Indian Railways Data Analysis Report

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1. Introduction

This report presents a comprehensive exploratory data analysis (EDA) on the Indian Railways dataset, which includes information about stations, trains, and schedules. The goal is to understand the structure, distribution, and key insights of the data, and to visualize geographical and operational patterns.

Datasets Used:

- `stations.json` – Station information including code, name, zone, state, and coordinates
- `trains.json` – Train information including type, route, distance, and duration
- `schedules.json` – Train schedules including station halts, arrival and departure times

Tools & Libraries:

- Python: `pandas`, `numpy`, `matplotlib`, `seaborn`, `folium`

2. Data Loading & Cleaning

2.1 Stations Dataset

- Loaded from `stations.json`
- Cleaned columns: `station_code`, `station_name`, `state`, `zone`, `address`, `longitude`, `latitude`
- Split coordinates into separate `longitude` and `latitude` columns
- Handled missing coordinates by replacing invalid values with `[None, None]`

Quick Overview:

Column	Missing Values
station_code	0
station_name	0
state	4532
zone	4532
address	4532

Column	Missing Values
longitude	293
latitude	293

Observation:
Many stations have missing zone/state information and a few missing coordinates. Cleaning was necessary for geospatial visualizations.

2.2 Trains Dataset

- Loaded from `trains.json`
- Cleaned columns: `train_number`, `train_name`, `train_type`, `zone`, `from_station_code`, `to_station_code`, `distance_km`, `duration_hr`, `arrival_time`, `departure_time`

Missing Values:

Column	Missing Values
distance_km	15
duration_hr	15

Observation:
Overall, the train dataset is clean. Minor missing values exist in distance and duration.

2.3 Schedules Dataset

- Loaded from `schedules.json`
- Cleaned columns: `train_number`, `train_name`, `station_code`, `station_name`, `arrival_time`, `departure_time`, `day`
- Replaced invalid entries such as `NA`, `?`, or `null` with `pd.NA`

Missing Values:

Column	Missing Values
train_name	8
station_name	2
day	22561

Observation:
Large dataset with 417,080 records. Missing days indicate incomplete scheduling info for some trains.

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3. Stations Analysis

3.1 Basic Stats

- Total Stations: 8,990
- Unique Zones: 18
- Unique States: 30

3.2 Stations per State

Top 10 states by number of stations:

State	Count
Uttar Pradesh	529
Rajasthan	451
Gujarat	422
Maharashtra	378
West Bengal	345
Madhya Pradesh	316
Karnataka	301
Tamil Nadu	253
Punjab	212
Bihar	210

Observation:
Uttar Pradesh, Rajasthan, and Gujarat have the highest concentration of railway stations.

3.3 Geospatial Map

- Stations plotted on an interactive map using Folium
- Stations represented as blue circle markers

Observation:
Most stations are concentrated in northern and western states. Sparse coverage is observed in northeastern India.

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4. Trains Analysis

4.1 Basic Stats

- Total Trains: 5,208
- Columns: train_number, train_name, train_type, zone, distance_km, duration_hr, etc.

4.2 Train Types Distribution

Train Type	Count
Pass	2,459
Exp	1,288
SF	719
MEMU	297
Hyd	121
Others	324

Observation:
Passenger trains dominate, followed by express (Exp) and superfast (SF) trains.

4.3 Trains per Zone

Zone	Count
NR	628
SR	606
WR	470
SCR	437
NER	394
ER	369

Observation:
Northern Railway (NR) and Southern Railway (SR) operate the most trains.

4.4 Journey Distances

- Average distance: 545 km
- Maximum distance: 4,279 km

Observation:
Trains cover a wide range of distances from short regional trips to long inter-state journeys.

4.5 Average Speed

- Calculated as `distance_km / duration_hr`
- Summary:

Metric	Value
Mean	47 km/h
Min	10.5 km/h
Max	225 km/h

Observation:
Most trains operate below 60 km/h. High-speed trains (SF) achieve up to 225 km/h.

5. Schedules Analysis

5.1 Busiest Stations (Most Train Halts)

Top 10 busiest stations:

Station Name	Train Halts
SABARMATI JN	342
KANPUR CENTRAL	312
ITARSI JN	293
GHAZIABAD	287
SAHIBABAD	285
HOWRAH JN	283
VIJAYAWADA JN	264
KOPAR ROAD	262
MUGHAL SARAI JN	259
VADODARA JN	254

Observation:
Busiest stations are mostly major junctions in northern and western India.

5.2 Train Coverage

- Number of stations served per train:
  - Median: ~35 stations
  - Maximum: 186 stations

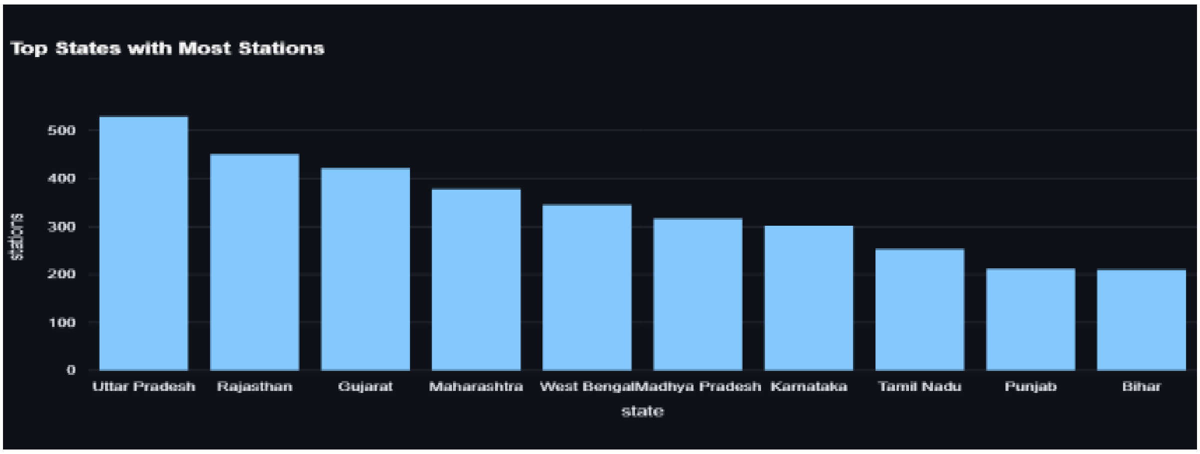
Observation:
Long-distance trains cover a large number of stations, while regional trains have fewer stops.

6. Key Insights

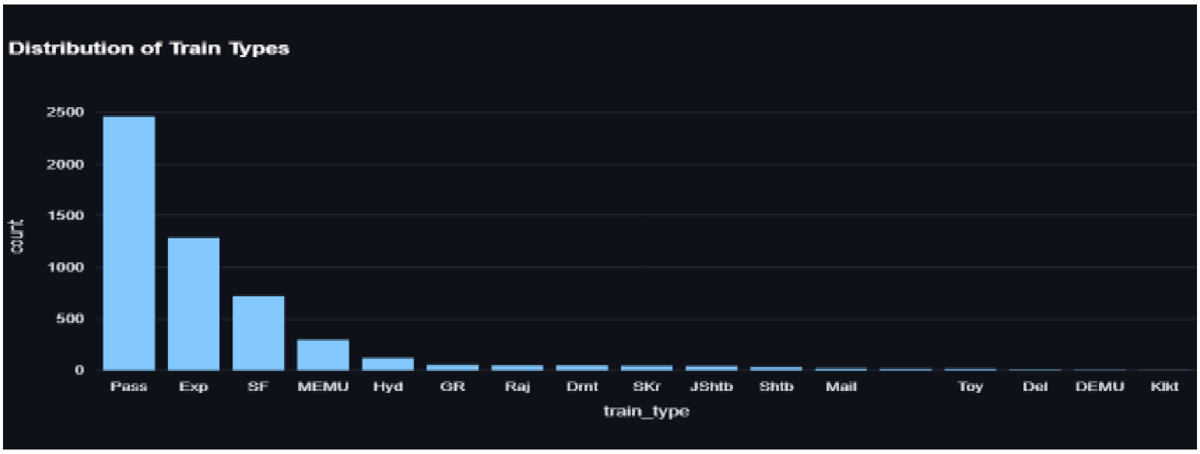
1. Northern and western states have the highest density of railway stations.
2. Passenger trains dominate the Indian Railways network.
3. Major hubs like SABARMATI, KANPUR, and HOWRAH handle the highest traffic.
4. Average train speed is 47 km/h, indicating slow regional trains and few high-speed services.
5. Long-distance trains serve a broad range of stations, providing connectivity across states.

7. Visualizations

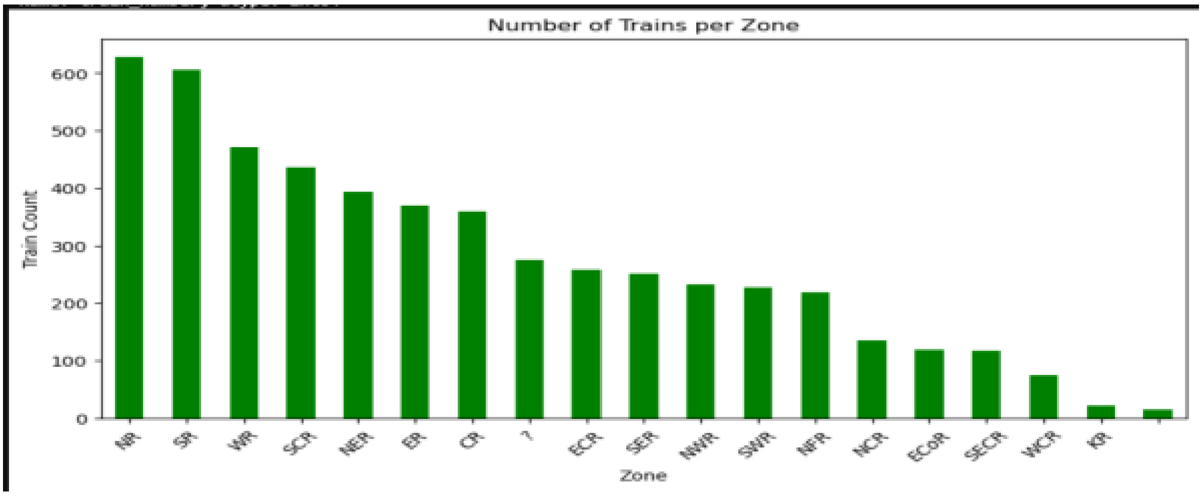
- **Stations per State:** Bar chart



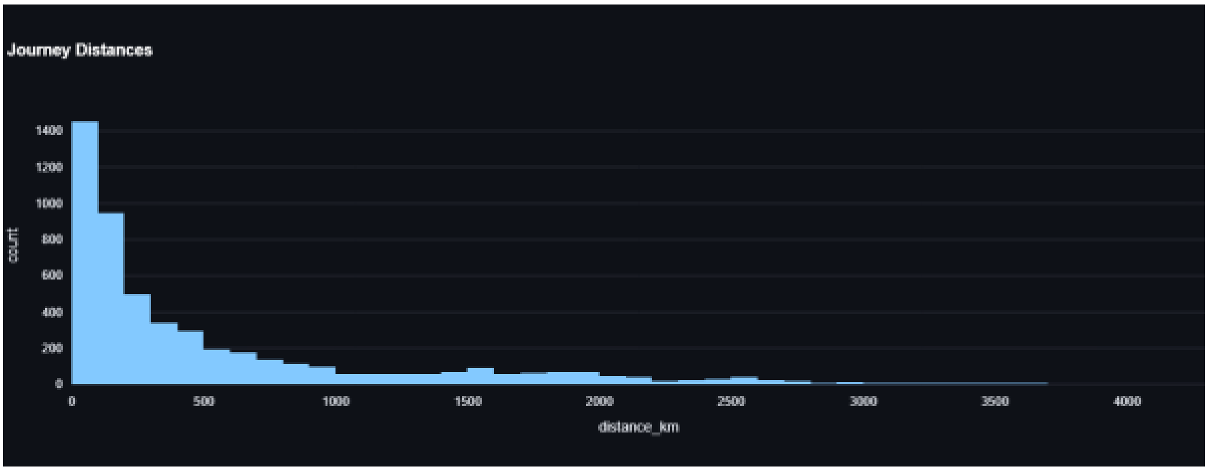
- **Train Types Distribution:** Bar chart



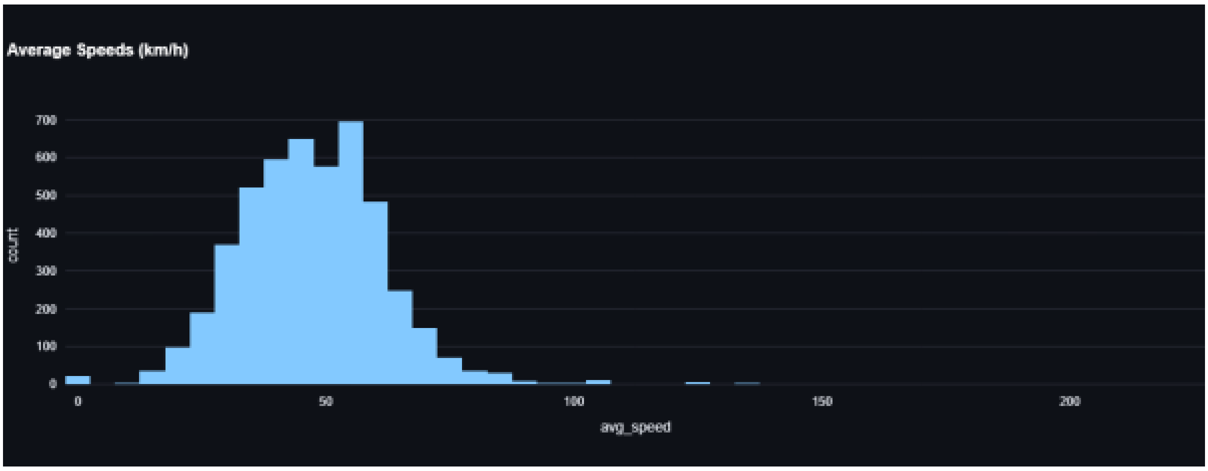
- **Trains per Zone:** Bar chart



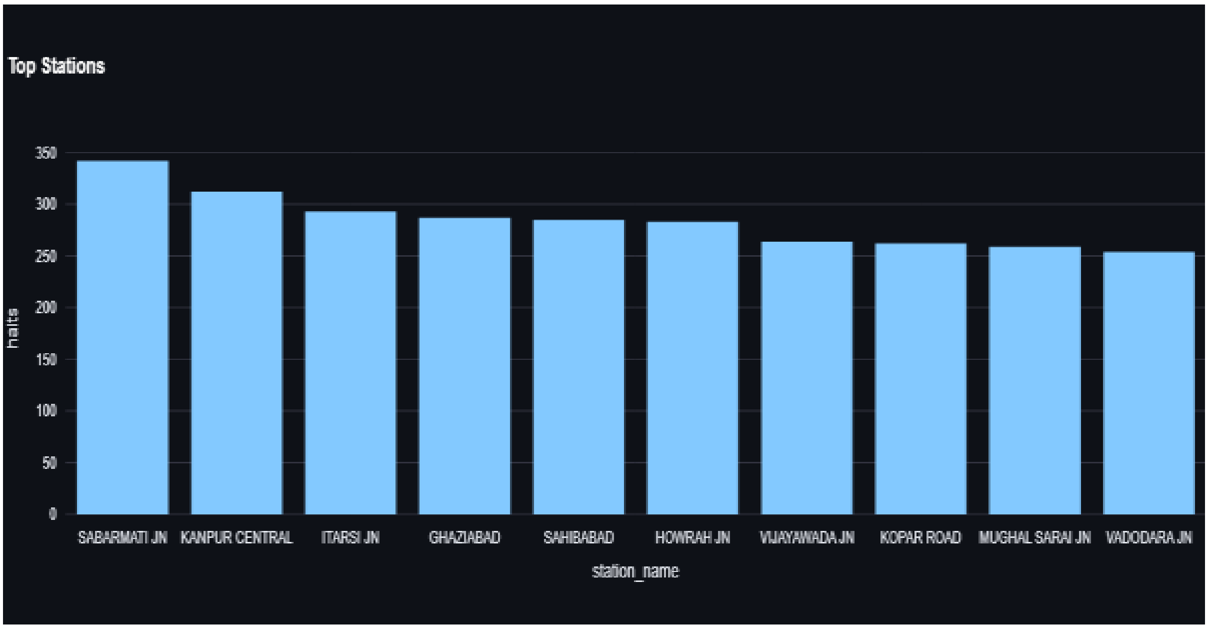
- **Journey Distances:** Histogram



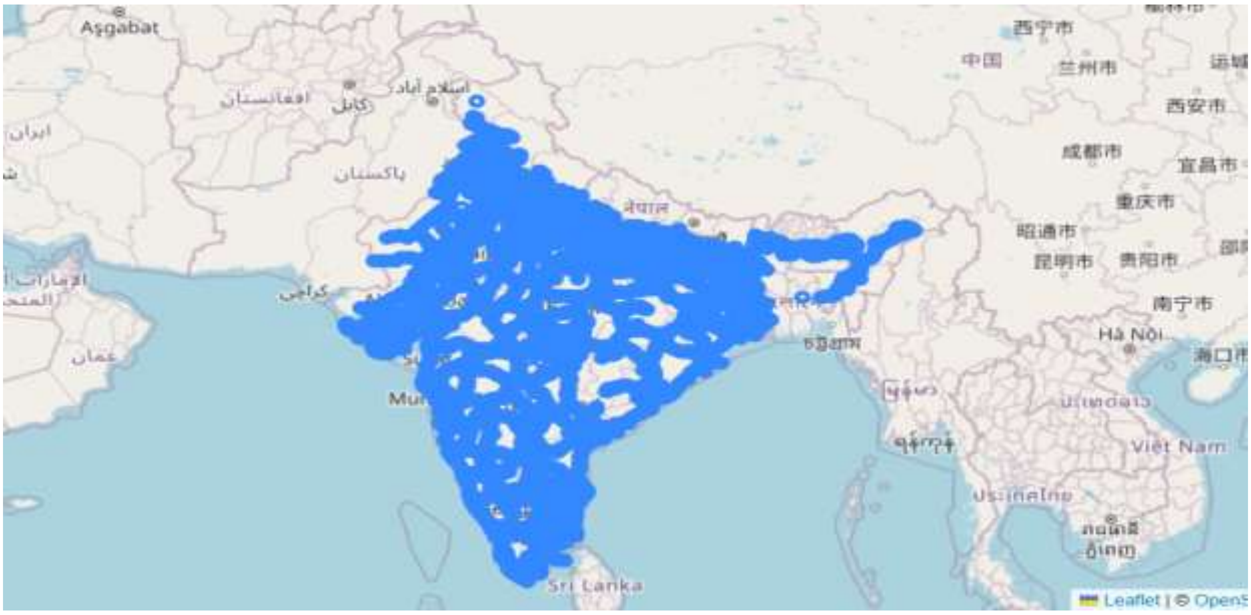
- **Average Speed:** Histogram



- **Busiest Stations:** Bar chart



- **Geospatial Map:** Interactive `stations_map.html`



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8. Conclusion

The exploratory analysis provides a clear view of the Indian Railways network:

- Coverage is dense in major states but sparse in the northeast.
- Passenger and express trains dominate, but high-speed trains are limited.
- Certain stations act as hubs for high traffic, offering opportunities for network optimization.
- The geospatial map enables interactive visualization of station locations.

This analysis lays the foundation for deeper studies such as train traffic optimization, predictive modeling, and geospatial planning.
