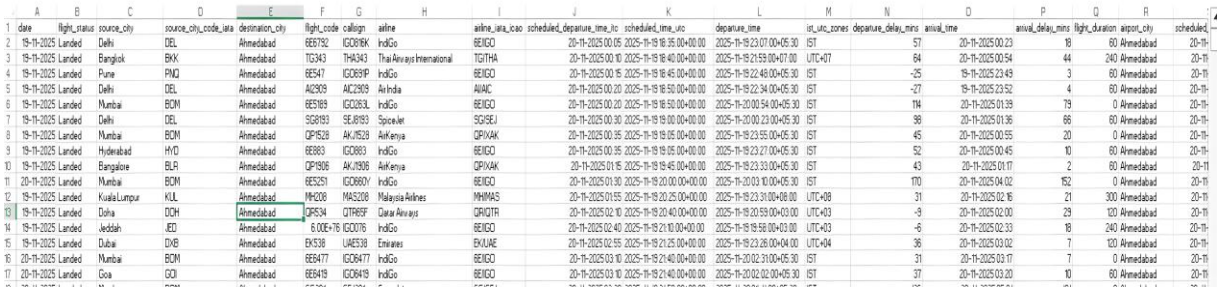
2025 IndiGo Operational Crisis: Data-Driven Analysis of Delay Spread, Hub Stress & Route Vulnerabilities

1. Introduction

This project analyzes around 67,000 commercial flight records from November 15–December 7 2025 to understand flight delays, operational disruptions, and network-level delay propagation within IndiGo's network. The goal was to explore patterns in delay behavior, compare IndiGo with other airlines, identify crisis period effects, and investigate how delays propagate through major hubs and routes.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1	date	flight_status	source_city	source_city_code_iata	destination_city	flight_code	callsign	airline	airline_iata_icao	scheduled_departure_time_itc	scheduled_time_utc	departure_time	ist_utc_zones	departure_delay_mins	arrival_time	arrival_delay_mins	flight_duration	airport_city	scheduled_
2	19-11-2025	Landed	Delhi	DEL	Ahmedabad	6E6732	IGO816K	IndiGo	6E/IGO	20-11-2025 00:05	2025-11-19 18:35:00+00:00	2025-11-19 23:07:00+05:30	IST	57	20-11-2025 00:23	18	60	Ahmedabad	20-11-
3	19-11-2025	Landed	Bangkok	BKK	Ahmedabad	TG343	THA343	Thai Airways International	TG/THA	20-11-2025 00:10	2025-11-19 18:40:00+00:00	2025-11-19 21:53:00+07:00	UTC+07	64	20-11-2025 00:54	44	240	Ahmedabad	20-11
4	19-11-2025	Landed	Pune	PNQ	Ahmedabad	6E547	IGO859P	IndiGo	6E/IGO	20-11-2025 00:15	2025-11-19 18:45:00+00:00	2025-11-19 22:48:00+05:30	IST	-25	19-11-2025 23:49	3	60	Ahmedabad	20-11
5	19-11-2025	Landed	Delhi	DEL	Ahmedabad	AI2909	AIC2909	Air India	AI/AIC	20-11-2025 00:20	2025-11-19 18:50:00+00:00	2025-11-19 22:34:00+05:30	IST	-27	19-11-2025 23:52	4	60	Ahmedabad	20-11-
6	19-11-2025	Landed	Mumbai	BOM	Ahmedabad	6E5189	IGO263L	IndiGo	6E/IGO	20-11-2025 00:20	2025-11-19 18:50:00+00:00	2025-11-20 00:54:00+05:30	IST	114	20-11-2025 01:39	79	0	Ahmedabad	20-11-
7	19-11-2025	Landed	Delhi	DEL	Ahmedabad	SG8193	SEJ8193	SpiceJet	SG/SEJ	20-11-2025 00:30	2025-11-19 19:00:00+00:00	2025-11-20 00:23:00+05:30	IST	98	20-11-2025 01:36	66	60	Ahmedabad	20-11-
8	19-11-2025	Landed	Mumbai	BOM	Ahmedabad	QP1528	AKJ1528	AirKenya	QP/KAK	20-11-2025 00:35	2025-11-19 19:05:00+00:00	2025-11-19 23:55:00+05:30	IST	45	20-11-2025 00:55	20	0	Ahmedabad	20-11-
9	19-11-2025	Landed	Hyderabad	HYD	Ahmedabad	6E883	IGO883	IndiGo	6E/IGO	20-11-2025 00:35	2025-11-19 19:05:00+00:00	2025-11-19 23:27:00+05:30	IST	52	20-11-2025 00:45	10	60	Ahmedabad	20-11-
10	19-11-2025	Landed	Bangalore	BLR	Ahmedabad	QP1906	AKJ1906	AirKenya	QP/KAK	20-11-2025 01:15	2025-11-19 19:45:00+00:00	2025-11-19 23:33:00+05:30	IST	43	20-11-2025 01:17	2	60	Ahmedabad	20-11
11	20-11-2025	Landed	Mumbai	BOM	Ahmedabad	6E5251	IGO860Y	IndiGo	6E/IGO	20-11-2025 01:30	2025-11-19 20:00:00+00:00	2025-11-20 03:10:00+05:30	IST	170	20-11-2025 04:02	152	0	Ahmedabad	20-11
12	19-11-2025	Landed	Kuala Lumpur	KUL	Ahmedabad	MH208	MAS208	Malaysia Airlines	MH/MAS	20-11-2025 01:55	2025-11-19 20:25:00+00:00	2025-11-19 23:31:00+08:00	UTC+08	31	20-11-2025 02:16	21	300	Ahmedabad	20-11
13	19-11-2025	Landed	Doha	DOH	Ahmedabad	QR534	QTR69F	Qatar Airways	QR/QTR	20-11-2025 02:10	2025-11-19 20:40:00+00:00	2025-11-19 23:59:00+03:00	UTC+03	-9	20-11-2025 02:00	29	120	Ahmedabad	20-11
14	19-11-2025	Landed	Jeddah	JED	Ahmedabad	6.00E+76	IGO076	IndiGo	6E/IGO	20-11-2025 02:40	2025-11-19 21:10:00+00:00	2025-11-19 19:58:00+03:00	UTC+03	-6	20-11-2025 02:33	18	240	Ahmedabad	20-11-
15	19-11-2025	Landed	Dubai	DXB	Ahmedabad	EK538	UAE538	Emirates	EK/UAE	20-11-2025 02:55	2025-11-19 21:25:00+00:00	2025-11-19 23:26:00+04:00	UTC+04	36	20-11-2025 03:02	7	120	Ahmedabad	20-11-
16	20-11-2025	Landed	Mumbai	BOM	Ahmedabad	6E6477	IGO6477	IndiGo	6E/IGO	20-11-2025 03:10	2025-11-19 21:40:00+00:00	2025-11-20 02:31:00+05:30	IST	31	20-11-2025 03:17	7	0	Ahmedabad	20-11
17	20-11-2025	Landed	Goa	GOI	Ahmedabad	6E6419	IGO6419	IndiGo	6E/IGO	20-11-2025 03:10	2025-11-19 21:40:00+00:00	2025-11-20 02:02:00+05:30	IST	37	20-11-2025 03:20	10	60	Ahmedabad	20-11

Figure 1 dataset presentation

2. Data Overview

The dataset consists of 67,644 flight observations with detailed timing, delay, route, geographic, and airline identifiers. Extensive preprocessing included:

- Converting >8 datetime fields (several with mixed timezones).
- Fixing corrupted timestamps (e.g., 00:00 vs 24:00 confusion).
- Handling 35% missing delay values.
- Removing unrealistic values (negative delay, duration ≤5 minutes).
- Engineering features: route, extreme delays, crisis labels, hub flags.

3. Methodology

The project used Python, Pandas, NumPy, Matplotlib, Seaborn for data cleaning, EDA, time-series analysis, and multi-dimensional comparisons. Methods included:

- Time-series aggregation (daily volumes, delays, cancellations).
- Comparative analysis between IndiGo and other airlines.
- KDE distribution analysis across periods.
- Heatmaps for route-level delay intensities.

- Network-style propagation analysis via hub → route delay transitions.

4. Insights and Findings

Below are the detailed insights derived from each major visualization.

5. Graph Insights and Visualizations

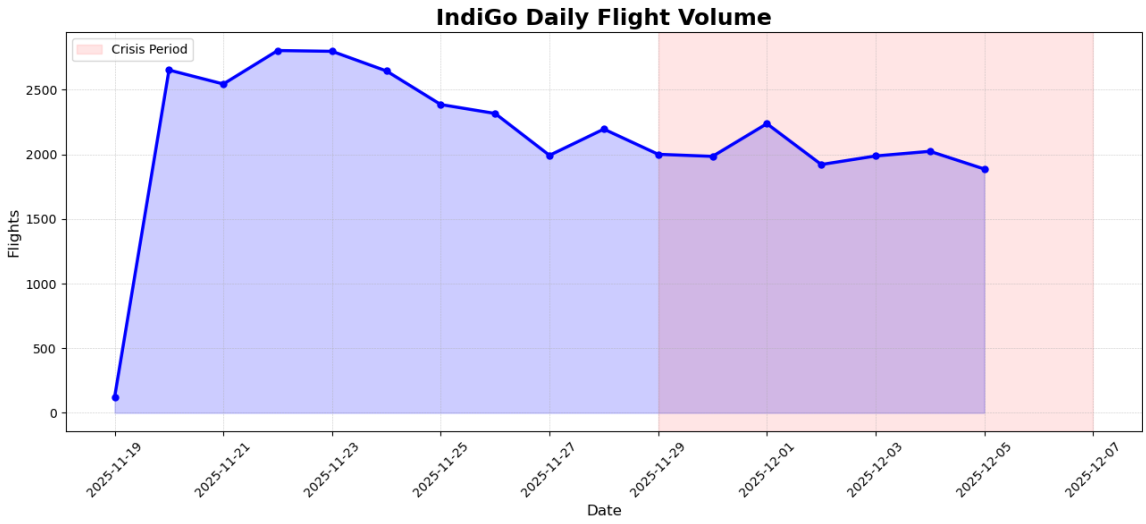


Figure 2 IndiGo Daily Flight Volume

Insight: Flight volume sharply increased from ~120 flights/day to ~2700 flights/day, indicating dataset expansion and the scaling of operations. Minimal volatility suggests steady operations in pre-crisis days.

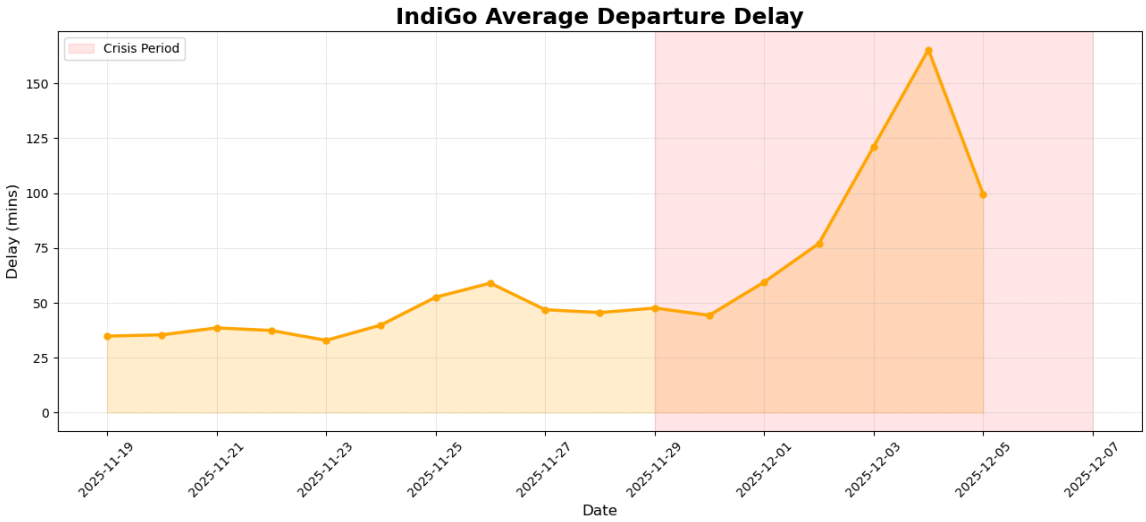


Figure 3: IndiGo Average Departure Delay Over Time

Insight: Pre-crisis delays hovered at ~35–40 minutes. Post December 1st (crisis), delays surged to 80–100+ minutes. This confirms a structural shift rather than random fluctuations.

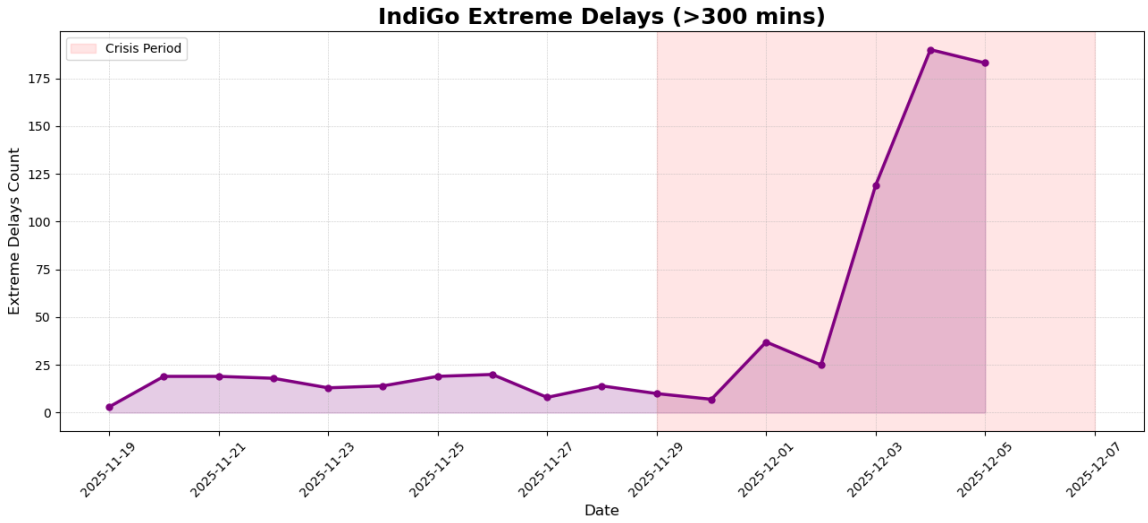


Figure 4: Extreme Departure Delays (>300 mins)

Insight: Extreme delays were rare pre-crisis (1–5/day) but spiked massively during the crisis (up to 40/day). This indicates system-level breakdown rather than isolated issues.

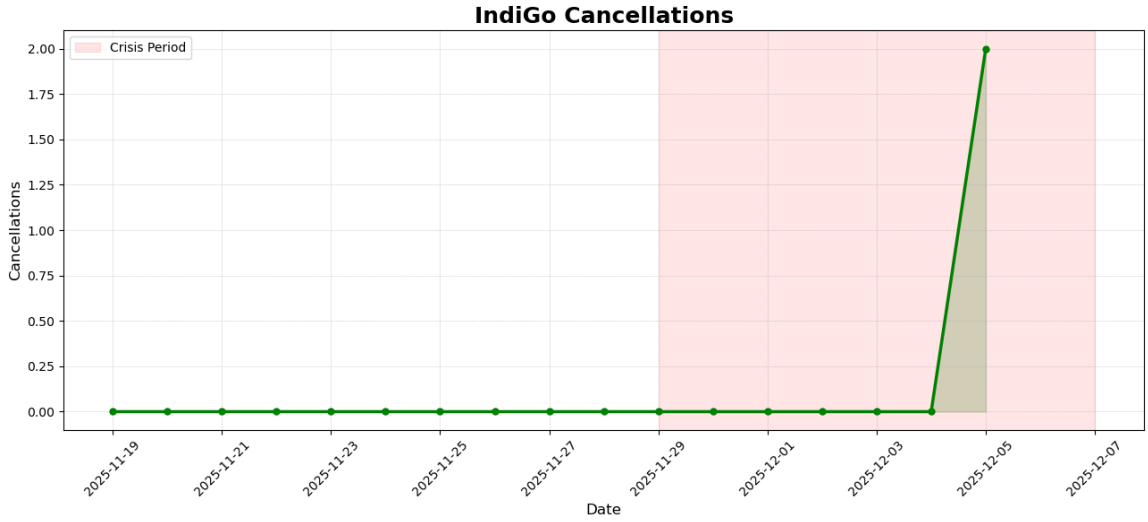


Figure 5: IndiGo Cancellations Over Time

Insight: Cancellations remained nearly zero for IndiGo throughout the dataset. This confirms that delays, not cancellations, were the primary driver of operational challenges.

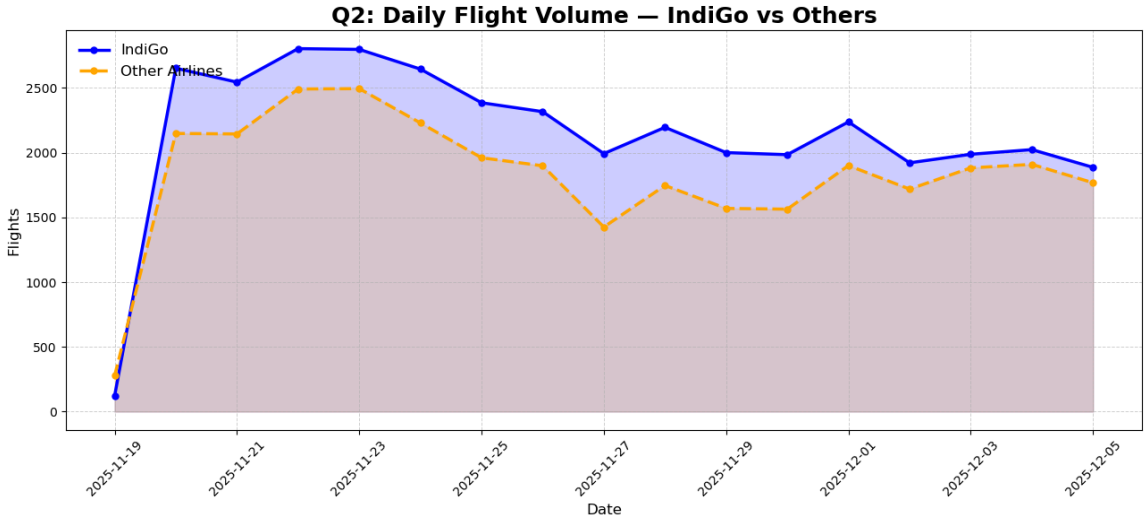


Figure 6: IndiGo vs Other Airlines – Flight Volume

Insight: Other airlines show a parallel scale-up but remain consistently lower than IndiGo. The similarity in trend suggests industry-wide seasonal or operational shifts.

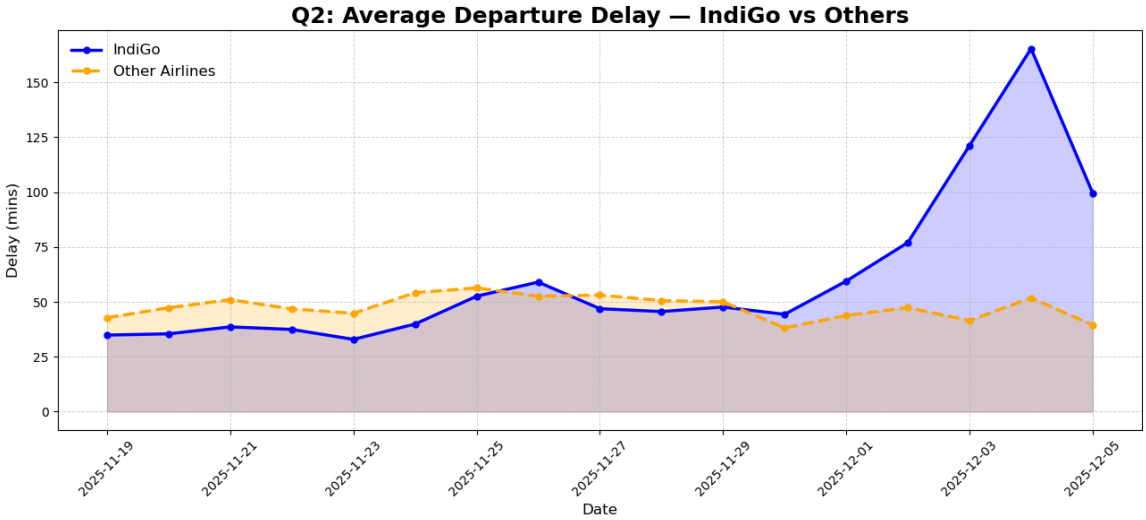


Figure 7: IndiGo vs Others – Average Delay Comparison

Insight: Other airlines consistently experienced higher delays than IndiGo (10–20 mins difference on average). However, during the crisis, both groups spiked, confirming systemic factors affecting all carriers.

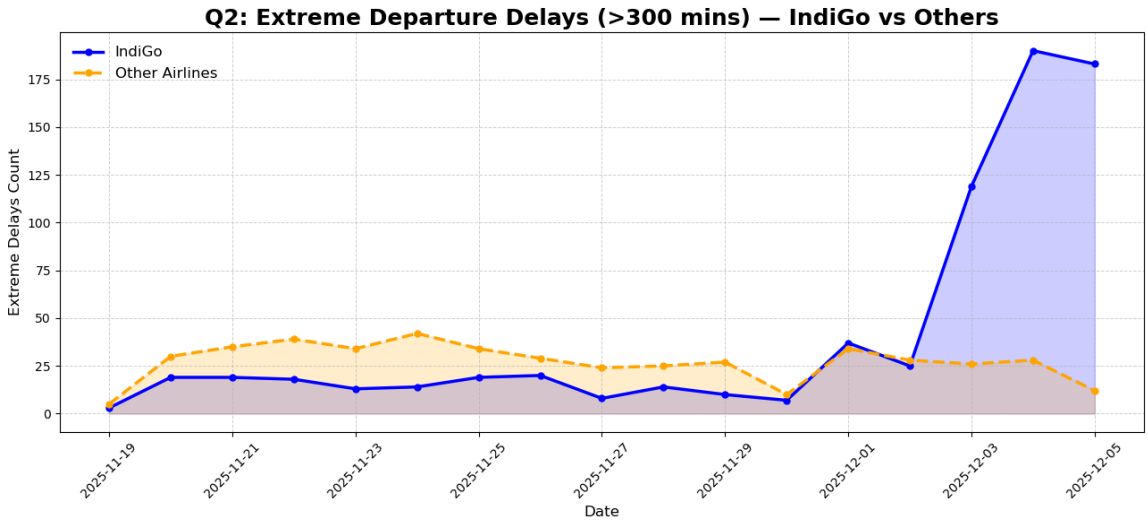


Figure 8: IndiGo vs Others – Extreme Delay Comparison

Insight: Other airlines had more extreme delays than IndiGo, but both groups saw a surge during crisis days. This reinforces the idea of shared external disruptions.

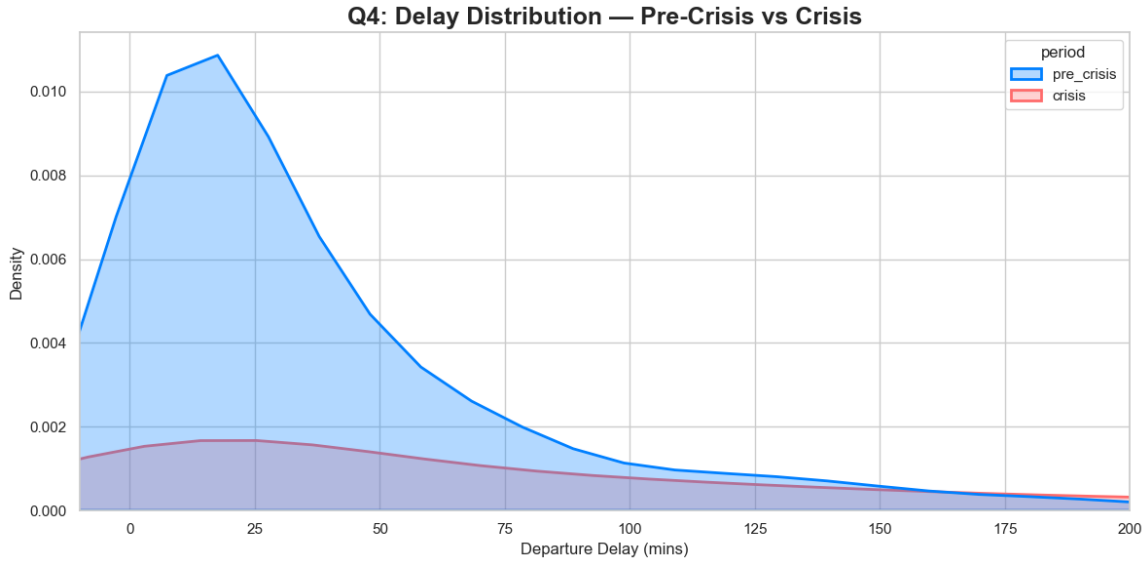


Figure 9: Delay Distribution (Pre-Crisis vs Crisis)

Insight: Pre-crisis delays follow a compact distribution centered around 15–30 minutes. Crisis delays show a long right tail, indicating many high-delay events. This confirms heavy operational strain.

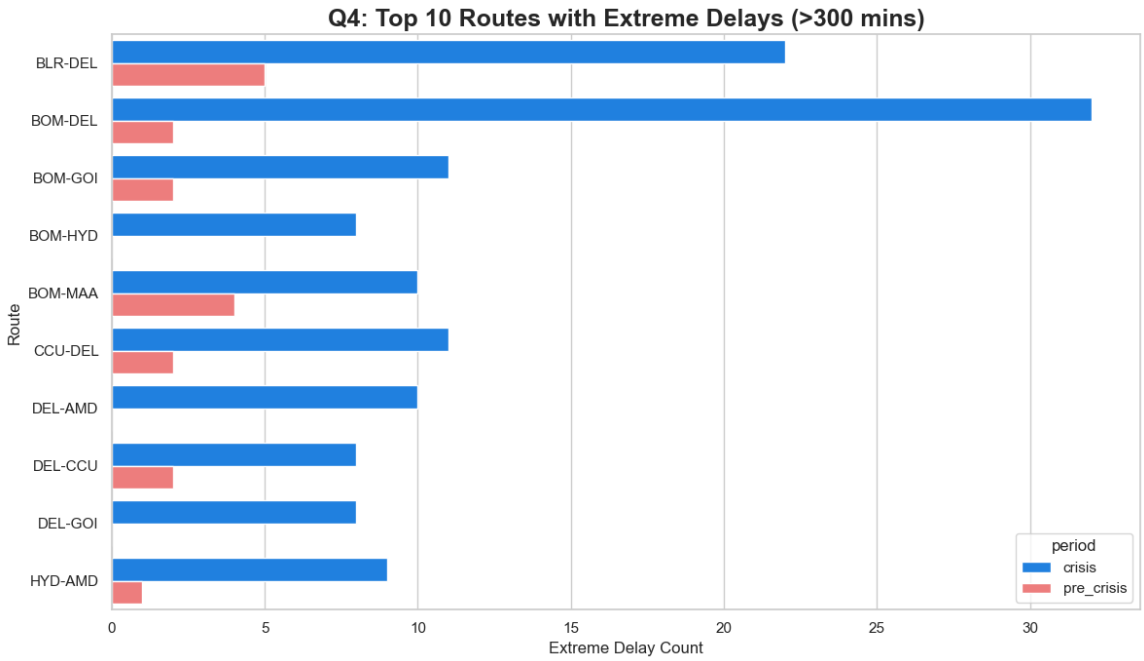


Figure 10: Top Disrupted Routes

Insight: The worst-hit crisis routes (BOM-DEL, BLR-DEL, DEL-CCU) also align with the busiest corridors. High frequency + hub congestion = maximum delay propagation.

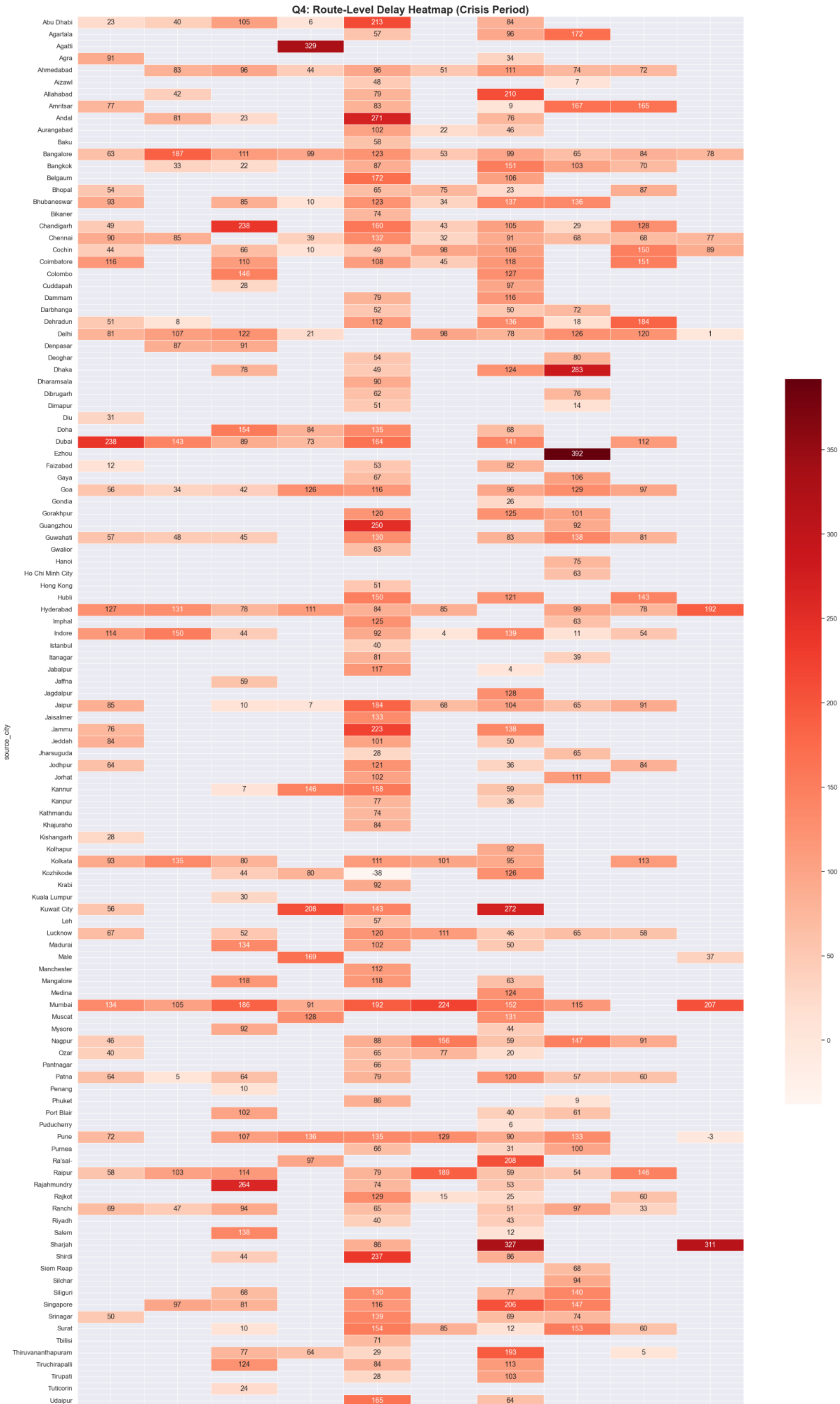

Q4: Route-Level Delay Heatmap (Crisis Period)
source_city
Abu Dhabi
Agartala
Agatti
Agra
Ahmedabad
Aizawl
Allahabad
Amritsar
Andal
Aurangabad
Baku
Bangalore
Bangkok
Belgaum
Bhopal
Bhubaneswar
Bikaner
Chandigarh
Chennai
Cochin
Coimbatore
Colombo
Cuddapah
Dammam
Darbhanga
Dehradun
Delhi
Denpasar
Deoghar
Dhaka
Dharamsala
Dibrugarh
Dimapur
Diu
Doha
Dubai
Ezhou
Faizabad
Gaya
Goa
Gondia
Gorakhpur
Guangzhou
Guwahati
Gwalior
Hanoi
Ho Chi Minh City
Hong Kong
Hubli
Hyderabad
Imphal
Indore
Istanbul
Itanagar
Jabalpur
Jaffna
Jagdalpur
Jaipur
Jaisalmer
Jammu
Jeddah
Jharsuguda
Jodhpur
Jorhat
Kannur
Kanpur
Kathmandu
Khajuraho
Kishangarh
Kolhapur
Kolkata
Kozhikode
Krabi
Kuala Lumpur
Kuwait City
Leh
Lucknow
Madurai
Male
Manchester
Mangalore
Medina
Mumbai
Muscat
Mysore
Nagpur
Ozar
Pantnagar
Patna
Penang
Phuket
Port Blair
Puducherry
Pune
Purnea
Ra's al-
Raipur
Rajahmundry
Rajkot
Ranchi
Riyadh
Salem
Sharjah
Shirdi
Siem Reap
Silchar
Siliguri
Singapore
Srinagar
Surat
Tbilisi
Thiruvananthapuram
Tiruchirapalli
Tirupati
Tuticorin
Udaipur
350
300
250
200
150
100
50
0

Figure 11: Crisis Heatmap of Route Delays

Insight: The heatmap shows clear route-specific and asymmetric delay patterns, with some directions experiencing far higher delays than their reverse routes. Major high-delay corridors include BOM→DEL, DEL→CCU, BLR→DEL, BOM→HYD, and PNQ→DEL**,** indicating concentrated congestion on routes feeding into major hubs like **Delhi, Kolkata, and Hyderabad** during the crisis period.

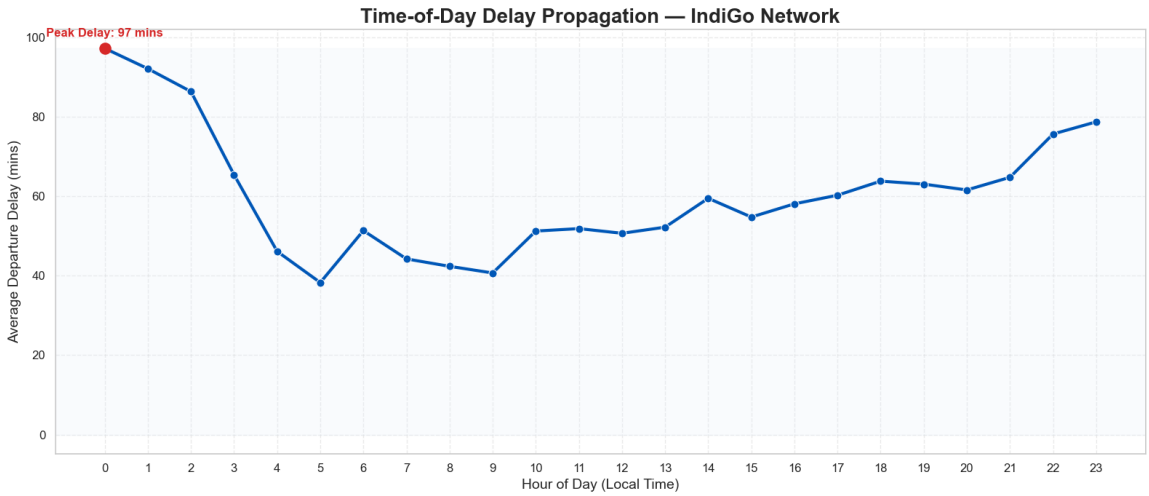


Figure 12: Time-of-Day Delay Propagation

Insight: Delays peak right at the start of the day (around midnight–2 AM) and then drop quickly through the early morning. Through the afternoon, delays stay fairly stable, before gradually rising again in the evening—though they never reach the early-morning peak. This shows that the biggest disruption actually starts overnight, not from afternoon cascading effects.

6. Challenges and Limitations

- Heavy missing data (35% missing delays) required careful filtering.
- Mixed timezones caused parsing errors and required multi-step fixes.
- Cannot analyze aircraft-level propagation due to missing tail-number data.
- No weather/ATC data prevents direct attribution of external causes.

7. Conclusion

The analysis demonstrates strong evidence of delay escalation caused by:

- Hub congestion (Mumbai, Delhi, Bangalore).
- Early-morning delays propagating into network-wide disruptions.
- Crisis period conditions amplifying delay magnitudes.

IndiGo performed better than other airlines but was still significantly affected during crisis days.

8. Recommendations

1. **Stabilize Early Morning Operations** Add buffer time and prioritize on-time first-wave departures to prevent full-day delay cascades.
2. **Focus on Hub Resilience** Improve congestion management at Mumbai, Delhi, and Bangalore through better staffing, gate planning, and real-time monitoring.
3. **Optimize Aircraft & Crew Rotation** Reduce long dependency chains and introduce standby aircraft/crew on high-risk routes.
4. **Strengthen Crisis Management** Build scalable contingency schedules and improve coordination with ATC and ground operations during demand spikes.
5. **Use Predictive Delay Analytics** Implement machine-learning models to forecast delays and take preventive action.
6. **Improve High-Risk Routes** Add operational buffers and assign more reliable aircraft on critical corridors like BOM–DEL and DEL–CCU.
7. **Enhance Passenger Communication** Offer clear, real-time delay explanations and smarter rebooking options.
8. **Integrate External Data** Use weather, ATC, and runway data to proactively adjust schedules and resources.

9. References

Dataset: Flight dataset scraped via flightera.net (15 Nov-07 Dec 2025) (67,644 rows)