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Rice distribution optimization using initial basic feasible and modified solution to increase food security in West Java

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Abstract

Rice is one of the main commodities needed by more than 95% of developing countries, including Indonesia. High population growth that is not accompanied by sufficient rice production will lead to many problems such as malnutrition, famine, and economic crisis, so the availability of rice in Indonesia is the main focus in food security. Farmer welfare is one of the factors in increasing rice production. But in reality, farmers are often constrained by the high cost of distributing rice. As one of the largest rice producing regions in Indonesia, optimisation of rice distribution costs in West Java needs to be done. the process of optimising rice distribution costs can be done using the transportation method. The transportation method is carried out in 2 stages, namely obtaining the initial solution and the optimal solution. Initial Basic Feasible Solution (IBFS) as one of the approaches in obtaining the initial solution works by considering the average value of new unit costs and columns. As for obtaining the optimal solution, MODI is used, which calculates the opportunity cost of cells that are not given a distribution allocation to assess the optimality of the table. Optimisation of rice distribution using IBFS and MODI resulted in an initial solution of Rp 27,259,921600 and an optimal solution of Rp 27,259,921600 with the Bandung area as the area that supplies the most rice in West Java.

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INTRODUCTION

Rice is one of the main commodities needed by more than 95% of developing countries, including Indonesia (Orjuela et al., 2021). For most people in Indonesia, rice is a staple or priority food that has a good source of carbohydrates and protein for their lives (Setiyowati et al., 2013). High population growth that is not accompanied by sufficient rice production will cause many problems such as malnutrition (Dipti et al., 2012), famine (Quddus & Becker, 2000), and economic crisis (Seck et al., 2013). Therefore, the availability of rice in Indonesia is a national concern and a major focus in

One of the contributing factors in increasing rice production is the welfare of farmers (Sulistyo et al., 2022). However, the reality is that farmers often struggle due to the high cost of distributing rice. The high distribution cost is the most common obstacle for farmers in West Java. As one of the largest rice producer areas in Indonesia, optimization of rice distribution costs in West Java needs to be implemented. The optimization of the distribution cost aims to maintain the stability

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of the price and supply of rice in West Java. The process of optimization the cost of rice distribution can be done using the transportation method. Optimization using the transportation method is done by arranging the distribution allocation so that the distribution cost is minimal and the transportation of rice from origin to destination can be arranged efficiently.

Optimization using the transportation method is made in two stages, namely compiling the initial table and finding the optimal solution. The initial table is used to determine the distribution of rice from source to destination which will be checked against the optimal solution. There are 4 approaches in compiling the initial table, namely Least Cost Method (LCM), North West Corner Method (NWCM), Russel's Approximation Method (RAM), and Vogel's Approximation Method (VAM).

LCM has been used in the distribution optimization of bar soap (Lestari et al., 2021) , chicken food (Astuti et al., 2022), tempeh (Fadylla & Azizah, 2023), and sandals (I Nugra et al., 2023). This method considers costs and produces better solutions. There is also research for optimization the distribution of goods (Putra et al., 2020), fish (Sitanggang & Ahyaningsih, 2023), and tape (Wulandari et al., 2018) using NWCM. The optimization process using this method is very simple and fast, but often results in solutions far from optimal because it does not consider costs. Cattle distribution optimization (Ahmed et al., 2023) uses RAM which offers a balance between simplicity and closeness to the optimal solution through cost adjustment, and VAM which although often produces near optimal solutions, has a complicated process and has been used in the distribution of 3kg gas cylinders (Dimasuharto et al., 2021). There is a new approach Initial Basic Feasible Solution (IBFS) that determines the initial solution to the transport problem by considering the average value of the new unit costs and columns. By using the average unit cost, IBFS offers a faster and simpler initial feasible solution (Ekanayake & Ekanayake, 2022).

In the optimal solution stage, there are two approaches: Stepping Stone Method (SSM) and Modified Distribution Method (MODI). SSM involves testing the optimality of the table through several stages to allocate one distribution to empty cells that can track changes in distribution costs (Zahro et al., 2022). Meanwhile, MODI calculates the opportunity cost of unallocated cells to assess the optimality of the table where opportunity cost is the price to be paid if a different action is chosen (Palmer & Raftery, 1999). MODI works more efficiently and simply because it requires fewer iterations, making it suitable in optimization transportation problems (Addini, 2018)). Thus, we will optimise rice distribution using IBFS as the initial table and MODI as the optimal solution.

METHOD

This research uses data obtained from the Ministry of Agriculture, the Agricultural Instrument Standardization Agency (BSIP), and the Statistics Indonesia (BPS) in 2022. The data used are rice production, rice price and rice distribution. This research focuses on the areas of Bandung, Cianjur, Cirebon, Indramayu, Karawang, Subang, and Ciamis.

Transportation Model

A technique to optimally organize the distribution from sources supplying the same product (supply) to locations in need (demand) is the transportation model. Product allocation needs to be organized because different destinations have different allocation costs from different sources, and different destinations have different allocation costs from multiple sources (Paulus et al., 2018). The amount of demand at each destination, the amount of availability at each source, and the transportation cost from each source to each destination are the parameters used in the transportation model.

The transportation problem can be expressed in an integer program as follows:
Minimize:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} \times C_{ij} \qquad (1)$$

The objective function Z is a function that describes the cost in the distribution system where X_{ij} is a coefficient related to the cost between points i and j, and C_{ij} is a decision variable that shows the amount or allocation between points i and j. This calculation is done for all i from 1 to m and all j from 1 to n, resulting in a total value of Z that describes the total cost or optimization cost of the distribution system.

Constraint Functions :

$$Pi = \sum_{j=1}^{n} X_{ij} = a_i \quad ,i = 1,2,3 \ldots \ldots ,m \tag{2}$$

The variable P_i is the supply constraint function from the warehouse at each supply location to the demand location. m is the number of supplys, P is the supply to i delivery from supply location i to delivery location j, and X_{ij} is the number of goods delivered from supply location i and delivery location j. This demand constraint function ensures that the total amount of goods received at each destination j fulfils the demand at that destination. The following are the calculation results of P_i for each supply location.

$$Qj \sum_{=1}^{m} X_{ij} = b_j \quad ,j = 1,2,3 \ldots \ldots ,m \tag{3}$$

The equation shows that m and n are the amount of procurement and the amount of demand, X_{ij} is the amount of goods shipped from procurement location i to delivery location j. This function ensures that the total amount of goods shipped from each source i does not exceed the capacity or supply available at that source. The following are the calculation results of P_i for each demand location.

The function is used to calculate the total cost by summing the product of the quantity delivered and the cost per unit of transportation for each source-destination pair. This problem is subject to supply constraints, where the total quantity shipped from each source must equal the available supply, and demand constraints, where the total quantity received at each destination must meet the required demand. In addition, the non-negativity constraint ensures that the amount shipped is not negative. By solving this linear programming problem, we can determine the optimal shipping plan that minimizes transportation costs while meeting all supply and demand requirements (Mustafia et al., 2023).

Initial Basic Feasible Solution

The IBFS algorithm is a new algorithm used to find the basic feasible solution using the average unit cost. It offers a basic feasible solution more quickly and simply than older methods. This approach provides a strong theoretical basis for further research and application in various practical contexts in transportation optimization. The following are the steps in IBFS (Ekanayake & Ekanayake, 2022b).

1. Add a dummy row or column if the transportation problem is not balanced.
2. Calculate the average value of transportation unit costs for each row and column. This gives an overview of the cost distribution in the transportation table
3. Create a new table using the new values calculated from the average unit cost and the actual unit cost
4. Select the first highest value in the first column of the table and allocate the goods accordingly. Repeat this process for the next column
5. Repeat the allocation process for all remaining highest values until all demands are met
6. Calculate the basic feasible solution to the transportation problem

Modified Distribution

MODI (Modified Distribution Method) is a variation of the Stepping Stone method that is based on a dual formulation. The main difference lies in the fact that MODI does not require the determination of all closed paths of non-base variables, except when performing table filling changes

(Kiftiah, 2019). The equations in MODI allow the calculation of non-base variables to be faster and more efficient. This makes MODI one of the most effective ways to determine the optimal solution in transportation problems, as the equations support a faster and more efficient calculation process. Here are the steps of solving with MODI:

1. Determine the initial solution
2. Calculate the potential cost reduction (also called potential cost) for each cell in the transportation table using equation $U_i + V_j = C_{ij}$, where U_i and V_j are the dual variables for row and column, and C_{ij} is the transportation cost from source i to destination j.
3. Set the potential cost values of U_i and V_j by assigning a value of zero to one of the variables, then use the above equation to calculate the value of the other variable.
4. Calculate the potential cost values for all non-base cells (cells not included in the initial feasible solution). If there is a negative potential cost value, it indicates that there is a possibility of cost reduction by moving one unit of the non-base cell.
5. Identify the change cycle (loop) of the non-base cell with a negative potential cost value. This cycle should include both the non-base cell and the connected base cell.
6. Determine the minimum amount that can be moved along the change cycle (theta) of the cell with the negative potential cost value. Move this amount from the base cell to the non-base cell and make the necessary adjustments to the other cells in the cycle.
7. Update the transportation solution by making adjustments according to the previous step. Recalculate the total distribution cost for this new solution.
8. Repeat steps 3 through 7 until there are no more negative potential cost values, indicating that the optimal solution has been reached.

RESULTS AND DISCUSSION

There are costs that must be incurred by 20 cities and districts in West Java in distributing rice to meet the demand required by the city/district. The initial value of the rice distribution solution in West Java will be searched using the IBFS method which obtains the initial cost, namely Based on Table 1, there are costs that must be incurred by 20 cities and districts in West Java in distributing rice to meet the demand needed by each region. The data used in this transportation method is obtained from our survey. The survey was conducted in rice supplying areas in West Java. Therefore, a process is carried out to obtain the initial distribution value and cost using the Initial Basic Feasible Solution (IBFS) method. The initial value of the rice distribution solution in West Java using the IBFS method resulted in an initial cost of

$$\begin{aligned} Z = {} & 7{,}270(312{,}800) + 9{,}405(120{,}100) + 6{,}389(99{,}700) + 0(623{,}116) + 15{,}466(222{,}800) \\ & + 6{,}688(236{,}600) + 6{,}389(125{,}700) + 8{,}151(117{,}000) + 0(2{,}061{,}715) \\ & + 7{,}315(105{,}900) + 7{,}527(226{,}000) + 12{,}749(109{,}100) + 0(29{,}851{,}215) \\ & + 6{,}971(128{,}800) + 0(16{,}121{,}020) + 8{,}778(120{,}100) + 5{,}090(126{,}600) \\ & + 8{,}778(215{,}400) + 17{,}974(106{,}700) + 0(1{,}863{,}214) + 0(3{,}585{,}585) \\ & + 15{,}466(110{,}800) + 6{,}553(238{,}200) + 7{,}389(128{,}400) + 12{,}958(122{,}700) \\ & + 6{,}225(122{,}300) + 0(12{,}342{,}896) = 27{,}671{,}890{,}000 \end{aligned}$$

So the total cost of shipping rice using the IBFS method is Rp 27,671,890,000.

Next, an optimization test is conducted to find the optimal solution using the Modified Distribution (MODI) method. The MODI method is applied to optimize distribution costs by adjusting existing allocations based on transportation costs. This process involves a thorough evaluation of each distribution route to determine whether the total cost can be reduced by changing the route used. This evaluation uses potential calculations, which allow us to assess possible improvements and cost savings. The results of this evaluation provide an idea of how the distribution can be reorganized to achieve optimal results. The optimal value of rice distribution in West Java using the MODI method is obtained at a cost of

$$\begin{aligned}Z = {} & 7{,}270(312{,}800) + 13{,}167(110{,}800) + 9{,}405(120{,}100) + 6{,}389(99{,}700) + 0(512{,}316) \\ & + 15{,}466(222{,}800) + 6{,}688(236{,}600) + 6{,}389(125{,}700) + 0(2{,}178{,}715) \\ & + 7{,}315(105{,}900) + 7{,}527(226{,}000) + 12{,}749(109{,}100) + 0(29{,}851{,}215) \\ & + 6{,}971(128{,}800) + 0(16{,}121{,}020) + 8{,}778(120{,}100) + 5{,}090(126{,}600) \\ & + 8{,}778(215{,}400) + 17{,}974(106{,}700) + 0(1{,}863{,}214) + 6{,}807(117{,}000) \\ & + 0(3{,}468{,}585) + 6{,}553(238{,}200) + 7{,}389(128{,}400) + 12{,}958(122{,}700) \\ & + 6{,}225(122{,}300) + 0(12{,}453{,}696) = 27{,}259{,}921{,}600\end{aligned}$$

So the total cost of rice distribution in West Java using the MODI method is Rp 27.259.921.600.

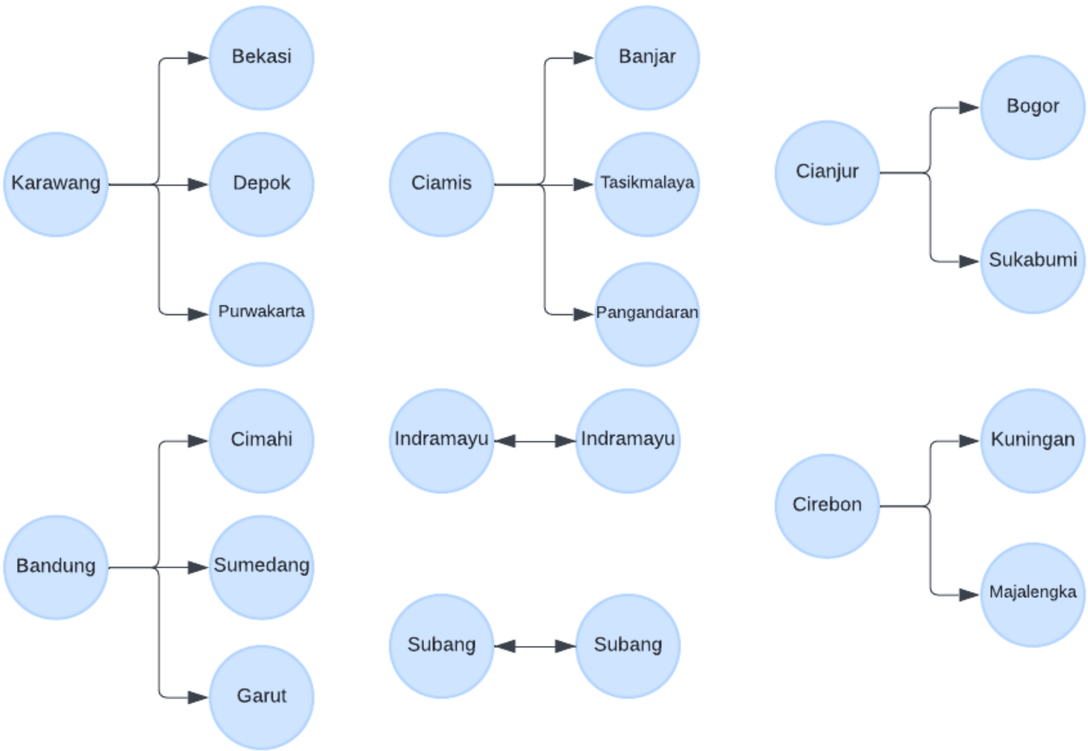

Figure 1. Optimize distribution of rice

From Figure 1, optimization results are obtained with distribution routes in West Java. Distribution from Karawang to Bekasi, Depok, and Purwakarta amounted to 568,600 kg. Distribution from Bandung to Cimahi, Sumedang, and Garut amounted to 643,400 kg. Distribution from Ciamis to Banjar, Tasikmalaya, and Pangandaran amounted to 611,700 kg. Distribution from Cianjur to Bogor, and Sukabumi amounted to 585,100 kg. The distribution from Cirebon to Kuningan, and Majalengka amounted to 441,000 kg. In this distribution, there are 2 regions that only distribute in their respective regions, namely Indramayu by 128,800 kg and Subang by 117,000 kg.

Table 1. Comparison of initial value determination methods

Method	Cost	Iteration
NWCM	Z= 84326874940	22 Iteration
VAM	Z= 30274294900	6 Iteration
RAM	Z= 36614106400	7 Iteration
IBFS	Z= 27671890000	3 Iteration

Table 1 shows a comparison of distribution cost optimization results using four different methods: NWCM (North-West Corner Method), VAM (Vogel's Approximation Method), RAM (Russell's Approximation Method), and ISBF (Initial Basic Feasible Solution). The results show that ISBF produces the lowest total cost ($Z = 27{,}671{,}890{,}000$) with only 3 iterations, compared to NWCM which produces the highest cost ($Z = 84{,}326{,}874{,}940$) and requires 22 iterations. VAM and RAM produced total costs of $Z = 30{,}274{,}294{,}900$ and $Z = 36{,}614{,}106{,}400$ with 6 and 7 iterations, respectively. This comparison underscores the superiority of the proposed ISBF algorithm in achieving the optimal solution with fewer iterations and lower cost than other methods, making it more efficient and effective for distribution optimization.

The results of this study can be used as a basis and consideration for the government in deciding policies when conducting rice distribution in West Java. It is expected to be able to improve the pattern and path of rice distribution in West Java through the data results obtained from the IBFS and MODI methods as a benchmark. When rice distribution can be carried out optimally, food security in West Java will be achieved.

CONCLUSION

The optimization process of rice distribution in West Java using IBFS initial solution and MODI optimal solution has been conducted. Rice distribution is said to be optimal if each region in West Java has received rice supply in accordance with demand and the minimum price. The initial solution obtained in the optimization of rice distribution in this study is Rp 27,671,890,000. The optimal solution is Rp 27,259,921600. The optimal solution shows that the Bandung area is the most supplying area in West Java followed by 2 other areas namely Ciamis and Cianjur. Compared to LCM, NWCM, RAM, and VAM, the IBFS method obtained the most optimal value in rice distribution in West Java. It can be seen that the IBFS method is more efficient with the least iteration process compared to other methods.

This research only considers the number of demands and existing rice suppliers. While in the distribution process there are other components that need to be considered such as the distance between the warehouse to the distribution location. For further research, it is necessary to take a different approach by considering all components that affect the rice distribution process.

AUTHOR CONTRIBUTIONS

Each author of this article played an important role in the process of method conceptualization, simulation, and article writing.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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