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A Literature Review of Distribution Solving Problems by Various Transportation Methods

***Nursafwah*[1]*, Nazaruddin Matondang*[2]*, and Aulia Ishak*[3]**

[1,2,3] *Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Padang Bulan, Medan, Sumatera Utara, 20155, Indonesia*

Abstract. The aim of this study to review the limited survey of a systematic various existing transportation problems and the application developed by different researchers and applied in some case studies. The methodology applied in this paper through various research papers that available at Google Scholar, Science direct, Elsevier, IOP and another publisher from 2014-2022 (twenty-four international researches). The main purpose of this review paper is to discuss, analyze and the existing forms of various types of transportation problems and their systematic development, Findings show that in addition to the MODI and VAM methods, other methods have also emerged to solve the transportation problem. One of them is Improve VAM (IVAM) that built by Nahar et.al (2018). IVDM on transportation or delivery strategy. Further, this paper concludes that mathematical models and algorithm method of transportation derivatives/techniques of MODI and VAM are most used to optimize single or multipurpose parameters such as distribution cost, profit earned, total transportation time etc.

Keyword: Review, Vogel Approximation Method, Modified Distribution, Least Cost Method, North-West Corner, Initial Basic Feasible Solution.

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1. Introduction

One of the most advanced functions in recent years in organizations is distribution. However, this evolution has led to an increase in the complexity of transport operations, which together with various factors, such as the need to reduce production costs, the continuous increase in transport prices or the increase in the level of demand in customer-supplier relations, have placed logistics [1]. Management as a key element in the company's strategy [2].

Distribution is one of the operational activities that are routinely performed for the sustainability of the company [2] In general, all companies, for example, those involved in production, construction services, delivery, suppliers, and distributors, carry out the distribution process, [3] Distribution can also be considered a part of marketing, which is the process of delivering products or services from companies to consumers [4].

*Corresponding author at: [Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Medan, 20155, Indonesia]
E-mail address: [nursafwah2022@gmail.com]

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Regarding the distribution of products or services, companies are required to bear various distribution expenses, including transportation costs. The magnitude of transportation costs during the distribution process is impacted by several factors, such as the distance between the origin and destination points and the chosen mode of transportation [5] To reduce these transportation costs, optimization techniques from the field of operations research can be employed. These techniques aim to optimize logistics and allocation processes, thereby achieving cost minimization and improving overall efficiency in the distribution network [6] [7]

Today, transport models present a wide range of applications in various fields of enterprise (commercial, industrial, etc.) that are not related to transport [8] However, the issue of transportation continues to be discussed. Many economic problems that are basically unrelated to transportation problems, through the use of certain transformations can be transformed into transportation problems and, subsequently, solved by using this type of problem method [9]

Today, this method is widely used today, because of its efficiency and significant savings in expenses assumed by companies, which intend to distribute their products using several means of transport [10], [11] Transportation plays an important role in the business economy. The availability of a safe and economical transportation system is very important for business survival [6] A characteristic of a supply chain is the movement of products from multiple origins to a set of distinct destinations at the lowest possible cost [12]

Different approaches have been developed to solve this distribution problem, such as: northwest corner method, modified northwest corner method (minimum cell), stepping stone method, modified distribution method (MODI), Vogel's approximation method and simplex method. To solve problem with a transportation method, it must meet three conditions [13]:

- Objective functions and constraints must be linear.
- The articles must be uniform and interchangeable, the coefficients of all variables in the equation must be 0 or 1.
- The total source capacity must be equal to the number of destination requirements, if there is an inequality, the slack variable must be added.

The purpose of this paper is to analyze the application of transportation models in the manufacturing industry. The research methodology in this article is compiled from the literature of previous scientific research articles published from 2012 to 2022 that focus on the application of transportation methods. For this reason, this paper attempts to examine and analyze methods and approaches to transportation, through a literature review of 21 articles. Case studies used in real applications are considered.

2. Theoretical Basis

The transportation method is a unique application of linear programming where the goal is to determine a transportation scheme that minimizes this total cost, is known as the unit cost of transportation from origin i to destination j [14]. This transport method is a linear programming method for assigning articles from an original series to a target series in a way that allows the target function to be optimized. This technique is mainly used in organizations that produce the same product in many factories and ship their products to different destinations (distribution centers, warehouses). It is also used in distribution, plant site analysis and production scheduling [15].

Transportation problems are concerned with the efficient distribution of goods from various supply points, often referred to as sources (such as factories), to multiple demand points, typically referred to as destinations (such as warehouses) [16]. In this context, each source possesses a predetermined capacity or availability, representing the fixed number of units of the product it can supply. Likewise, each destination has a fixed demand, known as the requirement, specifying the quantity of goods it needs [17]. The goal of solving transportation problems is to optimize the allocation and transportation of goods to meet the demand while minimizing costs and ensuring efficient logistics management.

The goal of the transportation model is to find a solution with the minimum cost to realize the delivery, transportation or distribution plan, from each group of supply centers called the origin, to each group of receiving centers called the destination, that is to determine the quantity of products or goods to be sent from each point origin to each point of destination, taking into account the constraints inherent in problems related to the capacity or availability of supply centers and demand centers of destination centers, in such a way as to minimize the total cost of transportation or distribution. Origin can be factory, warehouse or point or place [18].

Companies often encounter transportation problems arising from limited resources or capacity during the distribution process between multiple origins and destinations. The objective of solving transportation problems is to optimize transportation costs, which can be achieved by employing various allocation methods. These methods include the North West Corner method, which starts allocation from the top-left corner or the cells in the first column and first row but may yield suboptimal results by not considering transportation costs. Alternatively, the Least Cost method allocates goods based on the cell with the lowest transportation cost, typically offering more efficient outcomes than the North West Corner method. The Vogel calculation method, on the other hand, finds the difference between the two smallest costs, providing an alternative approach to address transportation issues. Additionally, the Russel approximation method identifies the highest cost for each row and column in the transportation schedule. Furthermore, the Modified Distribution method adjusts the North West Corner method results by incorporating elements of the Least Cost method. Lastly, the Stepping Stone method fills empty cells generated from previous methods, utilizing a different approach to tackle the problem. Each method possesses its own strengths and weaknesses, making them suitable for specific transportation scenarios [19].

Basically, the transportation problem is a linear programming problem that can be solved by the simplex method. Since the simplex method creates a more difficult solution, solving the transportation problem will be easier by using the methods of Stepping Stone, VAM, and MODI [20],[21]. To create a transportation problem with a transportation model and transportation schedule, the transportation problem must have data on the level of supply or capacity of each source location, the level of demand for each destination location, and the transportation cost per unit of commodity from each source location to the destination location [22].

2.1. Vogel Approximation Method (VAM)

Indeed, VAM operates on the principle of penalty or regret cost [4]. In the context of decision-making, if the decision-maker selects an incorrect alternative from multiple actions, a penalty is incurred, and the decision-maker may regret the choice made. In the transportation problem, the alternatives correspond to different paths, and the wrong decision arises when goods are allocated to a cell that does not offer the lowest cost [22]. VAM aims to minimize such penalties and regrets by carefully selecting the optimal allocation strategy.

One of the objectives of the VAM method is to minimize the cost of transporting goods from the factory (origin) to the destination (demand market). It is possible that, sometimes, in VAM, the initial feasible basic solution found is the optimal solution, or failing that, the minimum iterations required to reach it [4]. VAM effectively considers unit cost because the difference represents the minimum additional cost incurred by not allocating to the lowest-cost cell in a given row or column [6].

The fundamental concept of the Variable Neighborhood Search (VAM) algorithm revolves around determining the penalty cost based on the difference between the lowest cost and the nearest cost in each row and column. The highest penalty value indicates that one of the two minimum cost values is significantly higher than the other [15] To prevent selecting a higher penalty in the subsequent iterations, VAM chooses the cell with the highest penalty rate and assigns it to the lowest cost cell in that row or column.

In cases where two or more cells have the same smallest magnitude, VAM selects the smallest cost that is equal to the minimum cost and is adjacent to the minimum cost. In such situations, the penalty is set to zero [17].

In this scenario, the penalty will be determined as the smallest value within a specific row or column, considering all rows and columns. Consequently, this will render the corresponding row or column unsuitable for goods allocation [19]. If in the row or column there is a higher cost in addition to the same lower cost, then the probability of choosing a higher cost in the next iteration increases, and the total transportation cost may also increase [18]. In the VAM algorithm, the allocation depends on the penalty rate. To determine the VAM penalty, the lowest cost may not be guaranteed in all iterations, so the total cost of a viable solution may be higher [9].

The Variable Neighborhood Search (VAM) is a heuristic method and typically offers an improved initial solution compared to other approaches. However, using VAM for a problem does not assure the generation of an optimal solution. However, excellent solutions are always obtained with minimal effort [13] This method is good enough to obtain a basic feasible initial solution, which may be optimal or require a minimum number of interactions to obtain an optimal solution. The procedure for solving with VAM is as follows [16]:

- Calculate the difference between the two smallest costs for each row and column.Select the row or column with the largest difference value, then place brackets. J if the values in a row or column are the same, choose the value that can move the most items.

- From the rows/columns selected in (2), determine the number of items that can be transported by pay attention to restrictions imposed on rows or columns and cells with the lowest cost.

- Delete the rows or columns that have met the previous conditions (meaning the supply has been met).

- Repeat steps (1) to (4) until all allocations are met.

2.2. Modified Distribution (MODI)

The MODI algorithm, known as the design cost method, consists of adding a row and column cost matrix that aggregates arbitrarily defined design costs, allowing you to calculate the increment index for unused cells (boxes) without having to draw all the circuits (cycles) required by the Stepping-Stone algorithm [9].

After obtaining an initial feasible basic solution using one of the three previous methods, the subsequent step is to refine the model for the optimal solution, which aims to achieve the minimum total cost. There are two primary methods used for this purpose: the Stepping Stone method and the MODI method [12]. In this study, the Stepping Stone method will be demonstrated first. As the initial solution obtained through the minimum cell cost method yields the lowest total cost among the three initial solutions, it will be utilized as the starting point for the Stepping Stone method [19].

In general, this means time savings compared to using the Stepping-Stone algorithm in solving transportation problems, due to its speed and easy maintenance. The MODI method is summarized in the following steps [23]:

- Using the VAM method as an initial solution determination.

- Determine the value of u_i for each row and v_j for each column using the formula $c_{ij} = u_i + v_j$ for all basic variables by setting the value to zero on the initial assumption $u_i = 0$

- Calculate the cost change of k_{ij} = for every non-basic variable by employing the formula $k_{ij} = c_{ij} - u_i - v_j$

- Select the non-basic variable that has the most negative k_{ij} value that will then provide the greatest cost reduction. Allocate according to the path of the stepping stone in the selected cell;

- Repeat steps 2 to 4 until the value of k_{ij} is zero and there are no more negative values.

3. Research Methodology

In this study, the researchers employed the literature review method, encompassing literature published between 2012 and 2020. The literature was collected from two databases, namely Google Scholar and Science Direct. To identify relevant papers, key terms such as "transportation problem," "distribution," "minimum cost," and "least cost" were used. Following this initial search, a filtering process was implemented to select the most appropriate studies. The filtering process involved considering the title, relevance, feasibility, and whether the articles were based on case studies. As a result, a total of fifteen articles were ultimately chosen for inclusion in the study. The selected research papers were investigated and analyzed the contributions and benefits of implementing the transportation method using tables. The structure of this research is shown in Figure 1 as follows:

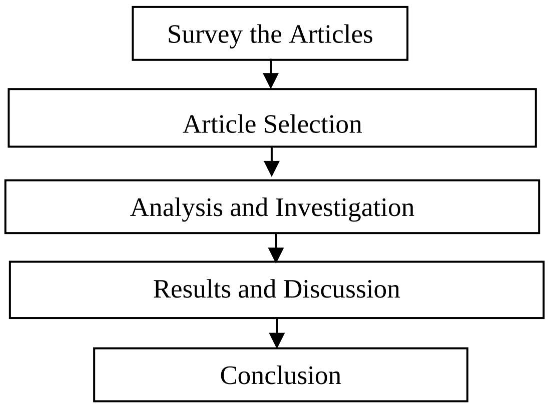

Figure 1 Methodology

4. Results

Fifteen case studies related to the application of transportation problems were reviewed for further analysis. Table 1 summarizes the investigation of the previous articles pertaining to the application of transportation methods in some case studies:

Table 1 Selected Literature Review of Methods for Solving Transportation Problems

Years/ Authors	Used Methodology & Variables	Contribution
2022/Krishan and Masrom [1]	Method: VAM, MODI, NWCM Variables: production capacity, shipment quantity, and shipping cost of polymer materials	This study focused on optimize delivery costs and meet demand by not exceeding the maximum capacity of the petrochemical plant, and determine the effect of the uncertainty of unit delivery costs on the company's total freight costs by carrying out sensitivity analysis.
2021/ Rogoz et.al [2]	Method: Northwest corner, least cost in the matrix, the row minimum, and VAM. Variables: minimum transportation and costs.	In their study, Rogoz et al. introduced a novel and innovative approach for solving transportation problems. To tackle the challenges of handling extensive calculations in conventional methods, they designed the source code in GNU Octave (version 3.4.3). The primary goals of their approach were to minimize transportation costs, reduce fuel consumption, and lower CO2 emissions associated with transportation operations.
2021/ Nugraha et.al [9]	Method: MODI and Least Cost Method. Variables: minimum transportation and costs.	MODI and Least Cost Method used in this research to evaluate the company's initial distribution channels to optimize distribution to reduce PT Petrokimia Gresik's high distribution costs. Petroganics.
2021/ Regia et.al [19]	Method: MODI. Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	The primary objective of this study was to determine the minimum distribution cost through the utilization of the Least Cost method as the initial solution. Additionally, the researchers aimed to examine the outcomes obtained from testing the MODI (Modified Distribution) method to identify the optimal solution in the context of PT. Indonesian Emerald Land.
2020/ Kaur et.al [14]	Method: VAM, MDM, KCM Variables: production facilities, warehouses, destinationsm sales, warehouses and outlets.	A novel method has been introduced to discover a feasible initial basic solution for transportation problems. This method is founded on allocating values in cells that represent the minimum cost, while also taking into account the maximum cost. By leveraging this approach, the researchers aim to enhance the efficiency of finding an appropriate initial solution for the transportation problem.
2020/ Hussein and Shiker [4]	Method: INFS, NWCM, MCM, VAM Variables: transportation time and transportation cost	Husein and Shiker employed the Variable Neighborhood Search (VAM) technique in combination with the Improved Basic Feasible Solution (IBFS) approach to address transportation problems. Their approach yielded results that were very close to the optimal solutions, as demonstrated through various solved numerical examples.
2020/Askerbeyli [22]	Method: VAM and MODI	The main objective of this paper is to investigate and explore ways to reduce

Years/ Authors	Used Methodology & Variables	Contribution
	Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	the total transportation costs associated with the finished products manufactured by Alter Iron and Steel Industrial Company at its production facility located in Karabuk.
2020/ Jain et.al [23]	Method: VAM, MODI and LCM Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	This paper attempted to determine a schedule for transporting goods from source to destination in a way that minimizes transportation costs while meeting supply and demand constraints.
2019/ Sasikala et.al [13]	Method: NECM, VAM, IBPS, MODI and SECM Variables: quantity of demand, quantity of supply, number of sources, number of destinations, and costs	Sasikila et. al built SECM and NECM to find an initial feasible solution to the transportation problem. These method were used to calculate Initial Basic Feasible Solutions (IBFS) of transportation problems.
2019/ Jude [24]	Method: LCM, NWCM, VAM Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	In this study, the researchers conducted a comparative test between established methods for solving linear transportation problems and new approaches proposed by other researchers. Specifically, Jude et al. focused on evaluating the allocation schedule method by solving various cost-minimizing transportation problems. The study's conclusion revealed that the allocation schedule method did not yield any results superior to the existing methods.
2018/ Agarana et.al [17]	Method: VAM and MODI Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	VAM and MODI method were used to determine basic feasible solutions early and to also find optimal solutions for each major perishable food item under consideration.
2018/ Nahar et. Al [12]	Method: VAM, Improved VAM (IVAM), and MODI Variables: Number of demands, Total supply, Number of origins, Number of destinations, Distribution costs and inventory	This research was conducted to analyze the initial solution that can be implemented and test the optimal solution whether the Improved VAM method can provide savings or cost efficiency in rice distribution.
2017/ Iheonu and Inyama [8]	Method: VAM, and MODI Variables: number of goods, production capacity, shadow price,	This research claims that the VAM and MODI techniques are able to solve real economic problems through the development of transportation schedule models at the Company's factories in Owerri, Port-Harcourt and Enugu. The VAM and MODI methods are able to provide solutions for optimal transportation schedules, thereby reducing the amount of money the company spends on distribution of finished products by 0.5% (N 217,543.10) per month.
2016/ Jude et.al [24]	Method: NWCM, LCM, and VAM Variables: Products to be delivered, Destination of each product, Source node capacity, Demand for destination, Total capacity from source to	This research undertakes a comparative analysis of established techniques for solving linear transportation problems against a novel approach. The study asserts that the effectiveness of the allocation schedule method has been evaluated through the resolution of multiple cost-minimizing

Years/ Authors	Used Methodology & Variables	Contribution
	destination, Cost per unit of transporting commodity.	transportation problems. Surprisingly, the findings demonstrate that the allocation schedule method does not yield superior results compared to the already established methods.

5. Conclusion

The analysis in this study reveals that the subject of goods delivery strategy has been extensively investigated by researchers. This review paper offers a comprehensive examination of how different transportation methods are applied in real-world scenarios. Furthermore, the various contributions made by researchers in the field of transportation network issues are also addressed. It is evident that, apart from the MODI and VAM methods, other approaches have emerged to tackle the transportation problem. One such method is the Enhanced VAM (Improve VAM) focusing on production delivery strategy. However, the different versions of this problem are categorized based on their objectives and the parameters involved. A considerable amount of research has been conducted in the literature to advance transportation problems. By utilizing the survey presented in this review article, we obtained insights into the contributions of several previous studies in resolving existing transportation problems and their organized development from various international journal publishers.

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