

Applications Of Operations Research In Real-Life Scenarios Supply Chain Optimization for FMCG Products using the Transportation Model

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Abstract: Operations Research (OR) is a scientific and analytical approach used to solve complex problems and support effective decision-making in real-life situations. It applies mathematical models, statistical techniques, optimization methods, and computational tools to identify the best possible solutions under given constraints. Operations Research has a wide range of applications in various fields, including healthcare, transportation, supply chain management, manufacturing, finance, agriculture, and education. In healthcare, it helps optimize hospital resources and patient scheduling. In transportation, it assists in route planning, traffic management, and reducing travel costs. In industries, it improves production planning, inventory control, and resource allocation. Similarly, businesses use Operations Research to minimize costs, maximize profits, and improve overall efficiency. This study explores the practical applications of Operations Research in real-life scenarios and highlights its importance in solving problems, utilizing resources efficiently, and improving organizational performance. The application of Operations Research enables individuals and organizations to make informed, data-driven decisions and achieve better outcomes in an increasingly complex and competitive environment.

Keywords: Operations Research, Optimization, Decision-Making, Resource Allocation, Linear Programming, Supply Chain Management, Cost Minimization, Profit Maximization, Scheduling, Real-Life Applications.

I. INTRODUCTION

Operations Research is a scientific approach to decision-making that uses mathematical models, quantitative techniques and logical analysis to identify the best possible decision under stated constraints. It is particularly useful when managers must allocate scarce resources among competing activities. Typical OR applications include production planning, transportation, assignment, inventory control, scheduling, routing, queuing and network optimization.

In supply chains, transportation decisions directly affect product availability and logistics expenditure. FMCG firms face especially demanding distribution conditions because products move in high volumes, demand is spread across many locations, replenishment is frequent and delays can quickly affect sales. A transportation model helps management determine how much should be shipped from each source to each destination so that demand is met without exceeding source capacity and the total distribution cost is minimized.

1.1 Transportation Problem

The transportation problem is a special form of linear programming. It contains a set of origins with available supply, a set of destinations with required demand, and a unit transportation cost for every origin–destination route. The decision variable x_{ij} represents the quantity transported from source i to destination j . The objective is to minimize the sum of cost multiplied by quantity across all routes.

Minimize $Z = \sum_i \sum_j C_{ij} X_{ij}$

$$\text{Total Cost} = \text{Cost per truckload} \times \text{No. of truckloads, for all routes}$$

Subject to source-capacity constraints, destination-demand constraints and non-negativity restrictions. A balanced transportation problem has total supply equal to total demand. When they are unequal, a dummy source or dummy destination is introduced so that the standard transportation algorithms can be applied.

1.2 Why the FMCG Case is Appropriate

- The decision involves several plants and several demand points.
- Transportation costs differ by route.
- Plant capacities and destination requirements are known.
- The objective, minimum distribution cost, is measurable.

II. SELECTED RESEARCH PAPER AND REAL-LIFE CONTEXT

2.1 Paper Selected

The quantitative case used for this project is based on “Supply Chain Management Optimization Problem” by A. C. Uzorh and Innocent Nnanna, published in The International Journal of Engineering and Science (IJES), Volume 3, Issue 6, 2014, pages 01–09. The paper applies mathematical optimization to a Coca-Cola supply-chain distribution problem and reports a TORA-based optimum. The numerical transportation model developed in this project reproduces that published optimum.

2.2 Industry and Business Problem

The case belongs to the beverage/FMCG industry. Finished products must be moved from four production plants to distribution markets in southern Nigeria. Management must decide the number of truckloads to dispatch on each route. Sending too much from a plant would violate its available

capacity, while sending too little to a destination would fail to satisfy its requirement. At the same time, routes have different unit costs, so an arbitrary shipment plan can be unnecessarily expensive.

2.3 Research Problem Reframed for Classroom Analysis

For transportation-method analysis, the problem is stated as follows: determine the number of truckloads to be transported from Aba, Owerri, Enugu and Port Harcourt to Mbaise, Orlu, Umuahia, Calabar and Uyo so that all destination requirements are met at the minimum possible transportation cost. Since aggregate plant capacity exceeds real destination demand by 72 truckloads, a dummy destination is added to absorb the unused capacity at zero cost.

2.4 Tools Used

- Transportation algorithms: NW Corner, Least Cost and VAM.
- MODI method for optimality testing and improvement.
- Excel Solver with the Simplex LP method for independent validation.
- Published TORA result from the selected paper for external comparison.

III. DATA AND MATHEMATICAL MODEL

3.1 Balanced Transportation Table

Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo	Dummy	Supply
Aba	280,800	417,600	230,400	554,400	691,200	0	1,152
Owerri	230,400	216,000	280,800	691,200	835,200	0	1,152
Enugu	554,400	691,200	417,600	835,200	972,000	0	1,152
Port Harcourt	374,400	460,800	280,800	554,400	691,200	0	1,152
Demand	288	504	1,152	1,296	1,296	72	4,608

Total supply = $1,152 \times 4 = 4,608$ truckloads. Real demand = $288 + 504 + 1,152 + 1,296 + 1,296 = 4,536$ truckloads. Therefore, dummy demand = $4,608 - 4,536 = 72$ truckloads.

The complete objective function contains all 24 plant–destination combinations, including the zero-cost dummy routes.

$$\text{Min } Z = \sum C_{ij} X_{ij}$$

3.2 Decision Variables

Let X_{ij} denote the number of truckloads transported from plant i to destination j . For example, $X_{Aba, Calabar}$ represents truckloads sent from Aba to Calabar, while $X_{Enugu, Dummy}$ represents unused capacity assigned to the dummy destination.

3.3 Objective Function

The objective is to minimize total transportation cost. Each decision variable is multiplied by its corresponding route cost.

3.4 Constraints

Each plant has a capacity of 1,152 truckload, giving four source constraints. Each destination must receive its stated requirement, giving six destination constraints after the dummy is included. All shipment variables must be non-negative.

- For each plant: $\sum_j X_{ij} = 1,152$.
- Destination requirements: Mbaise 288; Orlu 504; Umuahia 1,152; Calabar 1,296; Uyo 1,296; Dummy 72.

- Non-negativity: $X_{ij} \geq 0$.

3.5 Assumptions

- Unit transportation cost on each route is known and constant.
- Supply and demand quantities are known for the planning period.
- Truckloads are treated as divisible within the linear model, although the reported solution is integral.
- The dummy destination represents unused capacity and carries zero cost.
- The model focuses on transportation cost and does not separately model lead time, disruptions or inventory holding cost.

IV. INITIAL BASIC FEASIBLE SOLUTIONS

An Initial Basic Feasible Solution provides a starting allocation that satisfies all supply and demand requirements. Three standard methods are used so that the quality of different starting solutions can be compared before optimality testing.

4.1 North-West Corner Method

The North-West Corner Method begins at the top-left feasible cell and allocates the maximum possible quantity without considering transportation cost. After satisfying a row or column, the method moves right or downward. The first allocations are Aba–Mbaise = 288, Aba–Orlu = 504 and Aba–Umuahia = 360. The remaining Umuahia demand is then 792, which is allocated to Owerri–Umuahia.

Plant	Destination	Allocation	Unit Cost	Route Cost
Aba	Mbaise	288	₦280,800	₦80,870,400
Aba	Orlu	504	₦417,600	₦210,470,400
Aba	Umuahia	360	₦230,400	₦82,944,000
Owerri	Umuahia	792	₦280,800	₦222,393,600
Owerri	Calabar	360	₦691,200	₦248,832,000
Enugu	Calabar	936	₦835,200	₦781,747,200
Enugu	Uyo	216	₦972,000	₦209,952,000
Port Harcourt	Uyo	1,080	₦691,200	₦746,496,000
Port Harcourt	Dummy	72	₦0	₦0

4.2 Least Cost Method

The Least Cost Method prioritizes the currently available route with the lowest unit transportation cost. It generally gives a better starting solution than NW Corner because route cost influences the allocation sequence.

Plant	Destination	Allocation	Unit Cost	Route Cost
Aba	Mbaise	288	₦280,800	₦80,870,400
Aba	Orlu	504	₦417,600	₦210,470,400
Aba	Umuahia	360	₦230,400	₦82,944,000
Owerri	Umuahia	792	₦280,800	₦222,393,600
Owerri	Calabar	360	₦691,200	₦248,832,000
Enugu	Calabar	936	₦835,200	₦781,747,200
Enugu	Uyo	216	₦972,000	₦209,952,000
Port Harcourt	Uyo	1,080	₦691,200	₦746,496,000
Port Harcourt	Dummy	72	₦0	₦0

Least Cost IBFS = ₦2,422,483,200

Both methods satisfy the rim conditions, but their initial costs remain above the final optimum.

V. VOGEL'S APPROXIMATION METHOD (VAM)

VAM uses row and column penalties to estimate the opportunity loss of not selecting the cheapest route. At each stage, the difference between the two smallest available costs in every active row and column is calculated. The row or

column with the highest penalty is selected, and the maximum feasible allocation is made to its least-cost cell. Penalties are recalculated after each allocation until all supply and demand are assigned.

5.1 VAM Allocation Sequence

Stage	Decision / Allocation
P1	Enugu → Dummy = 72
P2	Owerri → Orlu = 504
P3	Enugu → Umuahia = 1,080
P4	Port Harcourt → Umuahia = 72
P5	Owerri → Mbaise = 288
P6	Owerri → Calabar = 360
P7	Aba → Calabar = 936
P8	Aba → Uyo = 216
P9	Port Harcourt → Uyo = 1,080
Stage	Decision / Allocation
P1	Enugu → Dummy = 72
P2	Owerri → Orlu = 504
P3	Enugu → Umuahia = 1,080
P4	Port Harcourt → Umuahia = 72
P5	Owerri → Mbaise = 288
P6	Owerri → Calabar = 360
P7	Aba → Calabar = 936
P8	Aba → Uyo = 216
P9	Port Harcourt → Uyo = 1,080

5.2 VAM Initial Solution

Plant	Destination	Allocation	Unit Cost	Route Cost
Aba	Calabar	936	₦554,400	₦518,918,400
Aba	Uyo	216	₦691,200	₦149,299,200
Owerri	Mbaise	288	₦230,400	₦66,355,200
Owerri	Orlu	504	₦216,000	₦108,864,000
Owerri	Calabar	360	₦691,200	₦248,832,000
Enugu	Umuahia	1,080	₦417,600	₦451,008,000
Enugu	Dummy	72	₦0	₦0
Port Harcourt	Umuahia	72	₦280,800	₦20,217,600
Port Harcourt	Uyo	1,080	₦691,200	₦746,496,000

VAM IBFS Cost = ₦2,309,990,400

5.3 Basic-Variable Check

For a non-degenerate transportation solution, the required number of basic allocations is $m + n - 1$. Here $m = 4$ sources and $n = 6$ destinations, so $4 + 6 - 1 = 9$. The VAM solution contains exactly nine positive allocations and therefore satisfies the basic-variable requirement.

5.4 Comparison of Starting Solutions

VAM gives the lowest initial cost of the three methods. Its gap from the final optimum is only ₦9,849,600, compared with ₦122,342,400 for Least Cost and ₦283,564,800 for NW Corner. This makes VAM the most efficient starting point for MODI in this case.

VI. MODI METHOD – OPTIMALITY TEST OF THE VAM SOLUTION

The Modified Distribution (MODI) method is used to test whether the VAM solution is optimal and, if necessary, improve it. For every occupied/basic cell, potentials u_i and v_j satisfy $u_i + v_j = C_{ij}$. Following the classroom convention, Owerri is assigned $u_i = 0$ because it contains the highest number of allocations.

6.1 Potentials for the VAM Basis

Potential	Value (₦)
u_{Aba}	-136,800
u_{Owerri}	0
u_{Enugu}	0
$u_{Port Harcourt}$	-136,800
v_{Mbaise}	230,400
v_{Orlu}	216,000
$v_{Umuahia}$	417,600
$v_{Calabar}$	691,200
v_{Uyo}	828,000
v_{Dummy}	0

6.2 Opportunity Values

The class convention used in this project is $\Delta_{ij} = u_i + v_j - C_{ij}$. Since this is a minimization problem, a positive Δ indicates that cost can be reduced by introducing that unoccupied cell. Optimality is reached when all unoccupied-cell deltas are less than or equal to zero.

Unoccupied Cell	Δ (₦)
Aba–Mbaise	–187,200
Aba–Orlu	–338,400
Aba–Umuahia	+50,400
Aba–Dummy	–136,800
Owerri–Umuahia	+136,800
Owerri–Uyo	–7,200
Owerri–Dummy	0
Enugu–Mbaise	–324,000
Enugu–Orlu	–475,200
Enugu–Calabar	–144,000
Enugu–Uyo	–144,000
PH–Mbaise	–280,800
PH–Orlu	–381,600
PH–Calabar	0
PH–Dummy	–136,800

The highest positive value is +₦136,800 at Owerri–Umuahia. Therefore, Owerri–Umuahia is selected as the entering cell for the improvement loop.

VII. MODI IMPROVEMENT LOOP AND θ ADJUSTMENT

7.1 Closed Loop

Starting from the entering cell Owerri–Umuahia, a closed path is formed through occupied cells by moving only horizontally and vertically. Signs alternate + and –, beginning with + at the entering cell.

Owerri–Umuahia (+) → Owerri–Calabar (–) → Aba–Calabar

(+) → Aba–Uyo (–) → PH–Uyo (+) → PH–Umuahia (–) → back

7.2 Determination of θ

The adjustment quantity is the smallest allocation at a negative corner of the loop:

$$\theta = \min(360, 216, 72) = 72$$

7.3 Revised Allocations

Cell	Old Allocation	Sign	Change	New Allocation
Owerri–Umuahia	0	+	+72	72
Owerri–Calabar	360	–	–72	288
Aba–Calabar	936	+	+72	1,008
Aba–Uyo	216	–	–72	144
PH–Uyo	1,080	+	+72	1,152
PH–Umuahia	72	–	–72	0

Port Harcourt–Umuahia becomes zero and leaves the basis. The other basic allocations remain unchanged. This single pivot produces the shipment pattern that is subsequently confirmed as optimal.

7.4 Cost Improvement

$$\text{Improvement} = 72 \times \text{₦}136,800 = \text{₦}9,849,600$$

$$\text{₦}2,309,990,400 - \text{₦}9,849,600 = \text{₦}2,300,140,800$$

The improvement exactly closes the gap between the VAM IBFS and the published optimum.

VIII. FINAL OPTIMALITY TABLE AND MINIMUM COST

8.1 Optimal Shipment Plan

Plant	Destination	Allocation	Unit Cost	Route Cost
Aba	Calabar	1,008	₦554,400	₦558,835,200
Aba	Uyo	144	₦691,200	₦99,532,800
Owerri	Mbaise	288	₦230,400	₦66,355,200
Owerri	Orlu	504	₦216,000	₦108,864,000
Owerri	Umuahia	72	₦280,800	₦20,217,600
Owerri	Calabar	288	₦691,200	₦199,065,600
Enugu	Umuahia	1,080	₦417,600	₦451,008,000
Enugu	Dummy	72	₦0	₦0
Port Harcourt	Uyo	1,152	₦691,200	₦796,262,400

8.2 Revised Potentials

ui	Value	vj	Value
uAba	–136,800	vMbaise	230,400
uOwerri	0	vOrlu	216,000
uEnugu	136,800	vUmuahia	280,800
uPort Harcourt	–136,800	vCalabar	691,200
		vUyo	828,000
		vDummy	–136,800

8.3 Final Opportunity Values

Unoccupied Cell	Δ (₦)
Aba–Mbaise	–187,200
Aba–Orlu	–338,400
Aba–Umuahia	–86,400
Aba–Dummy	–273,600
Owerri–Uyo	–7,200
Owerri–Dummy	–136,800
Enugu–Mbaise	–187,200
Enugu–Orlu	–338,400
Enugu–Calabar	–7,200
Enugu–Uyo	–7,200
PH–Mbaise	–280,800
PH–Orlu	–381,600
PH–Umuahia	–136,800
PH–Calabar	0
PH–Dummy	–273,600

All unoccupied-cell opportunity values satisfy $\Delta \leq 0$. Therefore, under the convention $\Delta = u_i + v_j - C_{ij}$, the solution is optimal for the minimization problem.

Minimum Transportation Cost = ₦2,300,140,800

IX. ALTERNATE OPTIMAL SOLUTION

The final MODI table contains an unoccupied cell, Port Harcourt–Calabar, with $\Delta = 0$. A zero opportunity value in an unoccupied cell at an optimum indicates that an alternate basic feasible solution can be generated without changing the total minimum cost.

9.1 Alternate-Optimum Loop

PH–Calabar (+) → PH–Uyo (–) → Aba–Uyo (+) → Aba–Calabar (–) → back $\theta = \min(1,152, 1,008) = 1,008$

9.2 Alternate Allocations

Plant	Destination	Allocation	Unit Cost	Route Cost
Aba	Uyo	1,152	₦691,200	₦796,262,400
Owerri	Mbaise	288	₦230,400	₦66,355,200
Owerri	Orlu	504	₦216,000	₦108,864,000
Owerri	Umuahia	72	₦280,800	₦20,217,600

Plant	Destination	Allocation	Unit Cost	Route Cost
Owerri	Calabar	288	₦691,200	₦199,065,600
Enugu	Umuahia	1,080	₦417,600	₦451,008,000
Enugu	Dummy	72	₦0	₦0
Port Harcourt	Calabar	1,008	₦554,400	₦558,835,200
Port Harcourt	Uyo	144	₦691,200	₦99,532,800

Alternate Optimal Cost = ₦2,300,140,800

The alternate solution changes the routing pattern but not the objective value. Aba now sends its full 1,152 truckloads to Uyo, while Port Harcourt sends 1,008 truckloads to Calabar and 144 to Uyo. All other allocations remain the same. This gives management flexibility: either optimal shipment pattern can be used, subject to operational considerations not represented in the mathematical model.

9.3 Confirmation through Delta

After moving to the alternate basis, all unoccupied-cell deltas remain less than or equal to zero. Aba–Calabar becomes an unoccupied zero-delta cell, linking the alternate basis back to the first optimal solution. Thus, both shipment plans are mathematically optimal.

X. EXCEL SOLVER VALIDATION AND CRITICAL ANALYSIS

10.1 Solver Formulation

The transportation model was also entered into Excel Solver as a linear program. The changing cells are the shipment quantities, the objective cell is the SUMPRODUCT of the allocation matrix and the cost matrix, and the objective is set to Min. Row totals are constrained by plant supply, column totals are constrained to equal destination demand, and all decision variables are non-negative. The Simplex LP solving method is used.

Solver Element	Setting
Objective	Minimize total transportation cost
Changing cells	Shipment quantities for all plant–destination routes
Supply constraints	Each plant total = 1,152
Demand constraints	Column totals = 288, 504, 1,152, 1,296, 1,296 and 72
Non-negativity	$X_{ij} \geq 0$
Method	Simplex LP

10.2 Validation Result

Excel Solver Minimum = ₦2,300,140,800

The Solver result is identical to the MODI optimum and to the published TORA optimum reported for the selected case. This three-way agreement provides strong numerical validation of the transportation solution.

10.3 Strengths of the Approach

- The model converts a practical distribution problem into a transparent quantitative decision framework.
- Three IBFS techniques allow the quality of starting solutions to be compared.
- MODI explains why a solution is or is not optimal rather than relying only on software output.
- Solver provides independent computational validation.
- The alternate optimum reveals operational flexibility at the same minimum cost.

10.4 Limitations

- Transportation costs are treated as linear and constant per truckload.
- The model is static and assumes supply and demand are known with certainty.
- Travel time, vehicle availability, road disruption and service-level requirements are not explicitly included.
- The dummy destination is a mathematical representation of unused capacity, not a physical market.
- A single cost objective does not capture emissions, risk or delivery priority.

10.5 Possible Extensions

Future work could extend the model into a multi-period distribution system with inventory, uncertain demand, route capacities, service-time constraints or multiple objectives. Integer programming could be used where vehicle counts must

obey additional discrete restrictions. Scenario analysis could also test fuel-price changes or temporary route disruptions.

XI. FINDINGS, MANAGERIAL IMPLICATIONS AND CONCLUSION

11.1 Major Findings

The analysis demonstrates that the choice of initial transportation method matters. NW Corner produces the highest starting cost because it ignores route economics. Least Cost improves the starting position substantially. VAM performs best, producing an IBFS only ₦9,849,600 above the optimum. MODI then reaches the minimum in one improvement cycle.

Measure	Result
Total supply	4,608 truckloads
Real demand	4,536 truckloads
Dummy demand	72 truckloads
NW Corner cost	₦2,583,705,600
Least Cost cost	₦2,422,483,200
VAM cost	₦2,309,990,400
Optimal cost	₦2,300,140,800
VAM saving after MODI	₦9,849,600
Alternate optimum	Exists; same minimum cost

11.2 Managerial Implications

For an FMCG distributor, the result shows that systematic allocation can create meaningful savings even when all feasible plans satisfy demand. The difference between the NW Corner plan and the optimum is ₦283,564,800, while the VAM starting plan is already close to the optimum. Management can therefore use a good heuristic such as VAM for quick planning and then apply an optimality test or Solver for final confirmation. The presence of an alternate optimum is also valuable because managers can switch between two minimum-cost shipment patterns if one route faces congestion, temporary capacity pressure or operational inconvenience, provided the underlying cost structure remains unchanged.

11.3 Conclusion

This project successfully applies Operations Research to a real FMCG supply-chain problem. The transportation model balances four plants against five real destinations and a dummy destination, compares three IBFS techniques, improves the strongest initial solution through MODI, identifies an alternate optimum and validates the final result using Excel Solver. The

minimum transportation cost is ₦2,300,140,800. The result matches the optimum reported in the selected research paper, demonstrating both the practical value and the mathematical reliability of transportation optimization for distribution planning.

REFERENCES

1. Uzorh, A. C., & Nnanna, I. (2014). Supply Chain Management Optimization Problem. The International Journal of Engineering and Science (IJES), 3(6), 01–09. Research paper PDF
2. ResearchGate record:
https://www.researchgate.net/publication/330486166_Supply_Chain_Management_Optimization_Problem
3. Project calculations and transportation tableaux: FMCG_Transportation_Final.xlsx (working workbook supplied for this report).