

Development of Simplex Method in Linear Programming: A Review of Artificial-Free Simplex Method, Big-M, and its Various Applications in Optimization

Rahmi Era Ilnika¹, Ferina², Zefriyenni³

University Of Putra Indonesia-YPTK

Email: ¹rahmierailnika@gmail.com, ²Ferina27@gmail.com, ³zefriyenni@upiupk.ac.id

Linear programming is one of the most widely used optimization methods in managerial decision-making. Among the various algorithms developed to solve linear programming problems, the Simplex Method remains one of the most popular and effective approaches. As optimization needs to continue to evolve, researchers have sought to improve the efficiency and effectiveness of the Simplex Method through the development of new algorithms and its application across various sectors. This article aims to review the development of the Simplex Method based on five scientific articles covering the Artificial-Free Simplex Method (ASM), modifications of the Big-M Method, the application of the Simplex Method in communication module production, various industrial applications of the Simplex Method, and the development of the Infinite Big-M Method. The study employs a literature review approach using a qualitative descriptive method. The review findings indicate that the Simplex Method remains a relevant optimization tool in various fields due to its ability to regularly generate optimal solutions. Furthermore, several developments and modifications have successfully addressed some limitations of the conventional Simplex Method, particularly those related to the use of artificial variables, the determination of penalty parameter M values, and computational efficiency. Therefore, this study highlights the significant role of the Simplex Method in supporting data-driven decision-making, especially in the fields of management and industry.

Keywords: Linear Programming, Simplex Method, Artificial-Free Simplex Method, Big-M Method, Optimization, Decision-Making, Industrial Applications.

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Corresponding Author:

Rahmi Era Ilnika

University Of Putra Indonesia-YPTK

rahmierailnika@gmail.com

1. Introduction

The increasingly dynamic development of the business and industrial world demands that every organization be able to make decisions effectively, efficiently, and precisely. Increasing competition, changing consumer needs, limited resources, and the increasing complexity of operational activities require organizations to have methods that can help determine the best alternative decisions. Organizational resources, such as labor, raw materials, capital, time, production capacity, and facilities, are inherently limited, so their use must be optimally planned. Decisions made must not only consider achieving organizational goals but also need to consider the various limitations inherent in the implementation process. In these conditions, a quantitative approach is an alternative that can be used to assist management in analyzing various options objectively based on data and mathematical calculations. One quantitative approach widely used to assist the decision-making process is Linear Programming. Linear Programming is a mathematical method used to determine the optimal value of an objective function by considering a number of specific constraints. Through this method, organizations can determine the most optimal combination of resource use so that goals such as maximizing profits or minimizing costs can be achieved in a more measurable and rational manner.

The Simplex Method is one of the most widely used techniques in solving Linear Programming problems, especially when the problem faced has a relatively large number of decision variables and constraints. This method was developed to find the optimal solution through a systematic iteration process by comparing various possible solutions that satisfy predetermined constraints. In its application, the Simplex Method is able to determine the optimal solution of an objective function while still considering various resource limitations owned by the organization. The objective function can be an effort to maximize profits, increase production levels, or minimize operational costs. Meanwhile, the constraints used can be related to limitations on raw materials, labor, capital, working time, machine capacity, or other resources. This capability makes the Simplex Method relevant for use in various decision-making fields. In the field of production, this method can help determine product combinations that generate optimal profits. In the field of distribution, this method can be used to determine the efficient allocation of resources. In addition, the Simplex Method is also widely applied in capacity planning, inventory control, scheduling, labor allocation, and various other optimization problems. Thus, the Simplex Method is one of the important approaches in supporting the decision-making process based on mathematical calculations.

Despite its extensive capabilities in solving various optimization problems, the conventional Simplex Method still has several limitations in its solution process. One frequently encountered problem is the need to obtain an initial basic feasible solution before the Simplex iteration process can be carried out. In certain problems, the initial basic feasible solution cannot be obtained directly due to the structure of the constraints, especially in the form of equations or constraints that use a greater-than-or-equal-to sign and equality constraints. This condition requires additional methods in the form of artificial variables. In solving it, artificial variables can be used through the Big-M Method or the Two-Phase Method. Although both approaches can help obtain an initial feasible solution, their use can increase the complexity of calculations and require additional solution stages. These limitations then encourage various studies to develop alternative approaches that can improve the efficiency of the Linear Programming problem-solving process. The development of computing technology also provides opportunities to develop more practical and easy-to-implement optimization methods. On the other hand, the application of the Simplex Method continues to experience development in line with the increasing needs of organizations and industries for data-driven decision-making processes. Therefore, a study of the development of Linear Programming solution methods is important to understand various innovations and their applications.

Based on these conditions, this study was conducted to examine the development of the Simplex Method, both from a theoretical and practical perspective, based on five scientific articles that focus on the development and application of Linear Programming-based optimization methods. A review of these scientific articles is necessary to gain a more comprehensive understanding of how the Simplex Method is developed, modified, and applied to address various optimization problems. From a theoretical perspective, the study is directed at examining the basic concepts, solution procedures, approaches used, and the forms of method development offered by each study. Meanwhile, from a practical perspective, the study focuses on how the method is used to solve real-world problems related to resource allocation, production planning, cost efficiency, and other decision-making. The five articles reviewed are expected to provide an overview of the development of the application of Linear Programming and the Simplex Method in various problem contexts. In addition, a comparison of research results can also be used to identify similarities, differences, advantages, and limitations of the approaches used by each researcher. Thus, this study not only provides an understanding of the conventional application of the Simplex Method but also shows the direction of the development of optimization methods that are increasingly adaptive to the needs of problem-solving in business and industrial environments.

2. Literature Review and Problem Statement

Linear programming is a mathematical optimization technique used to obtain the best solution to an objective function by considering a number of linear constraints. According to George B. Dantzig, the Simplex method is a systematic procedure that moves from one feasible solution to another until an optimum solution is found. This theory forms the basis for the development of various modern optimization methods.

Various studies have developed the Simplex method to overcome the limitations of conventional methods. Research on the Artificial-Free Simplex Method (ASM) shows that initial feasible solutions can be obtained without using artificial variables. Other research has developed the Infinite Big-M Method, which eliminates the need for manual determination of the M penalty value. Furthermore, the Simplex method is also widely applied to production optimization and various industrial problems.

However, most research still assumes linear relationships and fixed parameter conditions. Method testing is also often conducted on simulations or numerical examples, thus limiting its validity in complex industrial environments. Therefore, this study formulates the following questions: How has the Simplex method developed in overcoming the limitations of conventional methods and to what extent is its application effective in supporting optimization-based managerial decision-making?

3. Method

This study uses a literature review method with a qualitative descriptive approach. Data sources were obtained from five scientific articles discussing the development and application of the Simplex method, namely Artificial-Free Simplex Method, Modified Big-M Method, Application of the Simplex Method in the Production of Communication Modules, Some Applications of Simplex Method, and The Big-M Method with the Numerical Infinite M.

The analysis was conducted through several stages: article identification, research focus grouping, analysis of the methods used, evaluation of the research results, and identification of the strengths and weaknesses of each approach. The results were then synthesized to identify method developments, research gaps, and recommendations for more appropriate methods for future research..

4. Results and Discussion

No	Article	Research Focus	Key Results
1	Artificial Free Clone of Simplex Method for Feasibility	ASM Development	Eliminates the need for artificial variables
2	Modification of the Big-M Method	SME Production Optimization	Optimal profit Rp5,455,775/week
3	Application of the Simplex Method in the Production of Communication Modules	Communication Module Production	Optimal production combination
4	Some Applications of Simplex Method	Literature Review	Demonstrates various applications of the Simplex method.
5	The Big-M Method with the Numerical Infinite M	Infinite Big-M	Eliminates the need for M values

Development of the Simplex Method

The study results show that the development of the Simplex method focuses on increasing the efficiency of the optimization process. The Artificial-Free Simplex Method offers a solution without the use of artificial variables, thus simplifying the table structure. Meanwhile, the Infinite Big-M Method overcomes the problem of determining the M penalty value, which often causes numerical instability in conventional Big-M methods.

Application in the Industry World

Several studies have shown that the Simplex method remains highly relevant in solving industrial problems. In communication module production, the Simplex method successfully identified production combinations that yielded maximum revenue. In SME optimization, the Big-M method provided production solutions that yielded optimal profits and provided information on sensitivity to parameter changes.

Comparison With Previous Research

The study's results are consistent with optimization theory, which states that the Simplex method is an effective algorithm for solving linear programming problems. However, recent research has shown a growing trend toward developing methods that address the limitations of using artificial variables, relying on the M value, and improving computational efficiency in large-scale problems.

Research GAP

There are three main research gaps:

1. Testing of new methods is still dominated by mathematical simulations.
2. Most studies use the assumption of definite and linear parameters.
3. The integration of optimization methods with Artificial Intelligence and Decision Support System technology is still limited.

Implications For Quantitative Management

The Simplex method is a key tool in Quantitative Management because it supports data-driven decision-making. Its application can be used for production optimization, resource allocation, budgeting, and managing an organization's operational capacity. Therefore, understanding the Simplex method and its development is a crucial competency for management practitioners and students.

Analysis of the Weaknesses of Each Research Method

1. Weaknesses of the Artificial-Free Simplex Method (ASM)

The Artificial-Free Clone of Simplex Method for Feasibility study developed the Artificial-Free Simplex Method (ASM) as an alternative to the first-phase Simplex method without using artificial variables. While this method successfully simplifies the table structure and reduces memory requirements, several weaknesses were identified.

First, the ASM method still relies on an iterative pivot process, similar to the conventional Simplex method. The more variables and constraints a model has, the greater the number of iterations required. Second, the ASM algorithm is relatively difficult to understand for users new to linear programming because the concept is not widely discussed in standard textbooks. Third, testing of the method is still dominated by numerical examples and mathematical simulations, so its validity in complex industrial cases still requires further testing. A more suitable method for large-scale problems is the Interior Point Method because it has the ability to solve models with a very large number of variables more efficiently.

2. Weaknesses of Modifying the Big-M Method in SME Production Optimization

This study, Modified Big-M Method and Its Sensitivity Analysis for Optimizing Production in Small and Medium Enterprises, uses the Big-M method to determine the optimal production combination for

small and medium enterprises. The results show that optimal solutions and maximum profits can be achieved, but the method still has several limitations.

The main weakness of the Big-M method is its dependence on a very large penalty value, M , which must be determined. If M is too small, the optimal solution may be invalid. Conversely, if M is too large, the calculation can experience numerical errors. Furthermore, the research still assumes that all data is certain and constant, even though actual production conditions frequently experience changes in raw material prices and availability. In cases like this, the Two Phase Method is more recommended because it does not require determining the value of M . If the model contains uncertainty, the use of Fuzzy Linear Programming can be a more realistic alternative.

3. Weaknesses of Applying the Simplex Method to Communication Module Production

The study, "Application of the Simplex Method in the Production of Communication Modules," used the Simplex method to determine the communication module production combination that maximizes revenue. The results showed that this method was effective in identifying machine capacity, the primary production constraint.

However, the model used still has several weaknesses. First, all relationships between variables are assumed to be linear. In industrial practice, costs and productivity often change nonlinearly. Second, the model assumes machine capacity and product demand are fixed, thus failing to capture market uncertainty. Third, the study only used two product types, so the problem complexity is relatively low compared to modern production systems involving multiple products and resources. To overcome these weaknesses, the Stochastic Programming or Goal Programming method is more appropriate when there is uncertainty or more than one goal to be achieved simultaneously.

4. Weaknesses of the Simplex Method Application Study

The article "Some Applications of the Simplex Method" is a literature review that discusses various applications of the Simplex method in several fields, such as sand casting optimization, fuzzy linear programming, and model predictive control. This study provides a broad overview of the Simplex method's applications, but it has several limitations.

The main weakness of this study is the lack of development of new methods or empirical testing conducted directly by the author. Most of the discussion consists solely of summaries of previous research results, making its contribution primarily descriptive. Furthermore, there is no in-depth quantitative comparison of the efficiency of each method discussed. For further research, a comparative study is needed that tests several optimization methods using the same data to obtain a more objective picture of the performance of each method.

5. Weaknesses of the Infinite Big-M Method

The Big-M Method with the Numerical Infinite M study developed the Infinite Big-M Method (I-Big-M), which aims to overcome the weaknesses of the conventional Big-M method. This method utilizes the Grossone concept, eliminating the need for manual determination of M values.

Despite offering innovative solutions, this method still has several limitations. First, the Grossone and G-Simplex concepts are still relatively new and therefore not yet widely used and understood by the academic community or practitioners. Second, its implementation requires specialized algorithms that are not yet widely available in commercial optimization software. Third, testing of the method is still limited to numerical studies, so its applicability in complex industrial environments still needs further verification.

In current conditions, the Two Phase Method and Interior Point Method are still more practical to use because they are supported by various optimization software and have a wider level of acceptance among practitioners.

Recommendation of A More Appropriate Method

Based on the weaknesses found, several methods are recommended for further research.

1. Artificial-Free Simplex Method (ASM)

Although the Artificial-Free Simplex Method (ASM) successfully eliminates the need for artificial variables in the Simplex method, this method still relies on the pivot mechanism, which is the main characteristic of the Simplex algorithm. Therefore, further research is recommended to use the Interior Point Method because it can solve optimization problems without repeated pivot processes, has higher computational efficiency, and is more suitable for large-scale optimization problems. Thus, the Interior Point Method has the potential to provide better performance than ASM in increasingly complex industrial environments.

2. Modification of the Big-M Method in SME Production Optimization

Although the Modified Big-M Method successfully produces optimal solutions to SME production problems, the method still focuses on a single goal: maximizing profits. In practice, companies often face multiple objectives that must be achieved simultaneously, such as efficient use of raw materials, meeting market demand, and controlling production costs. Therefore, the Goal Programming method is considered more suitable for further research because it can accommodate multiple objectives simultaneously and produce more realistic decisions according to the organization's operational conditions.

3. Application of the Simplex Method in the Production of Communication Modules

Although the Simplex method is capable of generating optimal production combinations and maximizing company revenue, this method is still limited to a single objective function. In manufacturing practice, companies generally face multiple objectives that must be achieved simultaneously, such as maximizing profits, reducing production costs, increasing machine capacity utilization, and meeting market demand. Therefore, Goal Programming is recommended as a more suitable method for further research because it can accommodate various organizational objectives simultaneously, resulting in more realistic and comprehensive decisions.

4. Study of the Application of the Simplex Method

Application studies of the Simplex method show that it can be used in various fields, from manufacturing to control systems. However, the Simplex method still has limitations because it assumes all parameters are fixed and the relationships between variables are linear. In real-world conditions, many managerial decisions are influenced by high levels of uncertainty. Therefore, Fuzzy Linear Programming is recommended as a more suitable method for further research because it can accommodate data uncertainty and produce more realistic solutions than the conventional Simplex method.

5. Infinite Big-M Method

Although the Infinite Big-M Method successfully overcomes the difficulty of determining the M penalty value in the conventional Big-M method, its implementation still requires a special approach in the form of Grossone Methodology and the G-Simplex algorithm which are not widely used in industrial practice. Therefore, the Interior Point Method is recommended as a more suitable method for further research because it has the ability to solve large-scale optimization problems more efficiently, is more numerically stable, and has gained wide acceptance in various modern optimization applications.

5. Conclusion

Based on a review of five articles discussing the development and application of the Simplex method, it can be concluded that the Simplex method remains one of the most widely used optimization approaches in

solving linear programming problems. The advantages of this method lie in its ability to systematically produce optimal solutions, its ease of understanding, and its applicability to various fields, such as production planning, resource allocation, inventory control, and managerial decision-making.

This study demonstrates that the development of the Simplex method focuses not only on practical applications but also on algorithm refinement. The Artificial-Free Simplex Method (ASM) successfully eliminates the need for artificial variables in the initial phase of the Simplex method. Meanwhile, the Infinite Big-M Method (I-Big-M) offers a solution to the weaknesses of the conventional Big-M method by eliminating the need for manual determination of the M penalty value. Both developments demonstrate ongoing efforts to improve the efficiency and stability of the optimization process.

On the other hand, research on SME production optimization and communication module production has demonstrated that the Simplex method can provide optimal solutions that support objective and measurable decision-making. In addition to generating maximum profits, this method can also identify key constraints in the production process, thus providing a basis for developing a company's operational strategy.

However, all of the studies reviewed still have limitations, primarily due to the assumption of linear relationships and certain data. These conditions often differ from the reality of the uncertain business world. Therefore, future research should consider the use of more adaptive methods such as Goal Programming, Fuzzy Linear Programming, Stochastic Programming, and the Interior Point Method to produce more realistic solutions that meet the needs of modern organizations. Overall, the results of this study indicate that the Simplex method and its various developments continue to play a vital role in the field of Quantitative Management. This method serves not only as a mathematical tool for finding optimal solutions but also as a supporting instrument for rational, effective, and data-driven decision-making.

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