	**420**	**480**	**360**	**165**	**180**	**270**	**150**	**240**	

Obtained for Sum Column as follows:

I	II	III	IV	V	VI	VII	VIII	IX	X
165	480	420	480	360	165	180	270	150	240

Obtained for Sum Row as follows:

K_1	K_2	K_3
900	960	1050

d. Next, sort the results of the sum of columns and rows from the smallest to the largest.
Sum Column : IX, I, VI, VII, X, VIII, V, III, IV, II
Sum Row : K_1, K_2, K_3

e. Partition the matrix into an $m \times m$ balanced matrix. Partitioning must be in accordance with the existing constraints, so to solve the unbalanced matrix, namely by adjusting the smallest number of jobs and workers. Based on this, 4 matrices are obtained as follows:

$$A_1 = \begin{matrix} & \text{IX} & \text{I} & \text{VI} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{bmatrix} 60 & 45 & 45 \\ 30 & 60 & 60 \\ 60 & 60 & 60 \end{bmatrix}$$

$$A_2 = \begin{matrix} & \text{VII} & \text{X} & \text{VIII} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{bmatrix} 60 & 60 & 120 \\ 60 & 120 & 90 \\ 60 & 60 & 60 \end{bmatrix}$$

$$A_3 = \begin{matrix} & \text{V} & \text{III} & \text{IV} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{bmatrix} 120 & 60 & 210 \\ 120 & 180 & 60 \\ 120 & 180 & 210 \end{bmatrix}$$

$$\begin{matrix} & \text{II} \\ A_4 = K_1 & [120] \end{matrix}$$

Next, solve each matrix using the Modified Ghadle-Munot Algorithm.

f. Next, calculate the absolute value of the difference between the smallest entry and the next smallest entry available in each row/column in matrix A_1. Then the penalty value is obtained from the result of the difference. The penalty value obtained can be seen as follows:

$$A_{1P} = \begin{matrix} & \text{IX} & \text{I} & \text{VI} & \text{Penalty} \\ K_1 & 60 & 45 & 45 & 0 \\ K_2 & 30 & 60 & 60 & 30 \\ K_3 & 60 & 60 & 60 & 0 \\ \text{Penalty} & 30 & 15 & 15 & \end{matrix}$$

$$A_{2P} = \begin{matrix} & \text{VII} & \text{X} & \text{VIII} & \text{Penalty} \\ K_1 & 60 & 60 & 120 & 0 \\ K_2 & 60 & 120 & 90 & 30 \\ K_3 & 60 & 60 & 60 & 0 \\ \text{Penalty} & 0 & 0 & 30 & \end{matrix}$$

$$A_{3P} = \begin{matrix} & \text{V} & \text{III} & \text{IV} & \text{Penalty} \\ K_1 & 120 & 60 & 210 & 60 \\ K_2 & 120 & 180 & 60 & 60 \\ K_3 & 120 & 180 & 210 & 60 \\ \text{Penalty} & 0 & 120 & 150 & \end{matrix}$$

g. The maximum penalty value among all penalty values obtained is for matrix A_{1P} is 30, matrix A_{2P} is 30, and matrix A_{3P} is 150 or $P = 30$, $P = 30$, and $P = 150$.

h. matrices A_{1P}, A_{2P}, and A_{3P} and form the allocation matrix with each entry represented in the form $(r)^{(q)}$ where (r) is the remainder term $mod\ P$ and (q) is the quotient $mod\ P$, then:

$$c_{i,j} \equiv (r)\ mod\ P \Leftrightarrow c_{i,j} = P(q) + (r)$$

Calculation of congruence $mod\ P$ of all matrix entries A_{1P} is $P = 30$ and $c_{i,j} = 30(q) + (r)$, A_{2P} is $P = 30$ and $c_{i,j} = 30(q) + (r)$, and A_{3P} is $P = 120$ and $c_{i,j} = 120(q) + (r)$.

Then, based on the results of the previous congruent $mod\ P$ calculation, the allocation matrix can be seen as follows:

$$\begin{array}{cc} & \begin{array}{ccc} IX & I & VI \end{array} & \text{Penalty} \\ A_{1A} = \begin{array}{c} K_1 \\ K_2 \\ K_3 \end{array} & \begin{bmatrix} (0)^{(2)} & (15)^{(1)} & (15)^{(1)} \\ (0)^{(1)} & (0)^{(2)} & (0)^{(2)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{bmatrix} & \begin{array}{c} 0 \\ 30 \\ 0 \end{array} \\ \text{Penalty} & \begin{array}{ccc} 30 & 15 & 15 \end{array} & \end{array}$$

$$\begin{array}{cc} & \begin{array}{ccc} VII & X & VIII \end{array} & \text{Penalty} \\ A_{2A} = \begin{array}{c} K_1 \\ K_2 \\ K_3 \end{array} & \begin{bmatrix} (0)^{(2)} & (0)^{(2)} & (0)^{(4)} \\ (0)^{(2)} & (0)^{(4)} & (0)^{(3)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{bmatrix} & \begin{array}{c} 0 \\ 30 \\ 0 \end{array} \\ \text{Penalty} & \begin{array}{ccc} 0 & 0 & 30 \end{array} & \end{array}$$

$$\begin{array}{cc} & \begin{array}{ccc} V & III & IV \end{array} & \text{Penalty} \\ A_{3A} = \begin{array}{c} K_1 \\ K_2 \\ K_3 \end{array} & \begin{bmatrix} (45)^{\left(\frac{1}{2}\right)} & (10)^{\left(\frac{1}{3}\right)} & (60)^{(1)} \\ (45)^{\left(\frac{1}{2}\right)} & (30)^{(1)} & (10)^{\left(\frac{1}{3}\right)} \\ 1(45)^{\left(\frac{1}{2}\right)} & (30)^{(1)} & (60)^{(1)} \end{bmatrix} & \begin{array}{c} 60 \\ 60 \\ 60 \end{array} \\ \text{Penalty} & \begin{array}{ccc} 0 & 120 & 150 \end{array} & \end{array}$$

i. First allocation: based on the three matrices A_{1A} and matrix A_{2A} that have the same penalty value, a tie-breaking strategy is carried out by selecting the smallest value from each column or each row. For A_{1A}, we get.

$$\begin{array}{cc} & \begin{array}{ccc} IX & I & VI \end{array} & \text{Penalty} \\ A_{1P} = \begin{array}{c} K_1 \\ K_2 \\ K_3 \end{array} & \begin{bmatrix} (0)^{(2)} & (15)^{(1)} & (15)^{(1)} \\ (0)^{(1)} & (0)^{(2)} & (0)^{(2)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{bmatrix} & \begin{array}{c} 0 \\ 30 \\ 0 \end{array} \\ \text{Penalty} & \begin{array}{ccc} \mathbf{30} & 15 & 15 \end{array} & \end{array}$$

And for A_{2A}

$$\begin{array}{cc} & \begin{array}{ccc} VII & X & VIII \end{array} & \text{Penalty} \\ A_{2A} = \begin{array}{c} K_1 \\ K_2 \\ K_3 \end{array} & \begin{bmatrix} (0)^{(2)} & (0)^{(2)} & (0)^{(4)} \\ (0)^{(2)} & (0)^{(4)} & (0)^{(3)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{bmatrix} & \begin{array}{c} 0 \\ \mathbf{30} \\ 0 \end{array} \\ \text{Penalty} & \begin{array}{ccc} 0 & 0 & 30 \end{array} & \end{array}$$

As for A_{3A} does not have the same penalty, then proceed to the next step.

V III II Penalty

$$A_3 = \begin{matrix} K_1 \\ K_2 \\ K_3 \end{matrix} \begin{bmatrix} 45^{\left(\frac{1}{2}\right)} & 10^{\left(\frac{1}{3}\right)} & 60^{(1)} \\ 45^{\left(\frac{1}{2}\right)} & 30^{(1)} & 10^{\left(\frac{1}{3}\right)} \\ 45^{\left(\frac{1}{2}\right)} & 30^{(1)} & 60^{(1)} \end{bmatrix} \begin{matrix} 60 \\ 60 \\ 60 \end{matrix}$$

Penalty 0 120 **150**

j. In matrix A_{1A} because the largest penalty is in the first column, we see the smallest (q) which is 1 so that the selected entry is $(0)^{(1)}$ which is located in cell $(2,1)$ which is used as an allocation.

$$A_{1P} = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{IX} & \text{I} & \text{VI} \\ (0)^{(2)} & (15)^{(1)} & (15)^{(1)} \\ \mathbf{(0)^{(1)}} & (0)^{(2)} & (0)^{(2)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{matrix} \begin{matrix} \text{Penalty} \\ 0 \\ 30 \\ 0 \end{matrix}$$

Penalty **30** 15 15

And the second row of the first column is deleted.

$$A_{1P} = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{IX} & \text{I} & \text{VI} \\ \mathbf{(0)^{(2)}} & (15)^{(1)} & (15)^{(1)} \\ \mathbf{(0)^{(1)}} & \mathbf{(0)^{(2)}} & \mathbf{(0)^{(2)}} \\ \mathbf{(0)^{(2)}} & (0)^{(2)} & (0)^{(2)} \end{matrix} \begin{matrix} \text{Penalty} \\ 0 \\ 30 \\ 0 \end{matrix}$$

Penalty **30** 15 15

Furthermore, for matrix A_{2A} because the largest penalty is in the first column, we see the smallest (q) which is 1 so that the selected entry is $(0)^{(2)}$ which is located in cell $(2,1)$ which is used as an allocation.

$$A_{2A} = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{VII} & \text{X} & \text{VIII} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(4)} \\ \mathbf{(0)^{(2)}} & (0)^{(4)} & (0)^{(3)} \\ (0)^{(2)} & (0)^{(2)} & (0)^{(2)} \end{matrix} \begin{matrix} \text{Penalty} \\ 0 \\ \mathbf{30} \\ 0 \end{matrix}$$

Penalty 0 0 30

And the second row of the first column is deleted.

$$A_{2A} = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{VII} & \text{X} & \text{VIII} \\ \mathbf{(0)^{(2)}} & (0)^{(2)} & (0)^{(4)} \\ \mathbf{(0)^{(2)}} & \mathbf{(0)^{(4)}} & \mathbf{(0)^{(3)}} \\ \mathbf{(0)^{(2)}} & (0)^{(2)} & (0)^{(2)} \end{matrix} \begin{matrix} \text{Penalty} \\ 0 \\ \mathbf{30} \\ 0 \end{matrix}$$

Penalty 0 0 30

Furthermore, for matrix A_{3A} because the largest penalty is in the first column, we see the smallest (q) which is 1 so that the selected entry is $(0)^{\left(\frac{1}{2}\right)}$ which is located in cell $(1,2)$ which is used as an allocation.

$$A_3 = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{V} & \text{III} & \text{II} \\ 45^{\left(\frac{1}{2}\right)} & 10^{\left(\frac{1}{3}\right)} & 60^{(1)} \\ 45^{\left(\frac{1}{2}\right)} & 30^{(1)} & \mathbf{10^{\left(\frac{1}{3}\right)}} \\ 45^{\left(\frac{1}{2}\right)} & 30^{(1)} & 60^{(1)} \end{matrix} \begin{matrix} \text{Penalty} \\ 60 \\ 60 \\ 60 \end{matrix}$$

Penalty 0 120 **150**

And the first row of the second column is deleted.

$$A_3 = \begin{matrix} \\ K_1 \\ K_2 \\ K_3 \end{matrix} \begin{matrix} \text{V} & \text{III} & \text{II} \\ 45^{\left(\frac{1}{2}\right)} & 10^{\left(\frac{1}{3}\right)} & \mathbf{60^{(1)}} \\ \mathbf{45^{\left(\frac{1}{2}\right)}} & \mathbf{30^{(1)}} & \mathbf{10^{\left(\frac{1}{3}\right)}} \\ 45^{\left(\frac{1}{2}\right)} & 30^{(1)} & \mathbf{60^{(1)}} \end{matrix} \begin{matrix} \text{Penalty} \\ 60 \\ 60 \\ 60 \end{matrix}$$

Penalty 0 120 **150**

k. Next we move on to the second allocation. Since the remaining matrix is 2×2 then we can allocate.

I VI

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$$A_{1P} = \begin{matrix} K_1 \\ K_3 \end{matrix}\begin{bmatrix} \mathbf{45} & \mathbf{45} \\ 60 & 60 \end{bmatrix}$$

$$\begin{matrix} & \text{X} & \text{VIII} \end{matrix}$$
$$A_2 = \begin{matrix} K_1 \\ K_3 \end{matrix}\begin{bmatrix} 60 & 120 \\ \mathbf{60} & \mathbf{60} \end{bmatrix}$$

$$\begin{matrix} & \text{V} & \text{III} \end{matrix}$$
$$A_3 = \begin{matrix} K_1 \\ K_3 \end{matrix}\begin{bmatrix} 120 & \mathbf{60} \\ \mathbf{120} & 180 \end{bmatrix}$$

Based on the first and second allocations all tasks have been allocated. The overall allocation results can be seen below.

$$\begin{matrix} & \text{IX} & \text{I} & \text{VI} \end{matrix}$$
$$A_1 = \begin{matrix} K_1 \\ K_2 \\ K_3 \end{matrix}\begin{bmatrix} 60 & \mathbf{45} & \mathbf{45} \\ \mathbf{30} & 60 & 60 \\ 60 & 60 & 60 \end{bmatrix}$$

$$\begin{matrix} & \text{VII} & \text{X} & \text{VIII} \end{matrix}$$
$$A_2 = \begin{matrix} K_1 \\ K_2 \\ K_3 \end{matrix}\begin{bmatrix} 60 & 60 & 120 \\ \mathbf{60} & 120 & 90 \\ 60 & \mathbf{60} & \mathbf{60} \end{bmatrix}$$

$$\begin{matrix} & \text{V} & \text{III} & \text{IV} \end{matrix}$$
$$A_3 = \begin{matrix} K_1 \\ K_2 \\ K_3 \end{matrix}\begin{bmatrix} 120 & \mathbf{60} & 210 \\ 120 & 180 & \mathbf{60} \\ \mathbf{120} & 180 & 210 \end{bmatrix}$$

$$\text{II}$$
$$A_4 = K_1[\mathbf{120}]$$

Thus, the solution to the assignment problem is obtained and can be seen in the table below:

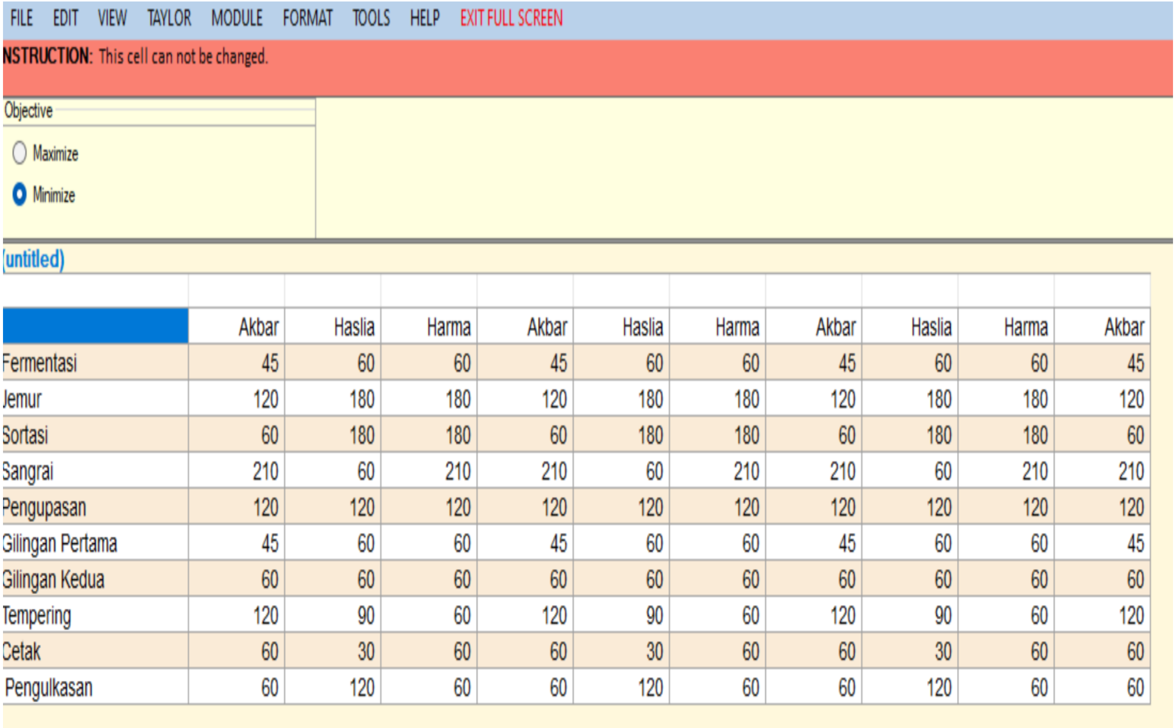
Tabel 3 Results of Employee Task Allocation

Employees	Production Stages	Time (Minutes)
A	• Fermentation	45
	• Drying	120
	• Sorting	60
	• First Mill	45
H	• Roast	60
	• Second Mill	60
	• Molding	30
HS	• Stripping	120
	• Tempering	60
	• Refinement	60
Total		**660**

These results can also be used as teaching materials in applied mathematics learning in the classroom. By using real data from the industrial world, students can be invited to develop mathematical models in the form of objective functions and constraints, and critically analyze the efficiency of optimization results.

Furthermore, the POM-QM application is used to test the results of the assignment problem above. The test results using POM-QM can be seen as follows:

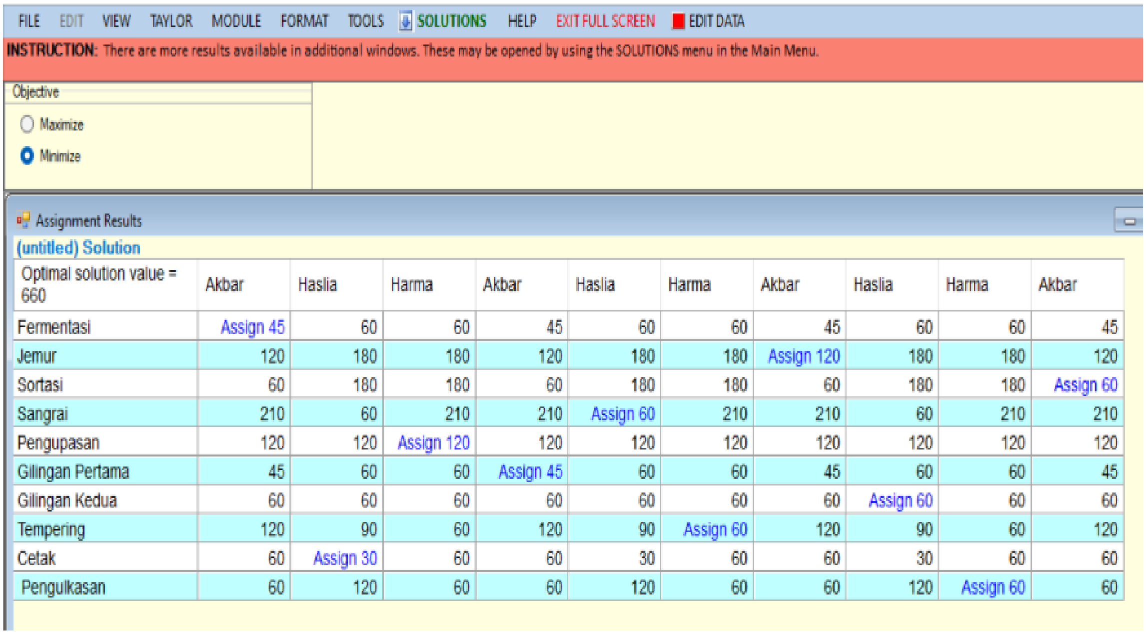
1) Input data of Decision Variable, Constraint Function, and Objective Function on Assigment.



	Akbar	Haslia	Harma	Akbar	Haslia	Harma	Akbar	Haslia	Harma	Akbar
Fermentasi	45	60	60	45	60	60	45	60	60	45
Jemur	120	180	180	120	180	180	120	180	180	120
Sortasi	60	180	180	60	180	180	60	180	180	60
Sangrai	210	60	210	210	60	210	210	60	210	210
Pengupasan	120	120	120	120	120	120	120	120	120	120
Gilingan Pertama	45	60	60	45	60	60	45	60	60	45
Gilingan Kedua	60	60	60	60	60	60	60	60	60	60
Tempering	120	90	60	120	90	60	120	90	60	120
Cetak	60	30	60	60	30	60	60	30	60	60
Pengulkasan	60	120	60	60	120	60	60	120	60	60

Figure 1 Input Decision Variables, Objective Function and Constraint Function

2) Then select Solve so that the result of the solution or allocation is visible



Optimal solution value = 660	Akbar	Haslia	Harma	Akbar	Haslia	Harma	Akbar	Haslia	Harma	Akbar
Fermentasi	Assign 45	60	60	45	60	60	45	60	60	45
Jemur	120	180	180	120	180	180	Assign 120	180	180	120
Sortasi	60	180	180	60	180	180	60	180	180	Assign 60
Sangrai	210	60	210	210	Assign 60	210	210	60	210	210
Pengupasan	120	120	Assign 120	120	120	120	120	120	120	120
Gilingan Pertama	45	60	60	Assign 45	60	60	45	60	60	45
Gilingan Kedua	60	60	60	60	60	60	60	Assign 60	60	60
Tempering	120	90	60	120	90	Assign 60	120	90	60	120
Cetak	60	Assign 30	60	60	30	60	60	30	60	60
Pengulkasan	60	120	60	60	120	60	60	120	Assign 60	60

Figure 2 Employee Allocation Result

The total time was reduced from 970 minutes to 660 minutes, indicating a 31.96% increase in efficiency. This is comparable to the improvements reported in (Zhao, Sun and Yamamoto, 2024), who optimized assignment cycles in multi-period production environments. Based on the above results, the Modified Ghadle-Munot Algorithm method on the assignment problem in this study is also a method that is rarely used on this problem compared to the Hungarian method which has been used in many studies. The Modified Ghadle-Munot Algorithm method is usually applied to transportation problems, namely in solving with respect to demand and supply. However, the results given by using the Modified Ghadle-Munot Algorithm method and the Hungarian method are the same. This activity can be replicated in a learning environment using the POM-QM application as a learning tool. Students can be involved in hands-on practice of modeling and solving assignment problems, which not only strengthens the understanding of algorithm concepts, but also improves real data-based problem solving skills. This can be seen in the test results using the manual method and the POM-QM application in this study. The difference between the two is that it lies in the calculation process where the Modified Gahdle-Munot Algorithm method involves the use of modulo while the Hungarian method only makes the deletion by paying attention to the zero value that is lined up like the research conducted by Wahyu Riyanto and Almedista Intan Atmayani (2023) who used the Hungarian method in solving the assignment problem by determining the deletion and assignment point to the Procurement Officer (Wahyu Riyanto and Almedista Intan Atmayani, 2023). The comparison between Modified Ghadle-Munot and Hungarian methods can also be utilized in advanced mathematics learning. By comparing the complexity of the algorithms, students can be trained to assess the advantages and disadvantages of certain methods against the conditions of the problem at hand.

Overall, the results of this study not only provide a practical contribution in solving operational problems in the business world, but also have high educational value. This case study can be used as a means of contextual learning, which integrates mathematical theory with real practice. With this approach, students will more easily understand the relevance of mathematics in professional and social life.

4. Conclusion

This study shows that the Modified Ghadle-Munot Algorithm method is effectively used in solving the unbalanced assignment problem in the chocolate production process at CV. Putra Mataram Sedalu. By applying this method, the total work time can be minimized from 970 minutes to 660 minutes, which means an increase in time efficiency by 31.96%. These results show that human resource management in the production process can be improved through the application of appropriate mathematical models and optimization algorithms. In addition to making a real contribution to the operational efficiency of small industries, this research also has educational value in the context of applied mathematics education. This case study can be used as contextual teaching material in higher education, especially in courses such as Linear Programming, Operations Research, or Industrial Optimization. Through this real problem-based approach, students can develop conceptual understanding as well as analytical skills in applying mathematical theories to the real world of work.

Thus, the results of this research are not only beneficial for the development of local cocoa-based industries, but also strengthen efforts to integrate theory and practice in mathematics-based higher education. This aligns with the need for contextual-based learning strategies in applied mathematics education, as emphasized in recent studies on fuzzy optimization and data-driven assignment models (Wang, Liu and Lin, 2022; Kimamporn and Nunkaew, 2025).

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