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Implementation of Hungarian Algorithms to Optimize the Assignments of Chefs at Roy Catering

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Abstract: ***This research tries to optimize the assignment time of the chef's. An executive chef assigns tasks to his subordinates on each allocation, including the task of cutting meat, cutting vegetables, cutting fruit, making pudding, and making rice. Every chef has different abilities and backgrounds for each task given. We found that some chef's got task not suitable with their capabilities. It caused lack of time efficiency Limited resources make this business need to require chef's with fast work capabilities. To solve this problem we recommend implementation of Hungarian algorithm. The results of this study there are two optimal assignment alternatives based on the chef's ability to complete each task.***

Keywords: hungarian algorithm, catering, production time, optimization, task assignment

1. Introduction

Now days all business needs an effective approach [1]. Food industries such as catering services need human for achieving their business goals. Optimization production time is crucial, so it needs to assign task to appropriate employees. [2]. Assigning correct employees to correct task will impact to company's performance [3]. We found some difficulties during lack of employees caused by employees leave. But in Roy Catering daily task, job desks have not been assigned to chef's specialization [4]. It affects to production time. Because of Roy Catering has several tasks with several specialization, we need to choose the best employees performance for each task. Hungarian algorithm is one of the best choice to solve this problem [5].

The assignment problems can be completed using the Hungarian algorithm. The Hungarian algorithm is a combinational algorithm for optimization that is used to obtain optimal results from personal method problems [6].

In other cases the use of the pinalty algorithm is another alternative to the assignment problem. The only difference is the number of iterations obtained [7].

2. Literature Reviews

Assignment problems can be expressed mathematically in a linear programming form as follows:

Maximize / Minimize Z **[7]** :

$$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \quad (1)$$

With Obstacles:

$$\sum_{i=1}^{m} {}_{ij} = 1; i = 1,2\ldots, m$$

$$\sum_{i=1}^{n} {}_{ij} = 1; i = 1,2\ldots, n \quad (2)$$

By *m* shows the number of workers and *n* shows the number of tasks. Whereas for *Z* is the total operating cost of the worker, *Cij* shows the cost or time of the worker *i* to complete the work of j [5].

This assignment problem can be explained easily by the form of a rectangular matrix, where each row shows the sources and the columns show tasks.

The following is a form of the opportunity cost matrix (m = n) with the matrix size m x n [8].

$$c_{ij} = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix}$$

Figure 1: Opportunity Cost Matrix

As for the assignment matrix:

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

Figure 2: Assignment Matrix

3. Result and Discussion

We found production time before optimalization was 19 hours for 2000 packages. Roy Catering assign task just based on experience. It leads to less efficient task assignment.

The following matrix shows each chef performances:

Chef's	*A*	*B*	*C*	*D*	*E*
Sukma	277	133	164	422	177
Novri	303	117	173	377	203
Dadang	286	123	159	382	168
Putut	311	142	155	368	179
Handrie	308	123	201	393	193

Figure 3: Opportunity Cost Matrix

Information:
A = Cutting meat 100kg
B = Cutting vegetable 60kg
C = Cutting 2000 pieces of fruit
D = Making rice160 Liters
E = Making Pudding for 100 Panes

Before using the Hungarian algorithm, optimal assignments for 2000 packages can be seen as follow :

Table A: Standarization of Production Time

Task	Target	Production Time
Cutting meats	100 kg	5 hours
Cutting Vegetables	60 kg	2 hours
Cutting Fruits	2000 pieces	3 hours
Making Puddings	100 panes	3 hours
Making Rice	160 liters	6 hours
Minimum Standard Of Time		19 hours

Step to find optimal value from specific matrix using basic formulation as follow:
1) Determine initial feasible answers
2) Test for optimality, if it is optimal, the process is stopped. If it's not optimal, do step 3.
3) Revised tables to improve optimality. Return to step two [9].

Chef's	A	B	C	D	E	
Sukma	277	133	164	422	177	133
Novri	303	117	173	377	203	117
Dadang	286	123	159	382	168	123
Putut	311	142	155	368	179	142
Handrie	308	123	201	393	193	123

Figure 4: Reduced Cost Matrix-1

Step 1, we need to find smallest value from each row. In this case, the minimum value for row one is 133, row two is 117, and so on.

Step 2, Subtract all elements in each row with the smallest value for each row. For example subtract row 1 with 133, row two with 117 and so on. The results are as follows:

Chef's	A	B	C	D	E
Sukma	144	0	31	289	44
Novri	186	0	56	260	86
Dadang	163	0	36	259	45
Putut	169	0	13	226	37
Handrie	185	0	78	270	70

Figure 5: Reduced Cost Matrix-2

Step 3, subtract all elements in each column with the smallest value for each column. For example subtract column 1 with 144, column two with 0 and so on. The results are as follows:

Chef's	A	B	C	D	E
Sukma	0	0	18	63	7
Novri	42	0	43	34	49
Dadang	19	0	23	33	8
Putut	25	0	0	0	0
Handrie	41	0	65	44	33

Figure 6: Test For Optimality Matrix-1

Step 4, Each row and each column in the matrix must contain element 0. Cover all 0 element in the matrix with combinations of horizontal and vertical lines as shown in the matrix below:

Chef's	A	B	C	D	E
Sukma	0	0	18	63	7
Novri	42	0	43	34	49
Dadang	19	0	23	33	8
Putut	25	0	0	0	0
Handrie	41	0	65	44	33

Figure 7: Test For Optimality Matrix-2

In the hungarian algorithm, to find the optimal matrix value is needed the number of lines = number of tasks. In this case, the matrix has three cover lines; it means that the number of assigning was not equal with the number of tasks. Thus, this matrix has not optimal yet.

Step 5, find the smallest value that is not cover with any lines, then subtract all element that not cover with any lines with the smallest value. But, for each element with intersection line add the element with smallest value. Repeat step 4. The result are as follows:

Chef's	A	B	C	D	E
Sukma	0	8	18	63	7
Novri	34	0	35	26	41
Dadang	11	0	15	25	0
Putut	25	8	0	0	0
Handrie	33	0	57	36	25

Figure 8: Revised Matrix-1

The optimality of the matrix must be tested. We need to get 5 cover lines that represent five assignments. Thus, we need to revice the matrix like step 5. So, the result are as follows:

Chef's	A	B	C	D	E
Sukma	0	8	3	48	7
Novri	34	0	20	11	41
Dadang	11	0	0	10	0
Putut	40	23	0	0	15
Handrie	33	0	42	21	25

Figure 9: Test For Optimality Matrix-3

In the matrix the number of lines ≠ 5, which means that it is not optimal so it needs to be revised until the number of lines

= number of assignments. In the matrix, the smallest element is 3. Then do the steps as before. So, that the following results will be obtained:

$$\begin{array}{c|ccccc} Chef's & A & B & C & D & E \\ Sukma & \boxed{0} & 8 & 0 & 45 & 4 \\ Novri & 34 & \boxed{0} & 17 & 8 & 38 \\ Dadang & 14 & 3 & 0 & 10 & \boxed{0} \\ Putut & 43 & 26 & 0 & \boxed{0} & 15 \\ Handrie & 33 & 0 & 39 & 18 & 22 \end{array}$$

Figure 10: Test For Optimality Matrix-4

In the matrix, the number of lines is still four, which means that it is not optimal so it needs to be revised by repeating the steps as before. The result are as follows:

$$\begin{array}{c|ccccc} Chef's & A & B & C & D & E \\ Sukma & \boxed{0} & 16 & 0 & 45 & 4 \\ Novri & 26 & 0 & 9 & \boxed{0} & 30 \\ Dadang & 14 & 11 & 0 & 10 & \boxed{0} \\ Putut & 43 & 34 & \boxed{0} & 0 & 15 \\ Handrie & 25 & \boxed{0} & 31 & 10 & 14 \end{array}$$

Figure 11: Optimal Allocation Matrix

Finally we have already got 5 lines in the matrix, so we can assign task to each chef. The optimal assignment can be calculate with this equalization:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad (1)$$

$$z = x_{1,1} + x_{2,4} + x_{3,5} + x_{4,3} + x_{5,2}$$

$$= 277 + 377 + 168 + 155 + 123$$

$$z = 1100$$

Based on this calculations, the optimal is obtained, which is 18.2 hours, with the assignment as follows:

Table B: The Result Of Optimal Allocation

Task	Chef's	Production Time
Cutting Meats	Sukma	277 minutes
Cutting Vegetables	Putut	123 minutes
Cutting Fruits	Dadang	155 minutes
Making Puddings	Handrie	168 minutes
Making Rices	Novri	377 minutes
Minimum Total Of Time		1100 minutes / 18.2 hours

From the results of the above calculations there is a difference in time from each task as follows:

Table C: Chef's Production Time Difference

Task	Chef's	Tme Difference
Cutting Meats	Sukma	+23 minutes
Cutting Vegetables	Putut	-3 minutes
Cutting Fruits	Dadang	+25 minutes
Making Puddings	Handrie	+12 minutes
Making Rices	Novri	-17 minutes
Minimum Total Of Time		40 Minutes

From the table C, there are two chef's namely Putut and Novri who have low performance, so the processing time exceeds the predetermined standard. To find alternative assignments to Putut and Novri, the prohibited allocations need to be made as follows:

$$\begin{array}{c|ccccc} Chef's & A & B & C & D & E \\ Sukma & 277 & 133 & 164 & 422 & 177 \\ Novri & 303 & 117 & 173 & M & 203 \\ Dadang & 286 & 123 & 159 & 382 & 168 \\ Putut & 311 & M & 155 & 368 & 179 \\ Handrie & 308 & 123 & 201 & 393 & 193 \end{array}$$

Figure 11: Opportunity Cost Matrix

In the matrix above, cells X_{24} and X_{42} are variables M = a large positive value that holds all the costs / time specified. The prohibited allocation is used when there are several tasks that are impossible for some workers to do, so that the cell cannot be allocated [9]. The examples of calculations are as follows:

$$\begin{array}{c|ccccc} Chef's & A & B & C & D & E \\ Sukma & 144 & 0 & 31 & 289 & 44 \\ Novri & 186 & 0 & 56 & m-117 & 86 \\ Dadang & 163 & 0 & 36 & 259 & 45 \\ Putut & 169 & 0 & 13 & 226 & 37 \\ Handrie & 115 & m-193 & 8 & 33 & 0 \end{array}$$

Figure 12: Reduced Cost Matrix-1

For the initial calculation, it is the same as the previous step, namely by reducing each row and column with the smallest value. The above matrix shows the results of the reduction in values in each row. It can be seen that the variable M is always filled with a specified time / cost.

The final results of the matrix calculation above are as follows:

$$\begin{array}{c|ccccc} Chef's & A & B & C & D & E \\ Sukma & \boxed{0} & 8 & 18 & 219 & 7 \\ Novri & 34 & \boxed{0} & 35 & m-195 & 41 \\ Dadang & 11 & 0 & 15 & 181 & \boxed{0} \\ Putut & 25 & 8 & \boxed{0} & 156 & 0 \\ Handrie & 8 & m-238 & 32 & \boxed{0} & 0 \end{array}$$

Figure 13: Optimal Allocation Matrix

From the above matrix can be determined alternative assignments based on a single zero value in each row and column so that it can be allocated as follows:

Table D: Alternative Assignment-2

Task	Chef's	Production Time
Cutting Meats	Sukma	277 minutes
Cutting Vegetables	Novri	117 minutes
Cutting Fruits	Dadang	155 minutes
Making Puddings	Handri	168 minutes
Making Rices	Putut	393 minutes
Minimum Total Of Time		1110 minutes / 18.5 hours

The difference in production time from each task is as follows:

Table E: Alternative Chef's Production Time Diference-2

Task	Chef's	Time Difference
Cutting Meats	Sukma	+23 minutes
Cutting Vegetables	Novri	+3 minutes
Cutting Fruits	Dadang	+25 minutes
Making Puddings	Handri	+12 minutes
Making Rices	Putut	-33 minutes
Minimum Total Of Time		30 Minutes

From the results of calculations using the Hungarian algorithm above, there are two alternative assignments as follows:

Alternative-1: Sukma-A, Novri-D, Dadang-C, Putut-B, Handrie-E
Alternative-2: Sukma-A, Novri-B, Dadang-C, Putut-D, Handrie-E

3.1 Calculation Accuracy Using POM QM

After doing the manual calculation, the accuracy of the data is then carried out by using windows software called POM QM. This POM QM software is used to perform calculations that are needed by management to make decisions in the fields of production and marketing. The following is the result of the accuracy of calculations using the POM QM :

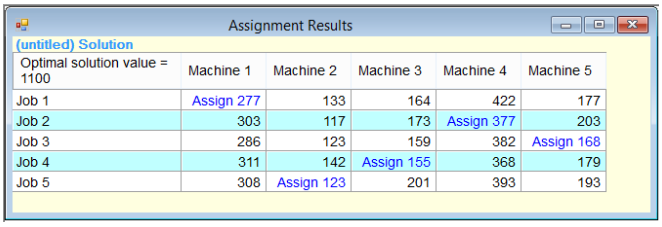

Figure 12: Assignment Result With POM QM

3.2 Calculation Accuracy Using Lingo 18.0

The next tests were carried out on the Lingo 18.0 software. Where software is used to build and solve linear, nonlinear, and integer optimization models. This Lingo software provides formulas in the form of variables that can be used for assignment problems. The following is a formula for finding optimal assignments:

```
SETS:
   TASK ;
   OPERATOR;
   LINK( TASK, OPERATOR): COST, X;
ENDSETS

DATA:

 TASK = A B C D E;

OPERATOR= Sukma Novri Dadang Putut
Handrie;

   COST = 277 133 164 422 177
          303 117 173 377 203
          286 123 159 382 168
          311 142 155 368 179
          308 123 201 393 193;
ENDDATA

SUBMODEL ASSIGN:

   MIN = TCOST;
     TCOST = @SUM( LINK( i, j):
       COST( i, j) * X( i, j));

   @FOR( OPERATOR( j):
    @SUM( TASK( i): X( i, j)) <= 1;
        );

   @FOR( TASK( i):
    @SUM( OPERATOR( j): X( i, j)) = 1;
        );
 ENDSUBMODEL

 CALC:
  @SET('TERSEO', 2);
  @SOLVE( ASSIGN);
  @WRITE('A Task Assignment
Problem.',@NEWLINE(1));
  @WRITE(' The assignments
are:',@NEWLINE(1), '      Task
Operator   Cost', @NEWLINE(1));
  @FOR( LINK(i,j) | X(i,j) #GT# 0.5:
    @WRITE('        ',TASK(i),'        ',
OPERATOR(j),'
',COST(i,j),@NEWLINE(1));
      );
  @WRITE(' Cost of the assignment= ',
TCOST, @NEWLINE(1));
```

From the formula, the assignment results are obtained as follows :

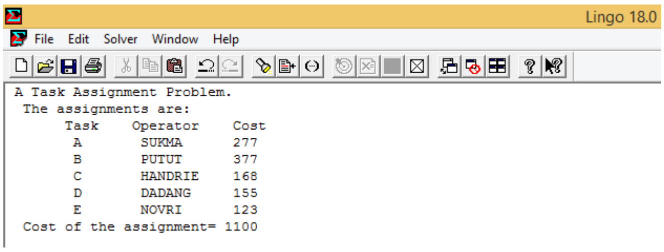

Figure 13: Assignment Result With Lingo

Based on the results of testing using POM QM software and Lingo software, it shows that the calculations performed are accurate. So the results obtained are A-task done by Sukma, B-task done by Putut, C-task done by Handrie, D-task done by Dadang, and finally E-task done by Novri. Based on manual calculations and with the help of software, the optimal production time is 1100 minutes or 18.2 hours, which means the difference of 40 minutes from the standard production time is 19 hours.

4. Conclusion

The use of this Hungarian algorithm is very helpful for finding the optimal allocation of several alternative assignments. However, this Hungarian algorithm has a weakness in its implementation, that is, it cannot measure in terms of health, demographic aspects, and stress levels of workers. So, to determine the allocation of tasks it needs to be considered from several other aspects.

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