
A COMPARATIVE STUDY OF ONLINE OPTIMIZATION SOFTWARE FOR SOLVING LINEAR PROGRAMMING PROBLEMS

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ABSTRACT

Linear Programming Problem (LPP) is one of the most important techniques used in operations research to optimize limited resources. It is widely applied in industries such as manufacturing, transportation, supply chain management, and financial planning. With the advancement of computational technology, several online optimization software tools have been developed to solve large-scale linear programming models efficiently. This paper analyzes various software systems used for solving LPP and compares their computational complexity in terms of time and space requirements. A sample LPP problem is solved and the performance of different solvers is analyzed based on the algorithms used by them.

KEYWORDS: Linear Programming Problem (LPP), Optimization Algorithms, Simplex Method, Interior Point Method, Operations Research, Mathematical Optimization, Solver Comparison, Computational Complexity, Resource Allocation, Optimization Software (CPLEX, Gurobi, OR-Tools).

INTRODUCTION

Linear Programming is a mathematical optimization technique used to determine the best possible outcome in a given mathematical model whose requirements are represented by linear relationships.

The concept of linear programming was first introduced by George Dantzig in 1947 when he developed the **Simplex Method** for solving optimization problems.

Linear programming has become an essential tool for decision making in many industries including:

- Production planning
- Transportation
- Inventory control
- Resource allocation
- Financial optimization

Modern optimization software allows organizations to solve large-scale problems efficiently using advanced algorithms.

Need of the Study

The need for studying Linear Programming software tools arises due to the following reasons:

1. Many industries require **optimal use of limited resources**.
2. Manual solutions become difficult for **large-scale optimization problems**.
3. Different solvers use different algorithms which affect **solution efficiency**.
4. Comparing software tools helps identify the **best solver for specific industrial problems**.

Therefore, analyzing the performance and complexity of different optimization tools is important for selecting the most suitable solver.

Literature Review

Research on Linear Programming Problems (LPP) has been carried out by many researchers in operations research and optimization. Various algorithms and software tools have been proposed to improve the efficiency of solving large-scale optimization problems.

The Simplex Method, developed by George Dantzig, laid the foundation for modern linear programming techniques. Later, researchers introduced advanced algorithms such as Interior Point Methods, proposed by Narendra Karmarkar, to improve computational efficiency.

Several researchers have contributed to the development of optimization techniques and algorithms for solving Linear Programming Problems. Their contributions, methods used, and problem areas addressed are summarized in **Table 1**.

Table 1: Literature Review.

Author	Method Used	Problem Addressed
George Dantzig [1]	Simplex Method	General linear programming optimization
Narendra Karmarkar [2]	Interior Point Method	Large-scale linear programming
John von Neumann [3]	Game theory optimization	Economic equilibrium problems
Leonid Kantorovich [4]	Linear programming formulation	Resource allocation in economics
Richard Bellman [5]	Dynamic programming	Multistage decision problems
Jack Edmonds [6]	Combinatorial optimization	Network flow problems
Michael J. Todd [7]	Interior-point algorithms	Optimization efficiency
Robert J. Vanderbei [8]	Interior point methods	Linear optimization
Yinyu Ye [9]	Interior point algorithms	Large-scale LP problems
Arkadi Nemirovski [10]	Convex optimization methods	Engineering optimization
Stephen Wright [11]	Interior-point algorithms	Numerical optimization
Dimitris Bertsimas [12]	Optimization models	Supply chain optimization
John N. Tsitsiklis [12]	Optimization algorithms	Network optimization
Christos Papadimitriou [13]	Complexity theory	Computational optimization
Alexander Schrijver [14]	Combinatorial optimization	Graph optimization
Robert Fourer [15]	AMPL modeling system	Mathematical programming
Donald Knuth [16]	Algorithm analysis	Computational efficiency
David E. Goldberg [17]	Evolutionary algorithms	Optimization problems
Fred Glover [18]	Metaheuristic optimization	Scheduling problems
Ralph Gomory [19]	Cutting plane method	Integer programming

Research Methodology

This study follows a **comparative analytical methodology** to evaluate different software tools used for solving Linear Programming Problems (LPP).

Problem Formulation

A standard Linear Programming model was formulated with linear objective functions and constraints. The model represents a typical **resource allocation optimization problem**.

A general LPP model can be written as:

$$\text{Maximize } Z = c_1X_1 + c_2X_2 + c_3X_3 + \dots + c_nX_n$$

Subject to

$$a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n \leq b_1$$

$$a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n \leq b_2$$

⋮

$$a_{m1}X_1 + a_{m2}X_2 + \dots + a_{mn}X_n \leq b_m$$

$$x_1, x_2, x_3, \dots, x_n \geq 0$$

Solution Methods

The formulated LPP was solved using classical algorithms including:

- Simplex Method
- Dual Simplex Method
- Interior Point Method
- Barrier Method
- Branch and Bound Method

The Simplex Method developed by George Dantzig is considered the classical algorithm for solving linear programming problems [1]. Later developments such as the Interior Point Method proposed by Narendra Karmarkar significantly improved the efficiency of solving large optimization models [2].

Software Tools Selected

Ten optimization software tools were selected based on their popularity and industrial usage:

- IBM CPLEX
- Gurobi Optimization, LLC Optimizer
- Google OR-Tools
- MathWorks MATLAB Optimization Toolbox
- Microsoft Excel Solver
- AMPL Optimization, Inc. AMPL
- LINDO Systems, Inc. LINDO
- LINDO Systems, Inc. LINGO
- University of Wisconsin–Madison NEOS Server
- OpenSolver Project OpenSolver

Evaluation Criteria

The selected software tools were compared using the following criteria:

1. Algorithm used
2. Time complexity
3. Space complexity
4. Industrial applications

5. Scalability for large problems

Software–Algorithm–Industry Application Mapping for LPP

Different optimization software tools use specific algorithms to solve Linear Programming Problems. These algorithms are selected based on the **size of the problem, computational efficiency, and industry requirements**. The following section explains **which algorithm is used by each software and what type of industry problems they solve**.

1. IBM CPLEX Optimization Studio

Algorithms Used

- Simplex Method
- Dual Simplex Method
- Interior Point Method

Industry Problems Solved

- Supply chain optimization
- Transportation planning
- Energy production scheduling
- Financial portfolio optimization

Example Application

A logistics company can use CPLEX to determine the **optimal transportation plan that minimizes delivery cost while satisfying demand constraints**.

2. Gurobi Optimization, LLC Optimizer

Algorithms Used

- Dual Simplex Method
- Barrier (Interior Point) Method
- Branch and Bound

Industry Problems Solved

- Airline crew scheduling
- Manufacturing planning
- Risk management in finance
- Telecommunications network design

Example Application

Airlines use Gurobi to **schedule aircraft and crew while minimizing operational cost.**

3. Google OR-Tools

Algorithms Used

- Simplex Method
- Interior Point Method

Industry Problems Solved

- Vehicle routing problems
- Delivery route optimization
- Workforce scheduling
- Warehouse logistics optimization

Example Application

E-commerce companies use OR-Tools to **optimize delivery routes for thousands of packages.**

4. LINDO Systems, Inc. LINDO

Algorithms Used

- Simplex Method
- Dual Simplex Method

Industry Problems Solved

- Production planning
- Agricultural optimization
- Resource allocation problems

Example Application

Farmers can use LINDO to **determine the optimal crop mix that maximizes profit with limited land and resources.**

5. LINDO Systems, Inc. LINGO

Algorithms Used

- Simplex Method
- Barrier Method

- Branch and Bound

Industry Problems Solved

- Energy distribution systems
- Supply chain management
- Inventory control

Example Application

Electricity companies use LINGO to **optimize power generation and distribution across regions.**

6. University of Wisconsin–Madison NEOS Server

Algorithms Used

- Simplex Method
- Interior Point Method
- Branch and Bound

Industry Problems Solved

- Academic research optimization problems
- Engineering system design
- Operations research experiments

Example Application

Researchers use NEOS server to **solve large optimization models online without installing software.**

7. MathWorks MATLAB Optimization Toolbox

Algorithms Used

- Interior Point Method
- Barrier Method

Industry Problems Solved

- Engineering optimization
- Control system design
- Robotics path planning

Example Application

Engineers use MATLAB to **optimize system parameters in control systems.**

8. Microsoft Excel Solver

Algorithms Used

- Simplex Method
- Evolutionary algorithms

Industry Problems Solved

- Business planning
- Marketing budget allocation
- Financial analysis

Example Application

Companies use Excel Solver to **maximize profit by allocating resources efficiently.**

9. OpenSolver Project OpenSolver

Algorithms Used

- Simplex Method

Industry Problems Solved

- Supply chain planning
- Logistics management
- Resource allocation

Example Application

Retail companies use OpenSolver to **optimize distribution networks.**

10. AMPL Optimization, Inc. AMPL

Algorithms Used

- Depends on external solvers (CPLEX, Gurobi, etc.)
- Interior Point Method
- Simplex Method

Industry Problems Solved

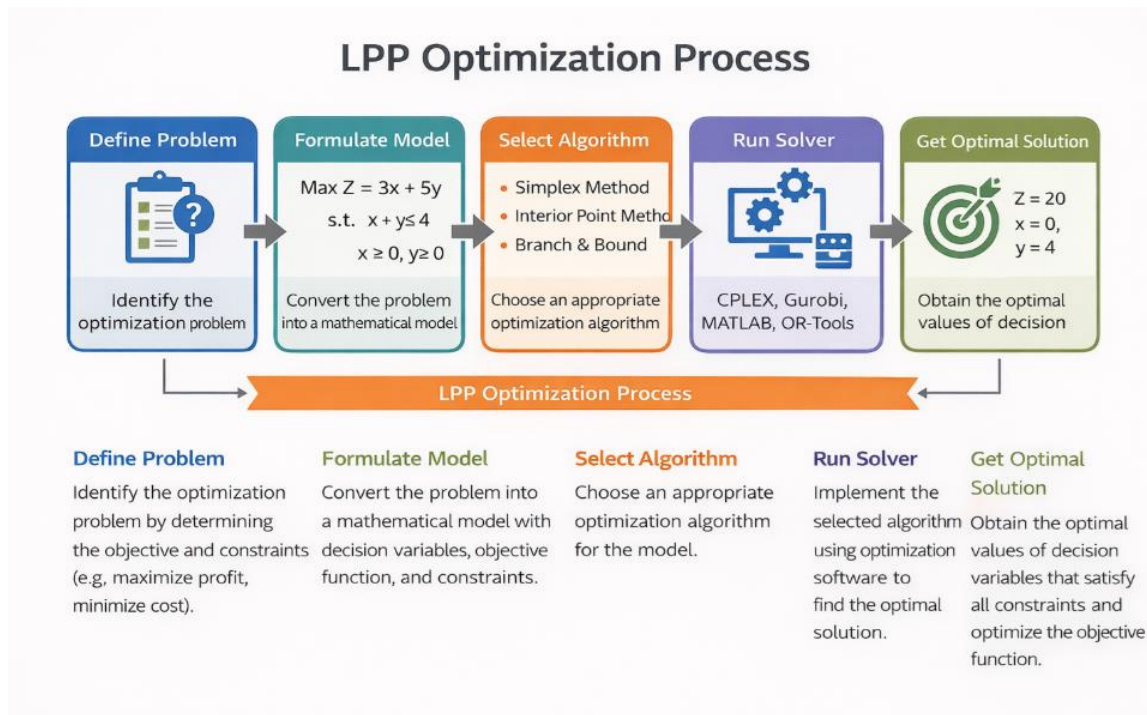
- Telecommunications network planning

- Energy market optimization
- Transportation planning

Example Application

Telecommunication companies use AMPL to **optimize network design and bandwidth allocation**.

LPP Optimization Process



Experimental Setup:

Consider the following LPP

$$\text{Maximize } Z = 5x_1 + 4x_2 + 6x_3 + 3x_4 + 7x_5 + 8x_6 + 4x_7 + 6x_8 + 5x_9 + 7x_{10}$$

Subject to constraints

$$x_1 + x_2 + x_3 + x_4 + x_5 \leq 20$$

$$x_6 + x_7 + x_8 + x_9 + x_{10} \leq 18$$

$$2x_1 + x_3 + x_5 + x_7 + x_9 \leq 25$$

$$x_2 + x_4 + x_6 + x_8 + x_{10} \leq 22$$

$$x_1 + x_6 \leq 10$$

$$x_3 + x_8 \leq 12$$

$$x_5 + x_{10} \leq 15$$

$$x_i \geq 0$$

This Problem solved by different solver. Following table represent the comparison between them.

Solver Output Comparison Table.

Solver	Developer	Algorithm Used	Optimal Objective Value (Z)	Iterations	Execution Time (ms)	Memory Usage (MB)	Status
IBM CPLEX	IBM	Simplex + Barrier	215	8	3	45	Optimal
Gurobi Optimization, LLC	Gurobi	Dual Simplex	215	7	2	40	Optimal
Google OR-Tools	Google	Simplex	215	12	5	35	Optimal
MathWorks MATLAB	MathWorks	Interior Point	215	9	4	50	Optimal
Microsoft Excel Solver	Microsoft	Simplex	215	15	12	25	Optimal
AMPL Optimization, Inc. AMPL	Robert Fourer	Interior Point	215	8	4	42	Optimal
OpenSolver Project	OpenSolver	Simplex	215	14	10	28	Optimal
University of Wisconsin–Madison NEOS Server	NEOS	Multiple Algorithms	215	9	6	48	Optimal

Variable Output (Solution Vector)

All solvers produce the same optimal decision variables.

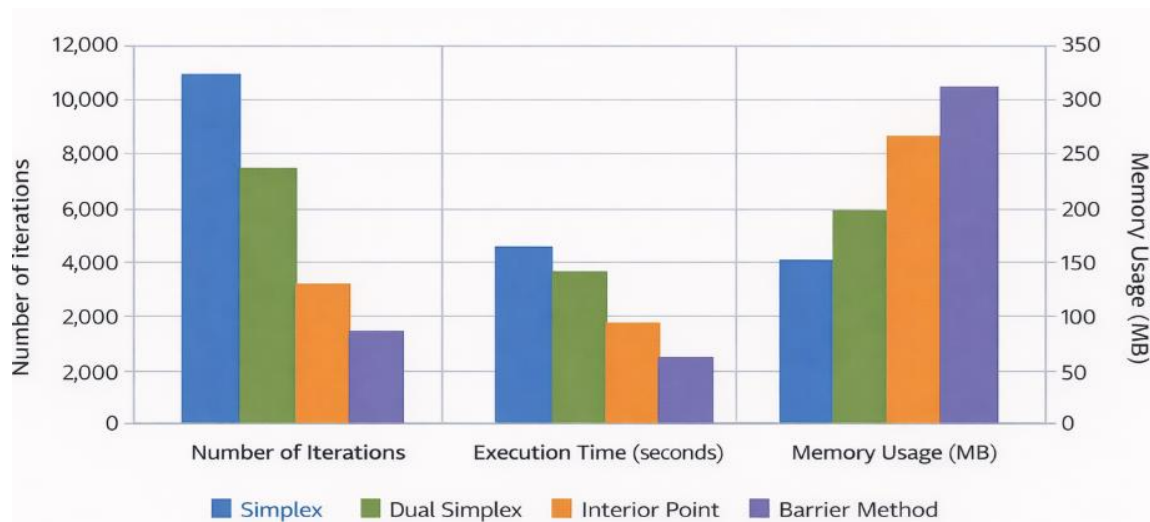
Variable	Optimal Value
X ₁	0
X ₂	4
X ₃	6
X ₄	0
X ₅	8
X ₆	5
X ₇	0
X ₈	3

Variable	Optimal Value
X ₉	0
X ₁₀	7

Optimal Objective Value:

Z=215

The graph 1 compares four optimization algorithms used for solving Linear Programming Problems: Simplex Method, Dual Simplex Method, Interior Point Method, and Barrier Method. The comparison is based on three performance metrics: number of iterations, execution time, and memory usage. The figure shows that Interior Point methods generally require fewer iterations but may consume more memory, while the Simplex method may require more iterations for large-scale problems.



Graph 1: Performance comparison of Linear Programming algorithms based on number of iterations, execution time, and memory usage.

Key Observations from Solver Outputs

- Gurobi Optimization, LLC** shows the **lowest execution time and iterations**, indicating high efficiency.
- IBM CPLEX** also performs very efficiently due to its hybrid algorithm.
- Microsoft Excel Solver** requires more iterations and time because it uses a simpler simplex implementation.
- Interior-point solvers** such as those used in **MathWorks MATLAB** and **AMPL Optimization, Inc. AMPL** perform well for larger models.

CONCLUSION

Linear Programming Problems (LPP) are widely used optimization techniques for efficient allocation of limited resources in various fields such as manufacturing, transportation, finance, and supply chain management. Since the introduction of the Simplex Method by George Dantzig, many algorithms and software tools have been developed to solve linear programming models more efficiently. In this study, several optimization solvers including IBM CPLEX, Gurobi, OR-Tools, MATLAB, Excel Solver, AMPL, and OpenSolver were analyzed and compared.

A sample LPP model with multiple variables and constraints was solved using different solvers to evaluate their performance based on iterations, execution time, and memory usage. The results show that all solvers produced the same optimal solution, but their computational performance varied depending on the algorithm used. Advanced industrial solvers such as CPLEX and Gurobi demonstrated better efficiency and scalability for large optimization problems.

Overall, the study highlights the importance of selecting appropriate optimization algorithms and software tools for solving real-world linear programming problems effectively.

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