Air Route Planning & Optimization

Project Information	
Project Title	Air Route Planning & Optimization
Program Title	To devise air routes in the network
Department	Network Design | Operations
Project Intern	Devashish Tripathi
Project Manager	Shubham Patil
Approver (s)	

Phase	Created by	Reviewed by	Approved by
1	Mr. Devashish Tripathi	Mr. Shubham Patil	Mr. Amol Zele

©2025 DTDC Express Limited

Table of Contents

©2025 DTDC Express Limited

A. Background

The Indian air express logistics network faces inherent challenges in ensuring optimal route planning, time efficiency, and resource utilization. This project focuses on building a transparent, data-driven routing framework for DTDC that reflects real-world constraints such as dynamic branch-to-hub mappings, airport proximity, and evolving load flows.

- The network spans 600+ OD pairs with complex hub-airport-branch interdependencies.
- An optimized route model is developed, replicating real-world flows: **Branch** → **Hub** → **Airport** ✈️ **Airport** → **Hub** → **Branch**.
- Efficient route suggestions are made by minimizing total transit time using actual distance and processing durations.
- A comparison of calculated vs. actual volume flows helps identify imbalances and optimize capacity utilization.

B. Objectives

The primary objective of this project is to design an optimized, time-efficient logistics routing system that closely mimics real-world flows and constraints. This system is intended to serve as a benchmark to compare against DTDC's existing operational routes and derive actionable insights.

- To identify optimal end-to-end shipment paths between all origin-destination (OD) branch pairs using a hybrid of air and road modes.
- To model the full logistics flow from **Branch** → **Hub** → **Airport** ✈️ **Airport** → **Hub** → **Branch**, incorporating time, distance, and mode constraints.
- To benchmark optimized routes against current operational flows, enabling identification of route inefficiencies and improvement areas.
- To analyze volume flow patterns, comparing calculated vs. actual volumes, and identify under-utilized or overloaded segments.

©2025 DTDC Express Limited

C. Assumptions

- A minimum **100 kg** consolidated volume is required for a route to be considered operationally feasible.
- Road time between any two branches is computed as direct city-to-city travel time plus fixed processing time; intermediate touchpoints are not considered.
- **EP and BP** products are grouped as Premium, and **ES** as Standard.
- Premium products are routed via PRIME flights (fallback to GCR if PRIME unavailable); Standard products must use GCR flights only.
- **Multi-airport** hops are excluded.
- Volume analysis is based on static daily-level data, extrapolated to monthly using **25** working days.

D. Dataset Overview

- **Data Provided**
  - **Shipment Master**: Contains shipment-level details including origin/destination branches, product type and weight.
  - **Flight Connections**: Lists available air connectivity between airport cities with flight categories (PRIME / GCR).
  - **Actual Flow Data**: Represents real-world volume flow between airport pairs at the daily level.

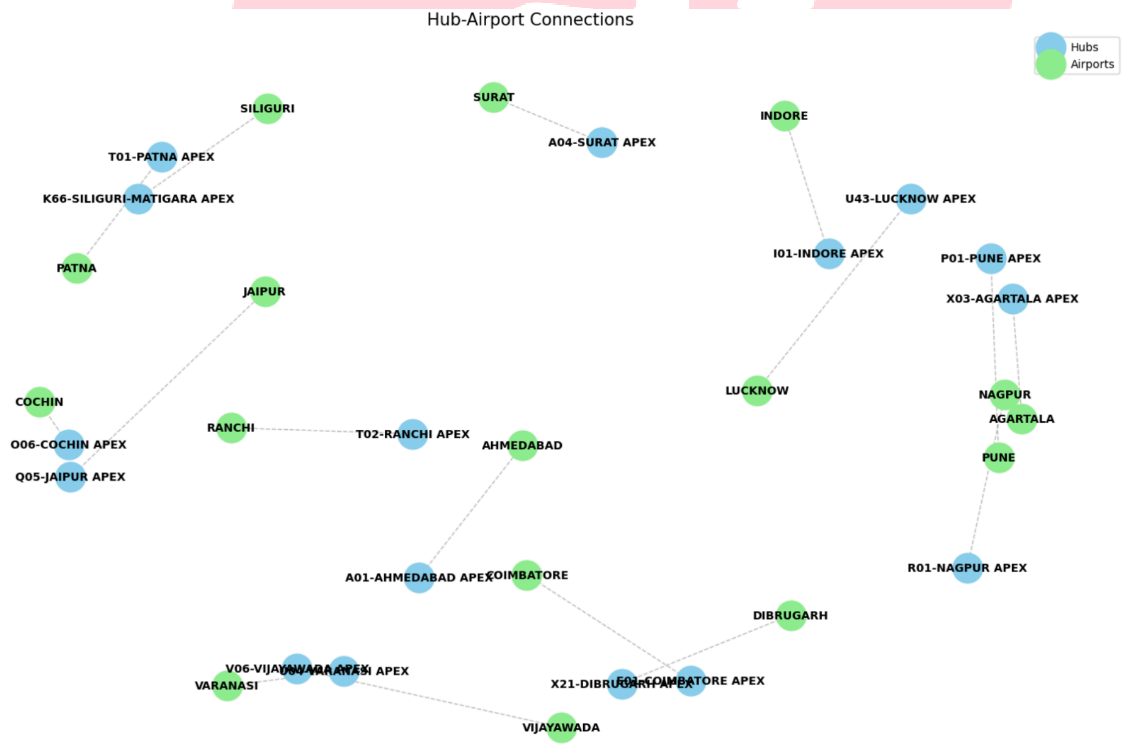
- **Derived Datasets**
  - **Optimal Route Paths**: Suggested end-to-end routes between any OD branch pair based on product type and flight availability.
  - **Branch, Hub & Airport Coordinates**: Combined geolocation data to map logistics routes across the network.
  - **Calculated Volume Matrix**: Estimated daily volume flow between airports based on optimized routing.

©2025 DTDC Express Limited

E. Methodology

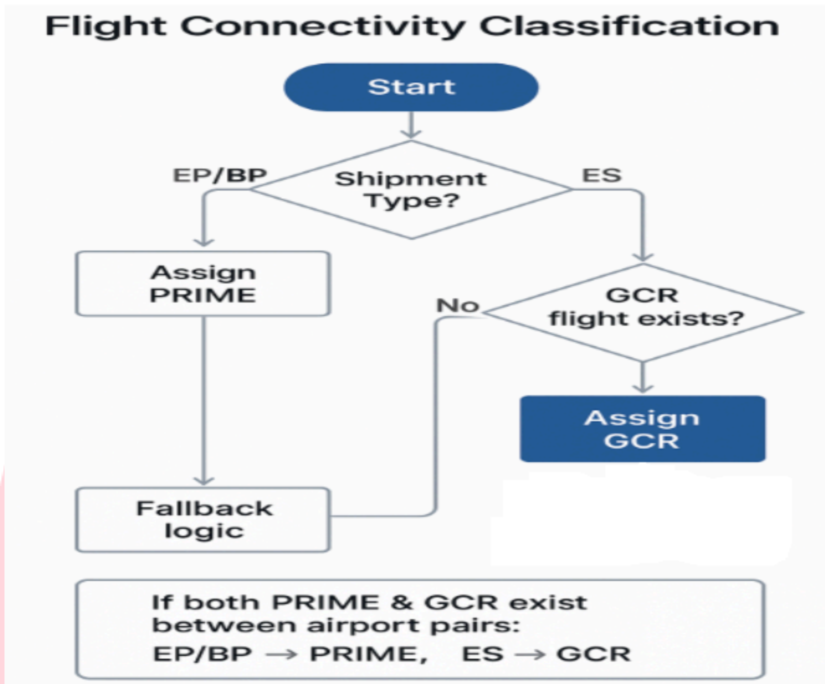
This section describes the step-by-step approach used to model the DTDC logistics network, from mapping entities to calculating optimized routes and analyzing volume flow patterns. The methodology is divided into 8 logical stages:

- **Branch to Hub Mapping**
  - Each branch is mapped to its nearest available hub based on **minimum travel time** from the city-wise road matrix.
  - The assumption is that branches dispatch through these hubs for further airport movement.
- **Hub to Airport Mapping (Dynamic + Static)**
  - The airport is assigned dynamically using travel duration, considering feasibility and operational efficiency.



©2025 DTDC Express Limited

- **Flight Path Modeling**



- **Route Path Generation**

  For each Origin-Destination branch pair:

  The path flow

  Origin Branch → Origin Hub → Origin Airport ✈️ Destination Airport → Destination Hub → Destination Branch

  If no direct flight exists, the system explores 1-stop indirect paths, treated as an optimization problem:

Objective: Minimize total end-to-end time

Constraints: Volume ≥ 100 kg, connectivity exists, product-flight compatibility

- **Time Calculation**

©2025 DTDC Express Limited

Time components (T1 to T13) are computed as per below structure:

Step	Code	Description	Source
1	T1	Branch to Hub (road time)	Road Matrix
2	T2	Hub processing time	Constant [2.5 Hrs]
3	T3	Hub to Airport	Road Matrix
4	T4	Pre-cooling period	Constant [2 Hrs]
5	T5	Air Transit Time	Direct Flight Data
6	T6	Post-cooling period	Constant [2 Hrs]
7	T7	Airport to Hub	Road Matrix
8	T8	Hub Processing	Constant [2.5 Hrs]
9	T9	Hub to Branch (if direct)	Road Matrix
10-13	T10–T13	If routed via intermediate hub	Sum of road + wait + transit times

- **Route Algorithm Logic**

  This project treats route selection as a constrained multi-modal pathfinding problem with hierarchical decisions, rather than a pure shortest-path problem. The algorithm is designed to simulate realistic logistics movement using a combination of road and air transportation while optimizing for time and adhering to product constraints and capacity limitations.

  - A rule-based decision engine is used
  - Check direct flight availability.
  - If not, explore 1-stop air paths where:
  - Midpoint is a viable air city

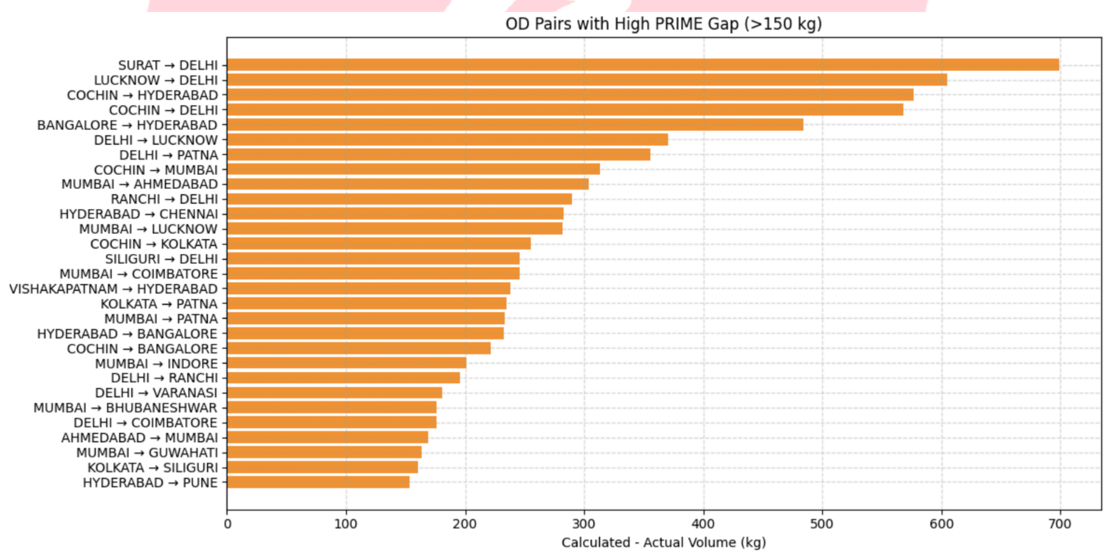
- Overall time < direct road timeChoose the path with minimum total time using (modified) **Dijkstra** with **optimization algorithms**

Code Logic Note: Each leg's weight is modeled as time + penalty

Volume Calculation

- Total Volume between OD branch pairs is aggregated for Premium (EP+BP) and Standard (ES) products.
- Daily volumes are extrapolated to monthly by multiplying by 25.

- **Updated Volume Flow Calculation**
  - The calculated volume was added to the base volume to get Updated Flow.
  - These values are compared against the actual flow from operations data.
  - Insights were drawn for:
    - Under-utilized but high-calculated potential routes
    - Overestimated paths



F. Route Recommendation Engine

©2025 DTDC Express Limited

The Route Recommendation Engine is designed to determine the most efficient and compliant logistics path from the origin branch to the destination branch. It evaluates direct and indirect air routes based on flight availability, product type, volume, and time efficiency, falling back to surface transport when necessary.

- **Routing Options**

  Each shipment can follow one of the following paths:

  - **Direct Air Route**: Origin Branch → Hub → Airport (Air) Airport → Hub → Destination Branch

  - **Indirect Air via Middle Airport**: Origin Branch → Hubs(1 or 2) → Airport (Air) Intermediate feasible Airport → Nearest Hub(1 or 2) → Destination Hub → Destination Branch

  - **Surface Route (Road Only)**: Origin Branch → Origin Hub → Destination Hub → Destination Branch (Various touch points may be there)
    (via road)
    - No valid air path exists
    - The volume is too low
    - Air route is slower than road

- **Variables**

  Let:

  - **Bo, Bd:** Origin and Destination Branch
  - **Ho, Hd**: Origin and Destination Hub
  - **Ao, Ad**: Origin and Destination Airport
  - **Am:** Middle (transit)
  - **AirportP** ∈ {EP, BP, ES}: Product type
  - **Wp**: Shipment weight of product p
  - **FM** ∈ {PRIME, GCR}:
  - **Flight modeTi:** Time segments defined belowTair,

- **Troad**: Total time via air and surfaceAdirect, Aindirect: Binary variables (1 if direct or indirect air is available)

- **Segmented Time Model**

  In the indirect air case, the total travel time is broken into three segments:

$$T_{total} = T_{road_1} + T_{air} + T_{road_2}$$

  - **Troad1** : Road time from Origin Branch → Nearest Hub(s) → Origin Airport
  - **Tair** : Air time between Origin Airport and feasible Intermediate Airport
  - **Troad2** : Road time from Middle Airport → Nearest Hub(s) → Destination Branch

  Each component may vary depending on network conditions and hub-airport mappings.

- **Route Variants Within Indirect Air Paths**

  The structure of the indirect air route adapts dynamically:

  - **Case A** (Efficient Initial Road):

$$B_o \rightarrow H_o \rightarrow A_o Air A_m \rightarrow H_d \rightarrow H_{dd} \rightarrow B_d$$

  - **Case B** (Efficient Final Road):

$$B_o \rightarrow H_o \rightarrow H_{o2} \rightarrow A_o Air A_d \rightarrow H_d \rightarrow B_d$$

  - **Case C** (Both Road Segments Needed):

$$B_o \rightarrow H_o \rightarrow H_{o2} \rightarrow A_o Air A_m \rightarrow H_m \rightarrow H_d \rightarrow B_d$$

©2025 DTDC Express Limited

The engine dynamically determines which configuration minimizes total time **T(total).**

- **Product Compliance Constraints**
  Let:
  - WEP_BP : Weight of EP + BP products
  - WES : Weight of ES products

    The product mode rules are:
    If P ∈ {EP, BP }, use PRIME if WEP_BP(between the airports) ≥ 100 kg
    If P = ES, use GCR if WES(between the airports) ≥ 100 kg

  If only GCR is available, all products are routed via GCR. If volume is below the threshold, indirect routes are evaluated.

- **Availability and Feasibility Checks**
  Let:

$$A_{direct} = \{ 1 \text{ if a direct air route } A_o \rightarrow A_d \text{ exists, and it supports the required flight mode} \qquad 0(O/W)$$

$$A_{indirect} = \{ 1 \text{ if a feasible indirect route exists such that } A_o \rightarrow A_m \text{ and } A_m \rightarrow A_d \text{ are valid air segments under the same flight mode} \qquad 0(O/W)$$

Middle Airport Constraint:

$$A_o \neq A_m, \quad A_m \neq A_d, \quad A_o \neq A_d$$

- **Time Superiority Check**

  An air route (direct or indirect) is selected only if it offers a time advantage over road:

$$T_{air} < T_{road} - \epsilon \quad (\epsilon \text{ is set to be } 0.05)$$

- **Objective Function**
  The final route is selected as the path minimizing total time:

$$\min(T_{direct}, T_{indirect}, T_{road})$$

  Where:
  - **Tdirect** = T1 + T2 + T3 + T4 + T5 + T6 + T7 + T8 + T9
  - **Tindirect** = Troad1 + Tair + Troad2
  - **Troad** = Roadtime

  Subject to:

  - Product compliance constraints
  - Mode availability (direct or indirect)
  - Time advantage

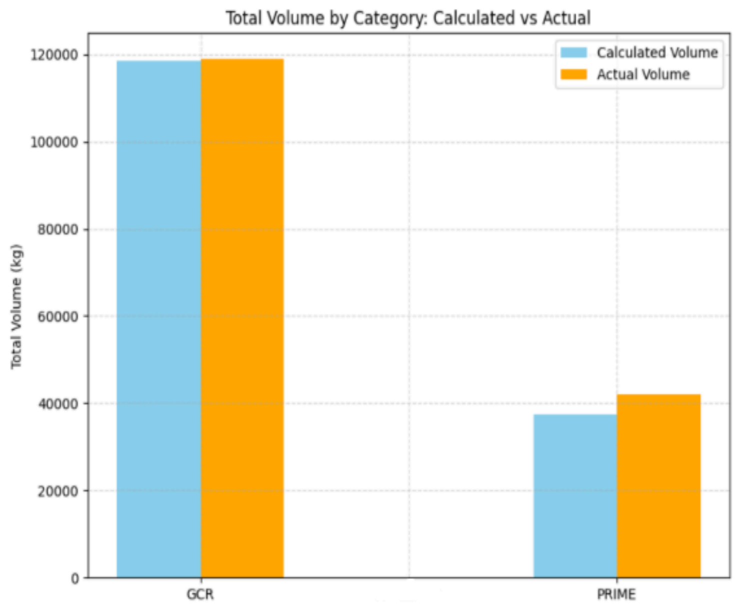
G. Volume Analysis & Correlation

This section presents a quantitative assessment of volume flow across the DTDC network, comparing system-generated (calculated) shipment volumes against actual movement. It helps identify underutilized lanes, optimize network planning, and validate the effectiveness of direct and indirect routing models.

- **Volume Aggregation Methodology**
  - Monthly Volume was computed at the branch and airport levels based on aggregated shipment data.
  - Daily Volume was approximated by dividing monthly totals by a factor of 25 operational days, assuming 5 non-operational or lean days per month:

$$\text{Daily Volume} = \frac{\text{Monthly Volume}}{25}$$

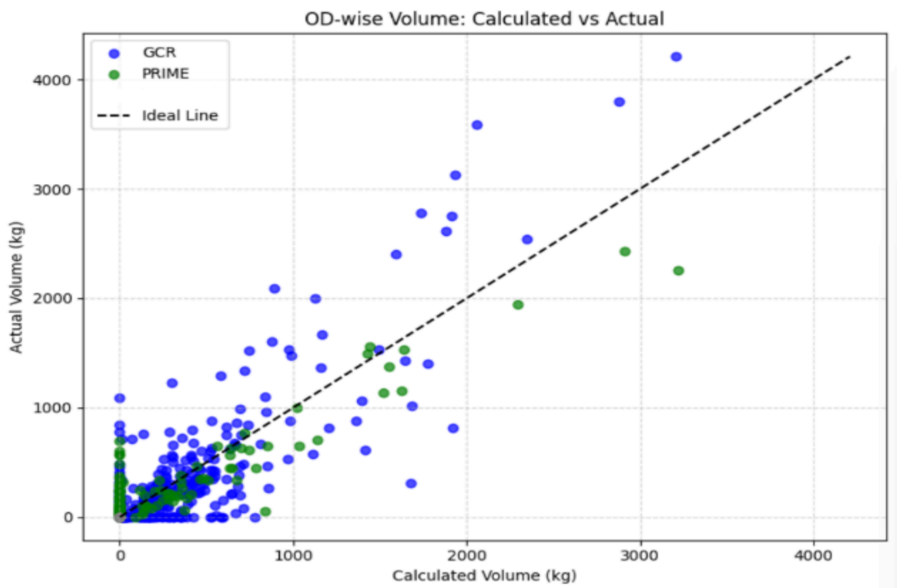
©2025 DTDC Express Limited



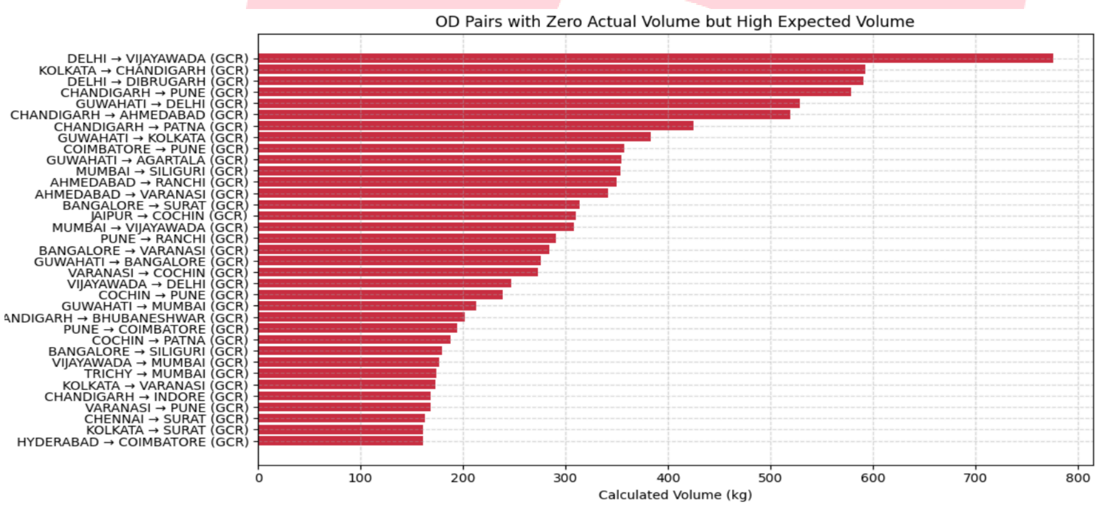
- **Two-Stage Correlation Analysis**
  - Initial Comparison (Direct Routes Only)
    - Compares actual branch-to-branch volume with calculated volumes using only direct air routes (PRIME or GCR).
    - Purpose: To benchmark how much of the actual volume is explained by direct connectivity alone.

- **After Indirect Route Integration**
    - Re-ran the volume estimation by adding indirect air paths via middle airports for ES shipments < 100 kg.
    - This significantly improved alignment with actual flows, especially for routes lacking direct connectivity.

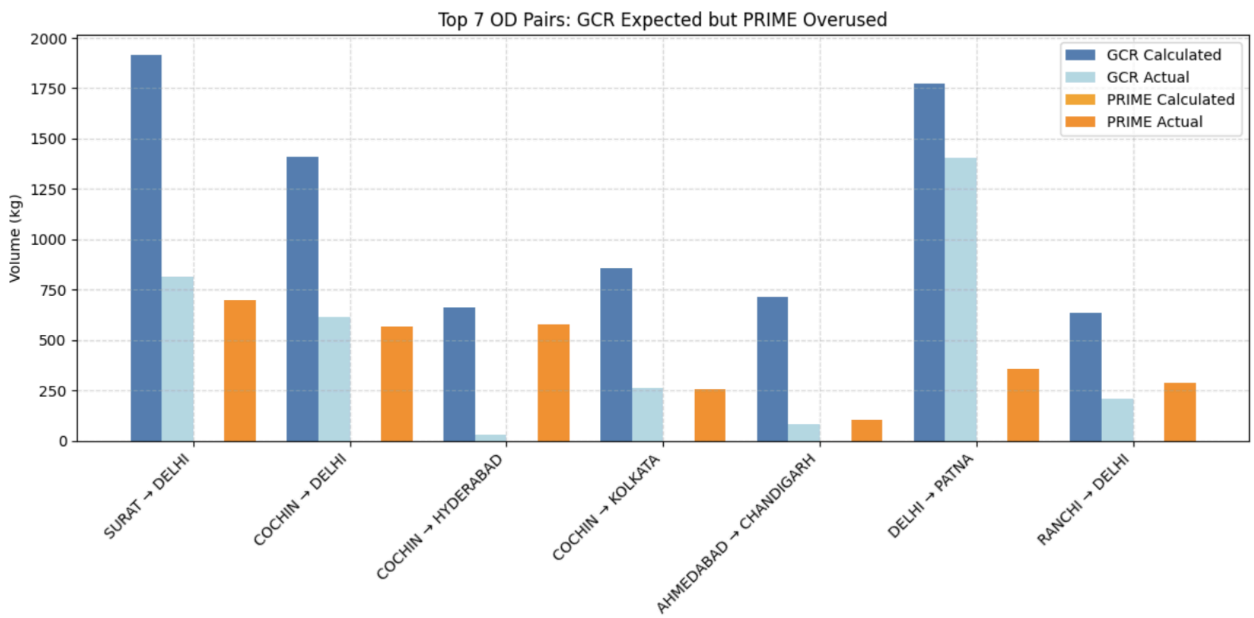
©2025 DTDC Express Limited



- **Top OD Pair Analysis**
    - Identified high-volume OD flows based on **calculated volume** post-route optimization.
    - These lanes are critical for air capacity planning and indirect air path prioritization.



©2025 DTDC Express Limited



H. Dashboard Features (Dashboard Link)

An interactive dashboard has been developed to visualize, analyze, and validate the air-road logistics optimization model. It provides dynamic tools for stakeholders to explore routes, volumes, and connectivity across the DTDC network.

- **Dynamic OD Pair Selection**

  Users can select any Origin-Destination (OD) city pair from dropdowns. Based on the selection:
  - The dashboard fetches the recommended route
  - Evaluates both direct and indirect connectivity
  - Applies product-mode logic (PRIME/GCR) and volume thresholds

- **Route Recommendation Details**

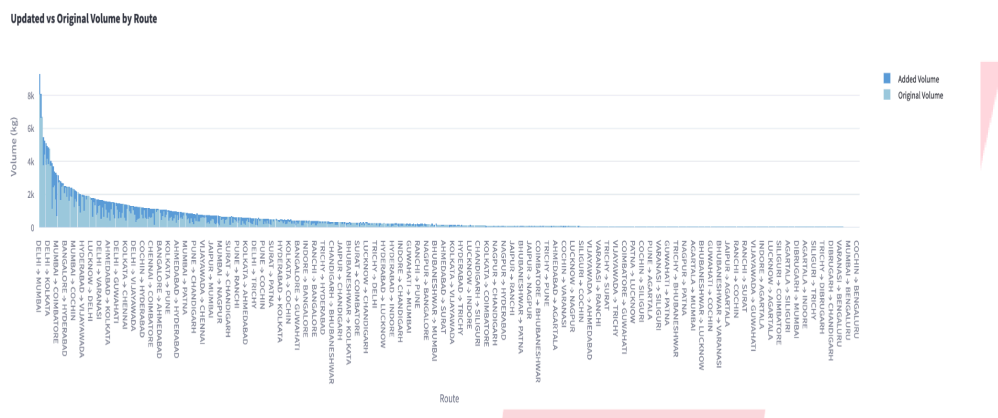
  For the selected OD pair, the dashboard displays:
  - Suggested route (including intermediate hubs and airports)
  - Total estimated delivery time, computed using T1–T13 logic
  - Mode split: Road vs Air
  - Product-based logic applied, including whether:
    - PRIME was chosen for EP_BP (≥ 100 kg)

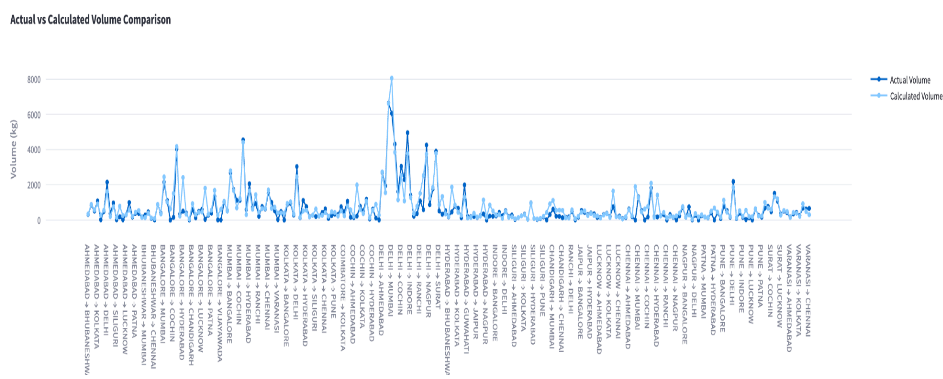
©2025 DTDC Express Limited

- GCR was assigned to ES
- Indirect routing was applied due to low volume

- **Volume Analysis Module**

  The dashboard provides branch- and airport-level volume insights:





©2025 DTDC Express Limited

- **Interactive India Route Map**

I. Recommendations and Insights

Based on the route optimization logic, volume analysis, and dashboard diagnostics, the following strategic recommendations are proposed to enhance DTDC's network performance and cost-efficiency:

- **Checking for Ground-Level Feasibility**
  - Model-recommended routes should be validated on-ground to ensure alignment with local operational constraints.
  - Route planning must be coordinated with branch and zonal teams before implementation.

©2025 DTDC Express Limited

- **Underutilization of Airports**
  - The analysis highlights multiple OD airport pairs with substantial modeled demand and valid flight connections but little to no actual usage.

  Examples:

  DELHI → VIJAYAWADA, KOLKATA → CHANDIGARH, and **DELHI → DIBRUGARH** show expected volumes exceeding 600 kg but zero recorded usage.

  - In many cases, these airports align with the optimal path for OD pairs but are bypassed due to legacy routing or manual overrides.
  - **Recommendation:**These routes should be evaluated for inclusion in the routing engine, especially for GCR shipments, as they offer untapped potential for cost-effective delivery.

- **Hardblock Recommendation**
  - Airport OD pairs where calculated volume flow of Prime is much higher than GCR but they are actually flowing with GCR.

  Examples:

  OD pairs like **COCHIN → DELHI** and **RANCHI → DELHI** have EP/BP volumes sufficient to justify PRIME flights but are being routed via GCR.

  - **Recommendation**: These are strong candidates for activating new PRIME lanes or increasing allocation, particularly for high-value EP/BP traffic where faster service is expected.

- **Avoiding Extra Cost**
  - In OD pair where actual GCR load is less than calculated and actual Prime load is higher than calculated
  - The probable reason can be sending of GCR load via Prime, which can be costly and should be adjusted via GCR flights.

©2025 DTDC Express Limited

- **For eg:** OD pairs like **COCHIN** → **HYDERABAD** and **COCHIN** → **KOLKATA** show high GCR demand but under-usage, while PRIME usage has exceeded expectations.

©2025 DTDC Express Limited