

Optimizing E-Commerce Delivery Using Transportation and Assignment Models

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. Introduction to Operations Research and Problem Type

Operations Research (OR) applies mathematical models to decisions made under limited resources. Every OR study follows the same pattern: define the decision variables, state an objective to minimise or maximise, list the constraints, solve the model, and interpret the answer. The Linear Programming Problem (LPP) is the parent model, and it is solved by the Simplex method or by software built on it. Two special LPPs are used in this project:

- **Transportation Problem:** ship one product from m sources to n destinations at minimum total cost, respecting supply and demand.
- **Assignment Problem:** match n people to n jobs one-to-one at minimum total cost or time (a transportation problem in which every supply and demand equals 1).

Both have special, simpler solution methods than the general Simplex. For the transportation problem we find an initial basic feasible solution (IBFS) by the Northwest Corner, Least Cost or Vogel's Approximation Method (VAM) and then test optimality by the MODI ($u-v$) method. For the assignment problem we use the Hungarian method (Kuhn, 1955). Table 1 shows how these map to e-commerce delivery.

Delivery decision	OR model	Solution method	Paper studied
How many parcels go from each warehouse to each delivery point?	Transportation problem	VAM (+ MODI test)	Banik & Hasan (2018)
Which courier serves which delivery point?	Assignment problem	Hungarian method	Rahman & Wahyudin (2021)
Both written as one cost-minimising model	LPP	Simplex / LP solver	Used to verify results (Section 5.4)

Table 1. Mapping class techniques to e-commerce delivery.

2. Real-Life Context: E-Commerce Delivery

E-commerce firms sell online but must physically move every order from a warehouse to the customer. Transport is often the largest controllable cost: in the first paper below, the owner states that because the firm has no manufacturing cost, transportation is the only factor left to improve profit. Delivery also has a time limit, so late or costly delivery hurts customer satisfaction. Two questions repeat in every delivery operation:

- Allocation: from which warehouse should each destination be supplied, and in what quantity?
- Assignment: which courier should deliver to which area or order, so total delivery time is smallest?

OR suits both because the costs (distance, fare, time) are known, the limits (stock, courier capacity) are fixed, and a linear objective is natural. Comparing all possible plans by hand is impractical: assigning just 14 couriers to 14 delivery points has $14! \approx 87$ billion possible assignments, and the 3-warehouse, 12-destination case has 36 shipment variables.

2.1 Why Transport Cost Matters in E-Commerce

Unlike a shop, an online seller ships each order separately to a different address. This makes delivery cost per parcel high, and the customer now expects it to be fast and cheap. A typical e-commerce supply chain has three stages: parcels are held at warehouses (sources), moved to local delivery or pick-up points (destinations), and finally handed to couriers who reach the customer. OR gives a model for each stage:

Stage	Decision	OR model	Objective
Warehouse to delivery point	Quantity on each route	Transportation problem	Minimise shipping cost
Delivery point to courier	Who serves which area	Assignment problem	Minimise delivery time
Overall planning	Combined allocation under limits	LPP (Simplex)	Minimise total cost

Table 1A. OR models along the e-commerce delivery chain.

2.2 Why OR Techniques Are Suitable

- The decision is quantitative: how many units, or which courier, can be written as numbers.
- Costs and times are known or measurable (distance from maps, bus fare per km, recorded delivery minutes).
- Resources are limited (warehouse stock, number of couriers), so the best use must be calculated, not guessed.
- The same model can be re-run when demand, prices or staff change, which suits fast-moving online business.

3. Literature Review: Selected Research Papers

3.1 Paper 1 – Transportation Cost Optimization of an Online Business Applying Vogel's Approximation Method

Banik, D. & Hasan, M. Z. (2018), World Scientific News, 96, 179–190. Domain: online retail and last-mile distribution, Bangladesh.

Problem. Red Tech BD, an online seller with its head office in Dhaka, wanted to expand from Rajshahi Sadar to the whole Rajshahi district. It chose not to buy its own vehicles, because of maintenance and driver costs, and instead sent parcels through local bus services at BDT 1.90 per km per unit. It needed to decide how many units to ship from each of 3 warehouses to 12 destination points (sub-districts) at the lowest transport cost.

Data and method. Distances were measured on Google Maps and converted to a cost per unit. The model is a balanced transportation problem: total supply (150 + 173 + 125) equals total demand (448 units). The authors solved it with Vogel's Approximation Method, coded in the C language, and verified the code against a hand calculation.

Result. The reported minimum transportation cost is BDT 11,576 (about USD 139.61). The authors conclude that the program lets the firm re-plan quickly whenever demand changes.

3.2 Paper 2 – Optimalisasi Penugasan Karyawan Jasa Ekspedisi Menggunakan Metode Hungarian (Case Study: CV. Anteraja, Mekarmukti Branch)

Rahman, L. N. & Wahyudin, W. (2021), Jurnal Serambi Engineering, 6(3). DOI: 10.32672/jse.v6i3.3245. Domain: courier and express parcel delivery, Indonesia.

Problem. Online orders rose during the Covid-19 pandemic. The Anteraja Mekarmukti branch had 14 couriers and 14 delivery points in Cikarang Baru, and the way couriers were allocated made delivery take too long, so parcels could not be completed within one day.

Method and result. The authors modelled it as an assignment problem (14 couriers $\times$ 14 points) with delivery time as the cost, and applied the Hungarian method. Total delivery time fell from 202 minutes to 172 minutes, a saving of 30 minutes or 14.85%.

3.3 Supporting study

Vásconez et al. (2024), Smart Cities, 7(3), 47, also use the Hungarian algorithm to assign delivery personnel to customer orders. Because the time for every courier–customer pair is unknown, they first estimate the cost matrix with linear and polynomial regression and then run the Hungarian method. Polynomial regression gave the better time estimates, with an error reduction of up to 11.59%. This shows the same assignment model working at much larger scale.

3.4 Summary Comparison of the Studies

Feature	Banik & Hasan (2018)	Rahman & Wahyudin (2021)
Business	Online retailer (Red Tech BD)	Courier company (Anteraja branch)
Country	Bangladesh	Indonesia
Problem type	Balanced transportation problem	Balanced assignment problem
Size	3 warehouses $\times$ 12 destinations	14 couriers $\times$ 14 delivery points
Objective	Minimise transport cost (BDT)	Minimise delivery time (minutes)
Method	Vogel's Approximation Method	Hungarian method
Tool	C program + hand check	Hungarian steps (manual)
Main result	Cost BDT 11,576	202 $\rightarrow$ 172 min (–14.85%)

Table 1B. Side-by-side summary of the two selected papers.

The two papers complement each other. The first optimises money across a network of warehouses and destinations; the second optimises time inside one branch. Together they cover the allocation and assignment decisions that make up most of basic e-commerce delivery planning.

4. Mathematical Modelling

4.1 Paper 1 as a Transportation Problem

Let Q_{ab} be the units shipped from warehouse a ($a = 1..3$) to destination b ($b = 1..12$), C_{ab} the cost per unit on that route, S_a the supply of warehouse a and D_b the demand of destination b . The data used by the authors are:

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	Supply
W1	1	8	10	12	38	42	38	34	55	36	31	51	150
W2	5	8	11	5	41	40	34	21	49	31	29	48	173
W3	6	9	12	5	35	33	31	40	51	35	34	52	125

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	Supply
Demand	20	20	50	60	30	39	40	37	37	41	38	36	448

Table 2. Cost per unit (BDT), supply and demand. Source: Banik & Hasan (2018), Table 4.

Decision variables: $Q_{ab} \geq 0$ = units sent from warehouse a to destination b (36 variables).

Objective function: minimise total transportation cost

$$\text{Minimise } Z = \sum_{a=1..3} \sum_{b=1..12} C_{ab} \cdot Q_{ab}$$

Constraints: supply and demand

$$\sum_b Q_{ab} = S_a \quad (a = 1, 2, 3) \quad \sum_a Q_{ab} = D_b \quad (b = 1, \dots, 12) \quad Q_{ab} \geq 0$$

For example, the W1 constraint is $Q_{1,1} + Q_{1,2} + \dots + Q_{1,12} = 150$, and the D1 constraint is $Q_{1,1} + Q_{2,1} + Q_{3,1} = 20$. Since $150 + 173 + 125 = 448 = 20 + 20 + 50 + 60 + 30 + 39 + 40 + 37 + 37 + 41 + 38 + 36$, the problem is balanced and no dummy row or column is needed.

Expanded objective function (first terms): $Z = 1 \cdot Q_{1,1} + 8 \cdot Q_{1,2} + 10 \cdot Q_{1,3} + 12 \cdot Q_{1,4} + 38 \cdot Q_{1,5} + 42 \cdot Q_{1,6} + \dots + 51 \cdot Q_{1,12} + 5 \cdot Q_{2,1} + 8 \cdot Q_{2,2} + \dots + 48 \cdot Q_{2,12} + 6 \cdot Q_{3,1} + 9 \cdot Q_{3,2} + \dots + 52 \cdot Q_{3,12}$.

Supply constraints (one per warehouse):

$$W1: Q_{1,1} + Q_{1,2} + Q_{1,3} + \dots + Q_{1,12} = 150$$

$$W2: Q_{2,1} + Q_{2,2} + Q_{2,3} + \dots + Q_{2,12} = 173$$

$$W3: Q_{3,1} + Q_{3,2} + Q_{3,3} + \dots + Q_{3,12} = 125$$

Demand constraints (one per destination):

$$D1: Q_{1,1} + Q_{2,1} + Q_{3,1} = 20$$

$$D2: Q_{1,2} + Q_{2,2} + Q_{3,2} = 20$$

$$D3: Q_{1,3} + Q_{2,3} + Q_{3,3} = 50$$

$$D4: Q_{1,4} + Q_{2,4} + Q_{3,4} = 60$$

$$D5: Q_{1,5} + Q_{2,5} + Q_{3,5} = 30$$

$$D6: Q_{1,6} + Q_{2,6} + Q_{3,6} = 39$$

$$D7: Q_{1,7} + Q_{2,7} + Q_{3,7} = 40$$

$$D8: Q_{1,8} + Q_{2,8} + Q_{3,8} = 37$$

$$D9: Q_{1,9} + Q_{2,9} + Q_{3,9} = 37$$

$$D10: Q_{1,10} + Q_{2,10} + Q_{3,10} = 41$$

$$D11: Q_{1,11} + Q_{2,11} + Q_{3,11} = 38$$

$$D12: Q_{1,12} + Q_{2,12} + Q_{3,12} = 36$$

Non-negativity: $Q_{ab} \geq 0$ for all 36 variables. In all there are $3 + 12 = 15$ equality constraints; because the problem is balanced, one is redundant, so a basic feasible solution has $m + n - 1 = 14$ basic (occupied) cells.

Assumptions stated by the authors: transport cost stays constant; destination locations do not change; supply and demand are equal; all data (supply, demand, cost) are known in advance. Costs are linear, so shipping twice the units costs twice as much.

4.2 Paper 2 as an Assignment Problem

Let $x_{ij} = 1$ if courier i is assigned to delivery point j, and 0 otherwise; t_{ij} is the delivery time of courier i at point j ($i, j = 1..14$).

$$\text{Minimise } Z = \sum_i \sum_j t_{ij} \cdot x_{ij}$$

$$\sum_j x_{ij} = 1 \text{ (every courier gets one point)} \quad \sum_i x_{ij} = 1 \text{ (every point gets one courier)} \quad x_{ij} \in \{0,1\}$$

Assumptions: the number of couriers equals the number of points (balanced), each courier does exactly one job, and the time of each courier–point pair is known and fixed. The paper's own 14×14 time matrix is not reproduced here; Section 5.3 uses a small illustrative matrix instead.

4.3 Link to the Linear Programming Problem

Both models are LPPs with a linear objective and linear equality constraints. The transportation model has $m + n$ constraints and $m \times n$ variables; the assignment model is the special case with all supplies and demands equal to 1, which is why its LP solution is naturally 0 or 1. The Simplex method can therefore solve either, and Sections 5.4 and 5.5 use an LP solver and MODI to check the paper's answer.

5. Solution Methodology

5.1 Vogel's Approximation Method (Paper 1)

- Step 1: for every row and column, compute the penalty = (second-lowest cost) – (lowest cost).
- Step 2: pick the row or column with the largest penalty (ties broken arbitrarily).
- Step 3: in that row or column, allocate as much as possible to the cheapest cell, then cross out the row or column that is exhausted.
- Step 4: recompute penalties and repeat until all supply and demand are met.

The authors implemented this in a C program that reads the cost matrix, supply and demand and prints the allocation and total cost, and checked it against a manual solution. VAM gives an IBFS that is usually near-optimal. The full optimum is then confirmed by the MODI test (compute $u_i + v_j - c_{ij}$ for empty cells; if none is positive, the solution is optimal).

Worked first iteration (our working on the paper's data). Row penalties are $W1 = 7$ (costs 1 and 8), $W2 = 0$ (5 and 5) and $W3 = 1$ (5 and 6). Column penalties are $D1 = 4$, $D2 = 0$, $D3 = 1$, $D4 = 0$, $D5 = 3$, $D6 = 7$, $D7 = 3$, $D8 = 13$, $D9 = 2$, $D10 = 4$, $D11 = 2$ and $D12 = 3$. The largest penalty is 13 in column D8, so we allocate to its cheapest cell, W2 (cost 21): $\min(173, 37) = 37$ units. Column D8 is satisfied and removed, and W2's supply becomes 136. The penalties are then recomputed on the remaining table and the process repeats, which gives the final allocation in Table 3.

Warehouse	Destination: units shipped (VAM allocation)	Total units
W1	D1: 20, D3: 50, D5: 4, D9: 2, D11: 38, D12: 36	150
W2	D2: 20, D7: 40, D8: 37, D9: 35, D10: 41	173
W3	D4: 60, D5: 26, D6: 39	125

Table 3. VAM allocation (reproduced by us from Table 2); total cost = BDT 11,576, matching the paper.

5.2 Hungarian Method (Paper 2)

- Step 1: row reduction – subtract the smallest value of each row from that row.
- Step 2: column reduction – subtract the smallest value of each column from that column.
- Step 3: cover all zeros with the minimum number of lines. If this number equals n , an optimal assignment exists among the zeros.
- Step 4: otherwise subtract the smallest uncovered value from uncovered cells, add it to cells covered twice, and repeat Step 3.

5.3 Illustrative Hungarian Example (our own numbers, not from the paper)

Four riders (R1–R4) must be assigned to four delivery zones (Z1–Z4); the entries are delivery times in minutes.

Rider	Z1	Z2	Z3	Z4	Row min
R1	14	10	16	12	10
R2	11	15	13	17	11
R3	16	12	10	14	10
R4	13	18	15	11	11

Table 4. Time matrix (minutes).

After row reduction the zeros fall at R1–Z2, R2–Z1, R3–Z3 and R4–Z4, which is already one zero per row and column, so the assignment is optimal: R1→Z2 (10) + R2→Z1 (11) + R3→Z3 (10) + R4→Z4 (11) = 42 minutes. The "obvious" diagonal assignment R1→Z1, R2→Z2, R3→Z3, R4→Z4 takes 14 + 15 + 10 + 11 = 50 minutes, so the Hungarian method saves 8 minutes (16%). This is the same kind of gain as the 14.85% reported by Rahman & Wahyudin.

Step-by-step working. Row reduction gives the matrix below (each row minus its minimum). The column minima are all 0, so column reduction changes nothing.

Rider	Z1	Z2	Z3	Z4
R1	4	0	6	2
R2	0	4	2	6
R3	6	2	0	4
R4	2	7	4	0

Table 4A. Matrix after row and column reduction.

Four lines are needed to cover all zeros, which equals $n = 4$, so the optimal assignment is chosen from the zeros. Each row and column has exactly one zero in the positions R1–Z2, R2–Z1, R3–Z3, R4–Z4, so the choice is unique. The total is read from the original matrix (Table 4), not the reduced one.

Assignment	Time (min)
R1 → Z2	10
R2 → Z1	11
R3 → Z3	10
R4 → Z4	11
Total	42

Table 4B. Optimal assignment.

5.4 Our Verification of Paper 1 Using a Linear Programming Solver

To check the paper's claim, we typed the data of Table 2 into Python (SciPy linprog, HiGHS solver) as a 36-variable LP, and also re-ran VAM and the Northwest Corner method:

Method	Total cost (BDT)	Comment
Northwest Corner (IBFS)	12759	Ignores costs; 12.0% above optimum
VAM (as in paper)	11576	Matches the paper exactly
LP optimum (simplex-based solver)	11390	True minimum

Table 5. Our re-computation of Paper 1 data.

The LP optimum shifts 186 BDT of cost: W1 supplies D2 (20) and D12 (22) instead of D5, D9 and part of D12, and W2/W3 rebalance D4, D9, D12. The optimal plan is W1: D1 20, D2 20, D3 50, D11 38, D12 22; W2: D4 44, D8 37, D9 37, D10 41, D12 14; W3: D4 16, D5 30, D6 39, D7 40. VAM's answer is therefore 1.6% above the true minimum, so a MODI optimality test (or Simplex) would improve it.

5.5 MODI (u-v) Optimality Test on the Optimal Plan

MODI assigns a number u_i to each warehouse and v_j to each destination so that $u_i + v_j = C_{ab}$ for every occupied cell. An empty cell is worth using only if $C_{ab} - u_i - v_j$ is negative. Taking $u_1 = 0$ for the LP-optimal plan of Section 5.4 gives:

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
v_j	1	8	10	8	38	36	34	24	52	34	31	51

Table 5A. Destination values v_j (warehouse values: $u_1 = 0, u_2 = -3, u_3 = -3$).

For example, $W1 \rightarrow D1$ is occupied: $0 + 1 = 1 = C$. $W2 \rightarrow D8$ is occupied: $-3 + 24 = 21 = C$. The reduced cost $C_{ab} - u_i - v_j$ of every empty cell is zero or positive (smallest examples: $W1 \rightarrow D4 = 12 - 0 - 8 = 4$; $W3 \rightarrow D8 = 40 + 3 - 24 = 19$; $W2 \rightarrow D1 = 5 + 3 - 1 = 7$), so no empty cell can lower the cost. The plan costing BDT 11,390 is therefore optimal. Applying the same test to the VAM plan finds at least one negative cell, which is why it can be improved by 186 BDT.

6. Results and Interpretation

6.1 Paper 1: Cost Analysis

Measure	Value
Total units shipped	448
Cost of VAM plan (paper)	BDT 11,576
Cost of LP-optimal plan (our check)	BDT 11,390
Average cost per unit, VAM	BDT 25.84
Average cost per unit, optimal	BDT 25.42
Cost of Northwest Corner plan	BDT 12,759
Saving of VAM over Northwest Corner	BDT 1,183 (9.3%)
Extra saving of optimal over VAM	BDT 186 (1.6%)

Table 6. Cost comparison for the Red Tech BD problem.

Interpretation: choosing routes sensibly (VAM) saves 9.3% compared with simply filling cells from the corner, and a full optimality test saves a further 1.6%. For a firm whose profit per unit is under BDT 200, a few percent on transport is a meaningful share of profit. Warehouse W3 is used mostly for D4 to D7, W2 for the far east destinations D8 to D10, and W1 for the nearer or western ones, which matches the geography of the cost matrix.

6.2 Paper 2: Time Analysis

Measure	Value
Delivery time before (existing allocation)	202 minutes
Delivery time after (Hungarian)	172 minutes
Reduction	30 minutes
Efficiency gain	14.85%

Measure	Value
Average time per courier after (172 / 14)	about 12.3 minutes

Table 7. Delivery-time comparison for the Anteraja branch.

Interpretation: the shorter total time lets couriers finish earlier, which supports same-day delivery and lowers the risk of late parcels during peak order periods. The gain comes purely from re-matching existing staff to existing delivery points, so it needs no new vehicles or hiring.

6.3 Managerial Implications

- Re-run the transportation model whenever weekly demand forecasts change, as Paper 1 recommends.
- Re-run the assignment model every morning, because delivery points and courier availability change daily.
- Always follow VAM with MODI or an LP solver, since an initial solution may not be optimal.
- Use Excel Solver or a free solver, so no programming is needed; the model needs only the cost table, supply and demand.

7. Critical Analysis

7.1 Key findings and impact

- Paper 1: VAM gives a low-cost parcel-distribution plan for 3 warehouses and 12 destinations (BDT 11,576), and the C program lets the firm re-plan instantly when demand changes.
- Paper 2: the Hungarian method cut courier delivery time from 202 to 172 minutes (14.85%), helping complete deliveries within one day.
- Together they show that simple class-level OR tools give measurable gains in e-commerce delivery without expensive software.

7.2 Strengths

- Simple, transparent models that a manager can understand and check by hand.
- Both are solved quickly and can be re-run whenever supply, demand, costs or couriers change.
- Paper 1 verified its code against a hand calculation; Paper 2 reports a before/after comparison on a real branch.

7.3 Limitations

- Paper 1 stops at the VAM solution and calls it the minimum; our LP check shows the true optimum is 1.6% lower (BDT 11,390). VAM is an initial solution, not a guarantee.
- Costs are fixed per unit (linear), with no vehicle capacity, fixed charges, delivery time windows or traffic.
- The transportation model decides quantities but not the order in which stops are visited, so it cannot replace route planning (the Vehicle Routing Problem).
- Paper 2 needs the same number of couriers and points, covers only one branch and one day, and compares against an informal earlier allocation, so the 14.85% depends on how good that baseline was.
- Both papers assume known, constant costs and times; real demand is uncertain.

7.4 Possible extensions

- Apply MODI or a Simplex solver after VAM to certify optimality.
- Add capacities, delivery deadlines or unbalanced cases (dummy rows or columns) to the models.
- Combine allocation and assignment, then add a routing step per courier.
- Estimate the cost matrix from past delivery data using regression, as Váscónez et al. (2024) do.

8. Conclusion

This report studied two published applications of basic OR techniques to e-commerce delivery. The transportation problem solved by VAM decides how many parcels move from each warehouse to each destination, and the assignment problem solved by the Hungarian method decides which courier serves which point. Both are special linear programmes with a clear objective and constraints. The first paper's plan cost BDT 11,576, and our re-solution shows the exact optimum is BDT 11,390, which highlights why an optimality test should always follow VAM. The second paper reduced delivery time by 14.85%. The main lesson is that simple OR models give real savings in logistics, and extensions such as capacity limits, time windows and routing can build on them.

Appendix: Key Terms

Term	Meaning
IBFS	Initial basic feasible solution: a first valid shipping plan that meets all supply and demand.
Balanced problem	Total supply equals total demand; otherwise a dummy row or column of zero cost is added.
Basic cell	A route actually used in the plan; there are $m + n - 1$ of them.
Penalty (VAM)	Difference between the two lowest costs in a row or column; the larger it is, the costlier it is to skip the cheapest cell.
MODI	Modified distribution method: tests whether any unused route could lower the cost.
Hungarian method	Row and column reduction method that finds the minimum-cost one-to-one assignment.
Degeneracy	Fewer than $m + n - 1$ occupied cells; fixed by adding a tiny allocation.
Simplex	General LP algorithm; the transportation and assignment methods are faster special cases of it.

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