

Mapping Tomorrow: Transforming Urban Infrastructure with OpenStreetMap Data

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Course: Big Data Management (BDM)

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DEPARTMENT OF AIDE
POST GRADUATE DIPLOMA IN DATA ENGINEERING
TRIMISTER - 3



Indian Institute of Technology (IIT) Jodhpur

Project Overview

Mapping Tomorrow: Transforming Urban Infrastructure with OpenStreetMap Data

Objective: Leveraging OpenStreetMap (OSM) data for smarter city planning.

- **Features:**

- Traffic heatmaps and congestion predictions.
- Optimal route suggestions for emergency services.
- Recommendations for expanding public transport.

- **Target Users:** City planners and decision-makers

Why This Project?

- As part of the **Big Data Management – course** at IIT Jodhpur, this project aims to demonstrate:
 - Understanding of Big Data tools and techniques like Google Big Query.
 - Practical application of geospatial data (OpenStreetMap) for urban planning.

Connecting Big Query, OpenStreetMap Data, and Urban Planning

- **Google Big Query:** Enables real-time analysis of large datasets efficiently.
- **OpenStreetMap Data:** A crowd-sourced, open dataset ideal for studying urban infrastructure.
- **Urban Planning Relevance:**
 - Provides insights into traffic, public transport, and road networks.
 - Helps design smarter solutions for city planners and policymakers.

Objective of This Presentation

- To showcase the technical understanding and application of:
 - Big Query for large-scale data analysis.
 - Visualization and insights derived from OpenStreetMap data.
- Highlight how such tools can solve urban planning challenges like traffic optimization, public transport expansion, and sustainable infrastructure design.

Broader Implications of OSM Data Globally

- **Crowd-Sourced and Open:**

- OSM is a free, open-source geospatial database with contributions from millions worldwide.
- Continuously updated, making it highly reliable for real-time planning and analysis.

- **Global Reach:**

- Covers a wide range of geographies, including underserved and under-mapped regions.
- Provides data for roads, buildings, amenities, natural features, and more.

- **Versatile Applications:**

- Widely used for transportation planning, disaster management, public health, and environmental monitoring.

- **Cost-Effective Solution:**

- Reduces dependency on expensive proprietary geospatial datasets.
- Easy integration with tools like Big Query, GIS software, and APIs for analytics and visualization.

Why Use OSM for Urban Planning?

- **Detailed Data for Cities:**

- Includes essential features like road networks, traffic flows, public amenities, and zoning information.

- **Real-Time Updates:**

- Keeps pace with rapidly changing urban landscapes.

- **Interoperable:**

- Easy integration with tools like Big Query, GIS software, and APIs for analytics and visualization.

Challenges & Technological Approach

Title: Tackling Challenges with Technology

Key Challenges:

- Managing large datasets from OSM.
- Real-time processing of traffic and transport data.
- Ensuring application scalability and performance.
- Building an intuitive user interface.

Technological Solutions:

- Backend: Node.js, Express.js, PostgreSQL with PostGIS, NodeDensity Histogram, Scatterplot, RoadLength Distribution, Node Density Heatmap, Node Orientation, Feature Type Frequency.
- Frontend: React.js, Leaflet.js, Material-UI for UI and map visualization.
- Cloud: AWS for scalability (EC2, S3, Kubernetes).
- APIs: OpenStreetMap API for real-time data.

Data Exploration Workflow for planet_nodes Table

- **Schema Details:**

- Key fields included:
- id: Unique identifier for each node.
- latitude and longitude: Geographical coordinates.
- geometry: Geospatial representation.
- osm_timestamp: Timestamp of the last update.
- all_tags: Metadata about the feature (e.g., amenity, highway).

- **Exploratory Data Analysis:**

- Key Visualized and analyzed the latitude and longitude data to understand spatial patterns.

- **Purpose of Analysis:**

- To derive actionable insights for urban planning and infrastructure optimization using node-level data.

geo_openstreetmap

CREATE TABLE SHARING COPY DELETE REFRESH

Dataset info

EDIT DETAILS

Dataset ID	bigquery-public-data.geo_openstreetmap
Created	Oct 4, 2019, 12:25:51 AM UTC+5:30
Default table expiration	Never
Last modified	Sep 20, 2022, 1:13:37 PM UTC+5:30
Data location	US
Description	
Default collation	
Default rounding mode	ROUNDING_MODE_UNSPECIFIED
Time travel window	7 days
Case insensitive	false
Labels	freebqcovid : freebqcovid
Tags	

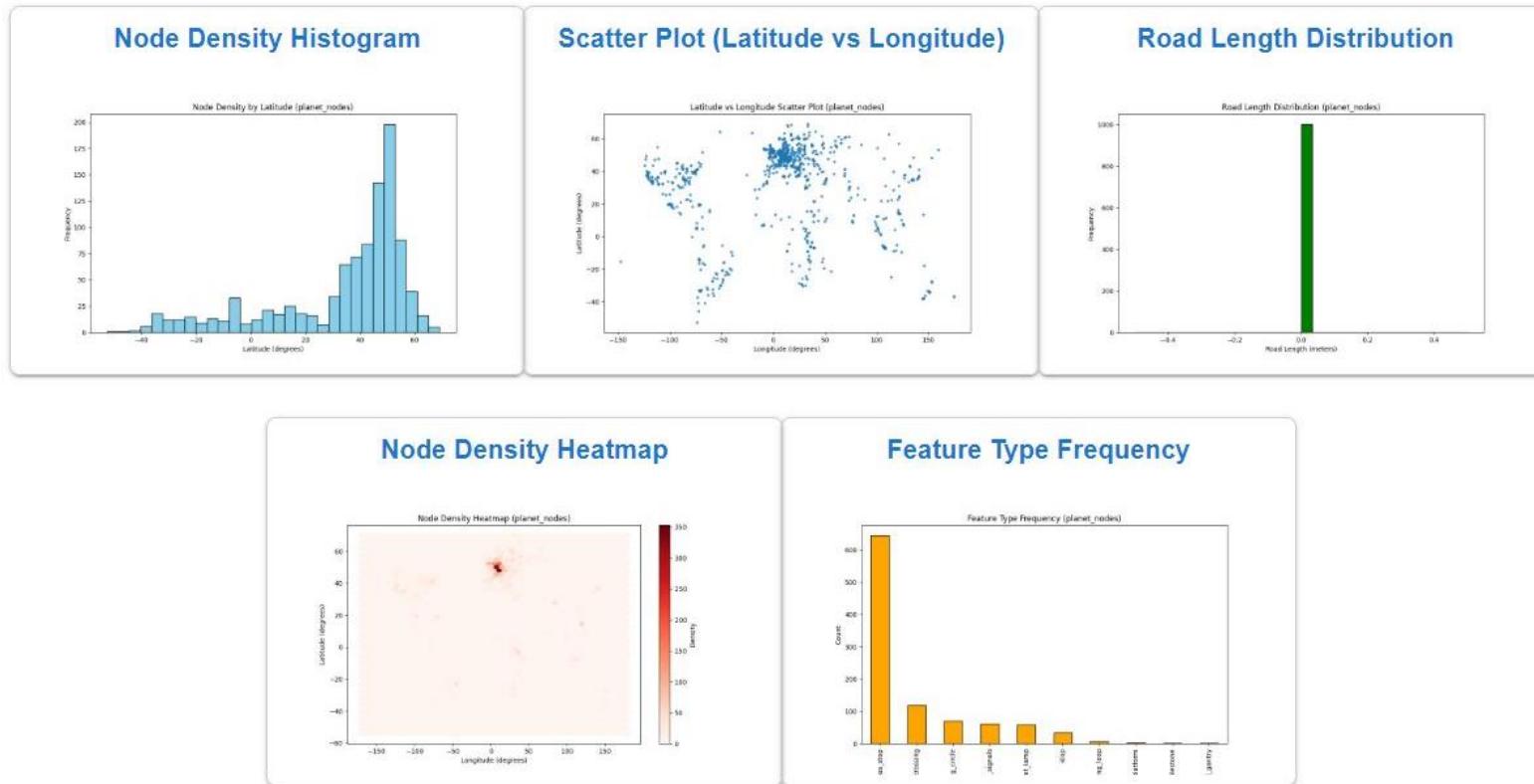
Dataset replica info

VIEW REPLICAS

Primary location	US
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Mapping Tomorrow: Transforming Urban Infrastructure with OpenStreetMap Data

Exploratory Data Analysis of OpenStreetMap Data



[PROCEED TO FURTHER ANALYSIS](#)

Graphical Insights from OpenStreetMap Data

- **Node Density Histogram:**

Displays the frequency distribution of nodes by latitude, highlighting areas with high mapping activity.

- **Scatter Plot (Latitude vs Longitude):**

Visualizes the geographical spread of nodes, revealing dense urban clusters and sparse rural areas.

- **Road Length Distribution:**

Shows the distribution of road lengths, providing insights into the structure of road networks.

- **Node Density Heatmap:**

A heatmap that pinpoints regions with the highest node concentrations, indicating urban centers or areas with detailed mapping.

- **Feature Type Frequency:**

Analyzes the frequency of different feature types, such as highways or residential roads, to understand the predominant map elements.

Analysis of *planet_features_lines*

This visualization provides an interactive map showcasing the road network data extracted from the `planet_features_lines` table of OpenStreetMap. The map highlights key road geometries, enabling users to delve into the spatial intricacies of transportation infrastructure. By analyzing the road network, we aim to shed light on connectivity patterns, urban planning, and the geographical layout of regions.

This map is particularly useful for:

- **Urban Planners:** To identify gaps in infrastructure and plan new road projects effectively.
- **Researchers:** To study how road networks impact urban growth, traffic flow, and accessibility.
- **Public Administrators:** To improve navigation and optimize routes for emergency services and public transport.
- **General Users:** To explore the spatial organization of roads and understand their interconnectivity.

Our analysis leverages cutting-edge tools like GeoPandas and Folium to render these geometries interactively, ensuring that even complex road structures can be explored seamlessly. Dive into this visualization to uncover insights about spatial patterns and their implications on urban mobility.



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Contributors:

Shubham Raj

Bhagchandani Niraj Bhavesh Arora





Indian Institute of Technology
Jodhpur

Date: 12/15/2024

Project Report on

URBAN MOBILITY AND
INFRASTRUCTURE OPTIMIZATION
USING OPENSTREETMAP DATA

Welcome to URBAN MOBILITY AND INFRASTRUCTURE OPTIMIZATION USING OPENSTREETMAP DATA

START



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Geo Open Street Map from BigQuery

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[SETS](#) [PLANET_FEATURES](#) [PLANET_FEATURES_LINES](#) [PLANET_FEATURES_POINTS](#) [PLANET_LAYERS](#) [PLANET_NODES](#) [PLANET_RELATIONS](#)

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id	nodes	osm_timestamp_max	osm_timestamp_min	relations	ways
24389786		1406487828	1406487828		
24188454		1405539404	1405539404		
44259512		1481208210	1481208210		
18328499		1381654052	1381654052		
64876102		1543176809	1543176809		

< 1 2 3 4 5 ... 20 >

Geo Open Street Map from BigQuery

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SETS **PLANET_FEATURES** PLANET_FEATURES_LINES PLANET_FEATURES_POINTS PLANET_LAYERS PLANET_NODES PLANET_RELATIONS

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feature_type	geometry	osm_id	osm_timestamp	osm_version	osm_way_id	tags
other_relations	LINESTRING(-122.4851604 37.7857538, -122.48623 37.7857054, -122.4873016 37.7856569, -122.4878159 37.7856336, -122.4882221 37.7856156)	12907989	Thu, 01 Jul 2021 19:11:45 GMT	1	-	
other_relations	POINT(-122.1898574 37.8618932)	8971337	Fri, 16 Nov 2018 20:13:21 GMT	1	-	
points	POINT(-122.4370478 37.8073651)	3130351249	Tue, 14 Oct 2014 23:27:32 GMT	1	-	Id: 0 amenity: bench backrest: yes colour: green material: wood maxlength: 12 feet

Geo Open Street Map from BigQuery

[Click here to redirect to BigQuery](#)

SETS PLANET_FEATURES **PLANET_FEATURES_LINES** PLANET_FEATURES_POINTS PLANET_LAYERS PLANET_NODES PLANET_RELATIONS

geometry	osm_id	osm_timestamp	osm_version	osm_way_id	tags
LINESTRING(-122.3152652 38.2343315, -122.3152479 38.2343315, -122.3150578 38.2343729, -122.3149026 38.2344552, -122.3147301 38.2345648, -122.3145576 38.2346607, -122.3144024 38.2347566, -122.31423 38.2348662, -122.3140747 38.2349621, -122.3139195 38.2350444, -122.3137989 38.2351538, -122.313661 38.2352497, -122.3135404 38.2353591, -122.3133851 38.2354414, -122.3132299 38.2355236, -122.3132812 38.2353871, -122.3133151 38.2352506, -122.3133491 38.2351141, -122.3134004 38.2349776, -122.3134171 38.2348411, -122.3134336 38.2346638, -122.3135195 38.2345272, -122.3134841 38.23435, -122.3135181 38.2342135, -122.3135695 38.2340906, -122.3136034 38.2339541, -122.3136721 38.2338311, -122.3136714 38.2336811, -122.3136708 38.2335311, -122.3136701 38.233381, -122.3136176 38.2332448, -122.3135479 38.2331086, -122.3134608 38.2329724, -122.3134256 38.2328361, -122.3133732 38.2326999, -122.313338 38.2325636, -122.3132855 38.2324273, -122.3132503 38.232291, -122.3132497 38.232141, -122.3133712 38.2322498, -122.3135271 38.2323176, -122.3137003 38.2323717, -122.3138046 38.2324941, -122.3137879 38.2326442, -122.3137713 38.2327943, -122.3138583 38.2329168, -122.3139626 38.2330393, -122.3140496 38.2331618, -122.3141539 38.2332843, -122.3141711 38.2332842, -122.3152652 38.2343315)	43100353	Sun, 25 Oct 2009 02:28:39 GMT	1	-	{}

Geo Open Street Map from BigQuery

[Click here to redirect to BigQuery](#)

SETS PLANET_FEATURES PLANET_FEATURES_LINES PLANET_FEATURES_POINTS PLANET_LAYERS PLANET_NODES PLANET_RELATIONS

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geometry	osm_id	osm_timestamp	osm_version	osm_way_id	tags
POINT(-117.7776978 33.8980546)	1793938577	Tue, 19 Jun 2012 02:41:18 GMT	1	-	APN: 350-432-19 addr:city: Yorba Linda addr:housenumber: 20465 addr:postcode: 92886-8605 addr:state: CA addr:street: Chianti Court source: OCGIS;USPS
POINT(-117.7773862 33.8979672)	1793938579	Tue, 19 Jun 2012 02:41:19 GMT	1	-	APN: 350-433-06 addr:city: Yorba Linda addr:housenumber: 4348 addr:postcode: 92886-8611 addr:state: CA addr:street: Genoa Way source: OCGIS;USPS

Geo Open Street Map from BigQuery

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SETS PLANET_FEATURES PLANET_FEATURES_LINES PLANET_FEATURES_POINTS **PLANET_LAYERS** PLANET_NODES PLANET_RELATIONS

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gdal_type	geometry	layer_class	layer_code	layer_name	osm_id	osm_timestamp	osm_version	osm_way_id
points	POINT(-121.7865811 36.7988827)	place	1003	village	150972031	Sat, 19 Nov 2016 01:43:22 GMT	7	-

Geo Open Street Map from BigQuery

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SETS PLANET_FEATURES PLANET_FEATURES_LINES PLANET_FEATURES_POINTS PLANET_LAYERS **PLANET_NODES** PLANET_RELATIONS

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changeset	id	latitude	longitude	osm_timestamp	tags	username	version	visible
74591024	1245051308	42.865620300	20.868627800	Tue, 17 Sep 2019 16:43:38 GMT	{}	HenryFjord	6	true
97695207	2758092863	30.083597400	31.022736800	Mon, 18 Jan 2021 11:32:11 GMT	{}	shimaa_magdy	8	true
74426844	86106726	43.691102500	10.833393100	Fri, 13 Sep 2019 09:24:50 GMT	{}	Pab09	54	true
26714657	432628661	48.812755600	8.978262000	Tue, 11 Nov 2014 16:11:56 GMT	{}	Geofreund1	5	true
35364608	60037007	50.719153800	8.509312300	Mon, 16 Nov 2015 23:50:04 GMT	{}	DoDoMR	6	true

< 1 2 3 4 5 ... 20 >

Geo Open Street Map from BigQuery

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.TS PLANET_FEATURES PLANET_FEATURES_LINES PLANET_FEATURES_POINTS PLANET_LAYERS PLANET_NODES PLANET_RELATIONS

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all_tags	changeset	geometry	id	members	osm_timestamp	username	version	visible
	19771014	-	2024066		Thu, 02 Jan 2014 18:10:36 GMT	AUM	11	true
	19770851	-	2024106		Thu, 02 Jan 2014 17:20:42 GMT	AUM	9	true
	19770851	-	2024535		Thu, 02 Jan 2014 17:17:40 GMT	AUM	11	true
	19770851	-	2024152		Thu, 02 Jan 2014 17:20:43 GMT	AUM	6	true
	19770851	-	2024145		Thu, 02 Jan 2014 17:20:42 GMT	AUM	11	true

< 1 2 3 4 5 ... 20 >

Please select a table to continue
with your analysis

Select Table

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PROCEED TO NEXT STEP

Schema Details for planet_nodes

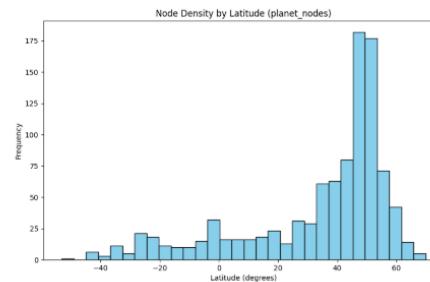
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longitude	NUMERIC	NULLABLE

[BACK](#)[NEXT](#)

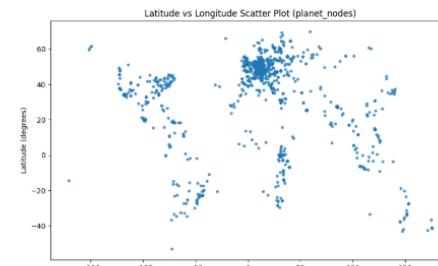
Contributors:

Exploratory Data Analysis (EDA) Graph Visualizations for planet_nodes

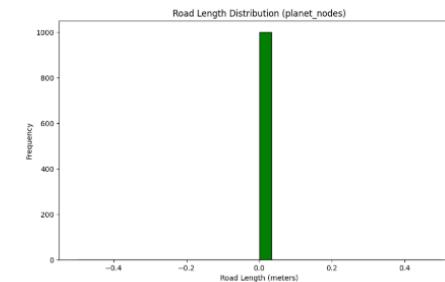
Node Density Histogram



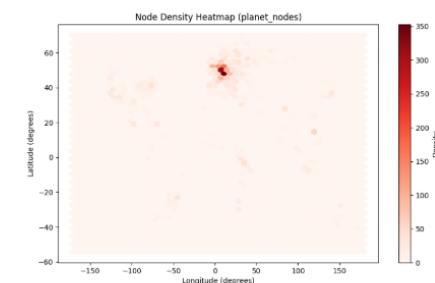
Scatter Plot (Latitude vs Longitude)



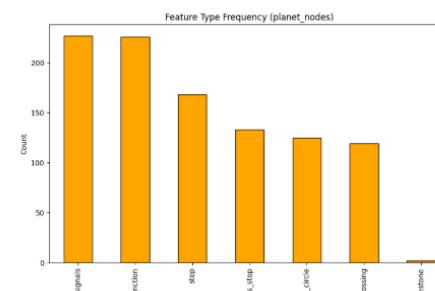
Road Length Distribution



Node Density Heatmap



Feature Type Frequency



PROCEED TO FURTHER ANALYSIS



⚠ Not secure

54.160.26.39:5173/select-table



**Please select a table to continue
with your analysis**

Select Table

planet_layers

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PROCEED TO NEXT STEP

Schema Details for planet_layers

Field Name	Field Type	Mode
layer_code	INTEGER	NULLABLE
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osm_way_id	INTEGER	NULLABLE
osm_timestamp	TIMESTAMP	NULLABLE
osm_version	INTEGER	NULLABLE
all_tags	RECORD	REPEATED
geometry	GEOGRAPHY	NULLABLE

**Please select a table to continue
with your analysis**

Select Table

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[PROCEED TO NEXT STEP](#)

Schema Details for planet_features_points

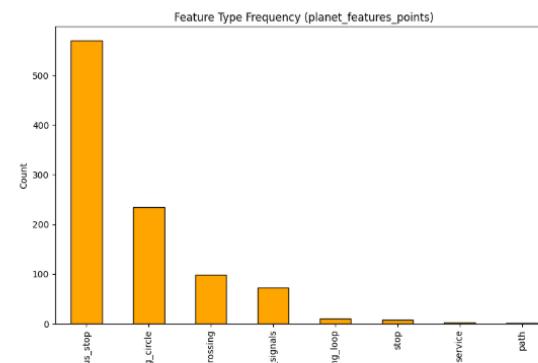
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osm_version	INTEGER	NULLABLE
osm_way_id	INTEGER	NULLABLE
osm_timestamp	TIMESTAMP	NULLABLE
geometry	GEOGRAPHY	NULLABLE
all_tags	RECORD	REPEATED

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Exploratory Data Analysis (EDA)

Graph Visualizations for planet_features_points

Feature Type Frequency

[PROCEED TO FURTHER ANALYSIS](#)

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5 ▾

id	nodes	osm_timestamp_max	osm_timestamp_min	relations	ways
24389786		1406487828	1406487828		
24188454		1405539404	1405539404		
44259512		1481208210	1481208210		
18328499		1381654052	1381654052		
64876102		1543176809	1543176809		

< 1 2 3 4 5 ... 20 >

[NEXT STEP](#)

Schema Details for history_changesets

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osm_timestamp_min	INTEGER	NULLABLE
osm_timestamp_max	INTEGER	NULLABLE
relations	INTEGER	REPEATED
ways	INTEGER	REPEATED
nodes	INTEGER	REPEATED

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**Please select a table to continue
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Select Table

planet_features

You have selected: *planet_features*

PROCEED TO NEXT STEP

Schema Details for planet_features

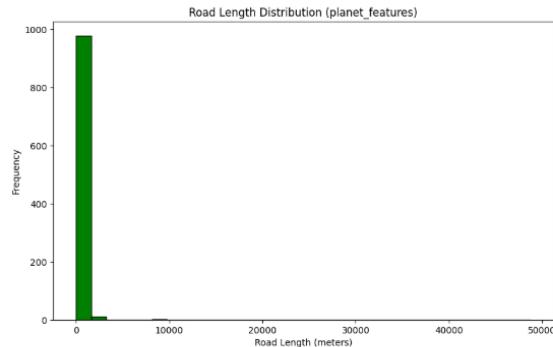
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geometry	GEOGRAPHY	NULLABLE

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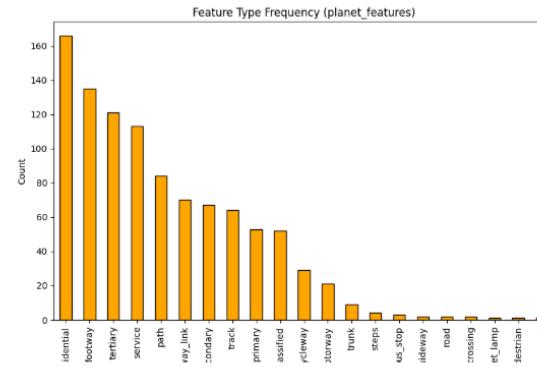
Exploratory Data Analysis (EDA)

Graph Visualizations for planet_features

Road Length Distribution



Feature Type Frequency



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**Please select a table to continue
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Select Table

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You have selected: *planet_features_lines*

PROCEED TO NEXT STEP

Schema Details for planet_ways

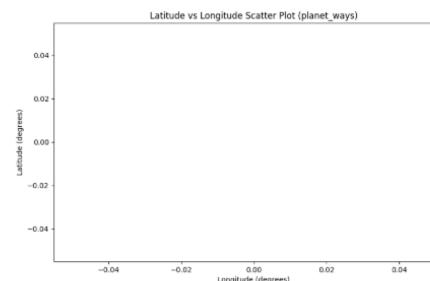
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nodes	RECORD	REPEATED

[BACK](#)[NEXT](#)

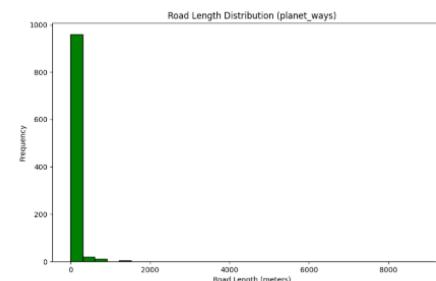
Exploratory Data Analysis (EDA)

Graph Visualizations for planet_ways

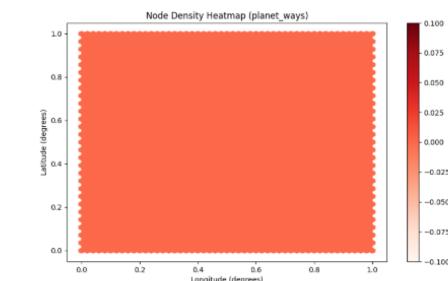
Scatter Plot (Latitude vs Longitude)



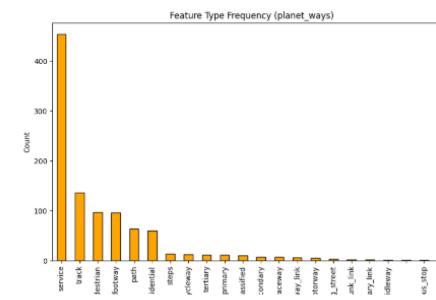
Road Length Distribution



Node Density Heatmap



Feature Type Frequency



PROCEED TO FURTHER ANALYSIS

**Please select a table to continue
with your analysis**

Select Table

history_changesets

You have selected: *history_changesets*

PROCEED TO NEXT STEP

Schema Details for planet_features_lines

Field Name	Field Type	Mode
osm_id	INTEGER	NULLABLE
osm_version	INTEGER	NULLABLE
osm_way_id	INTEGER	NULLABLE
osm_timestamp	TIMESTAMP	NULLABLE
geometry	GEOGRAPHY	NULLABLE
all_tags	RECORD	REPEATED

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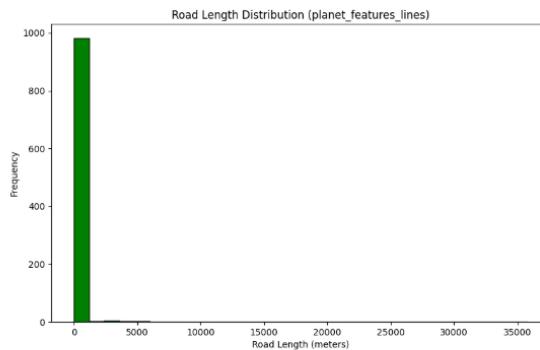
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Exploratory Data Analysis (EDA)

Graph Visualizations for planet_features_lines

Road Length Distribution



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**Please select a table to continue
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Select Table

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You have selected: *planet_ways*

PROCEED TO NEXT STEP



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**Please select a table to continue
with your analysis**

Select Table

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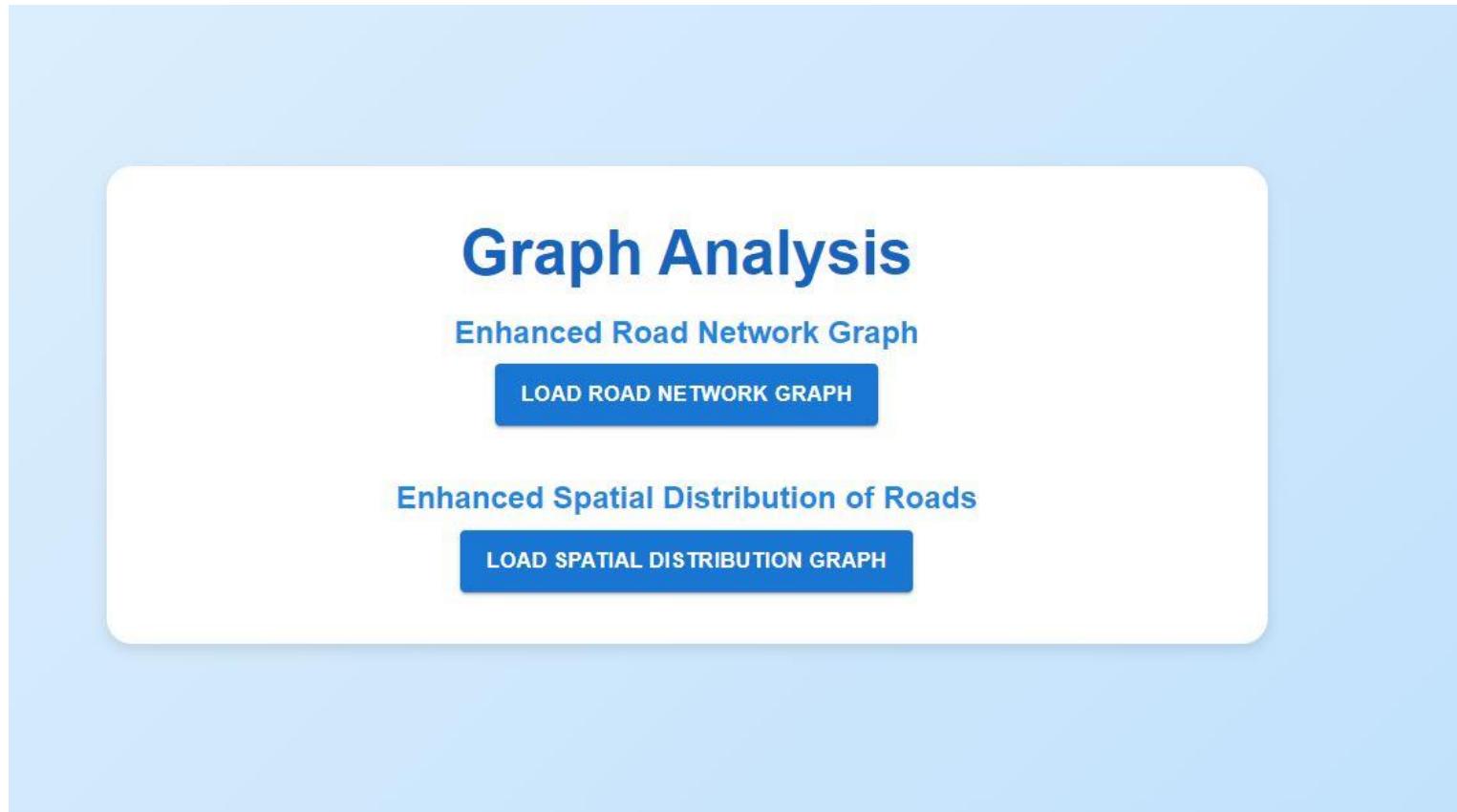
PROCEED TO NEXT STEP

Schema Details for planet_relations

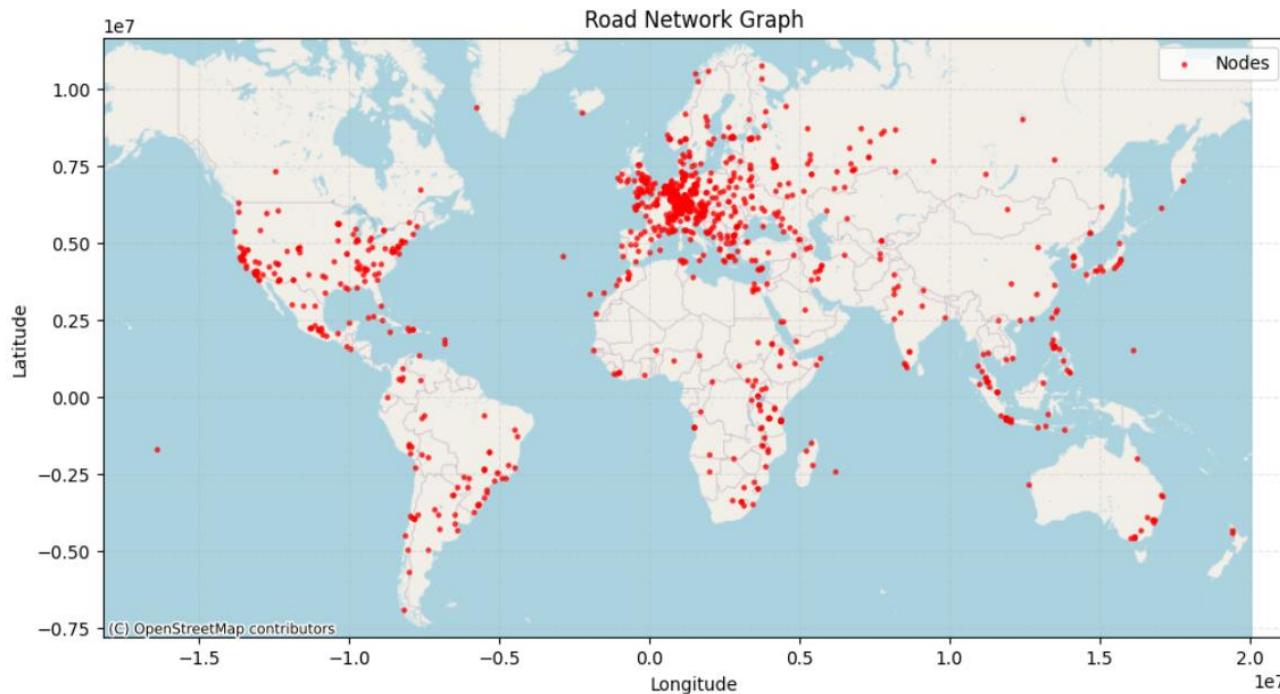
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changeset	INTEGER	NULLABLE
visible	BOOLEAN	NULLABLE
osm_timestamp	TIMESTAMP	NULLABLE
geometry	GEOGRAPHY	NULLABLE
all_tags	RECORD	REPEATED
members	RECORD	REPEATED

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Graph Analysis



Road Network Graph

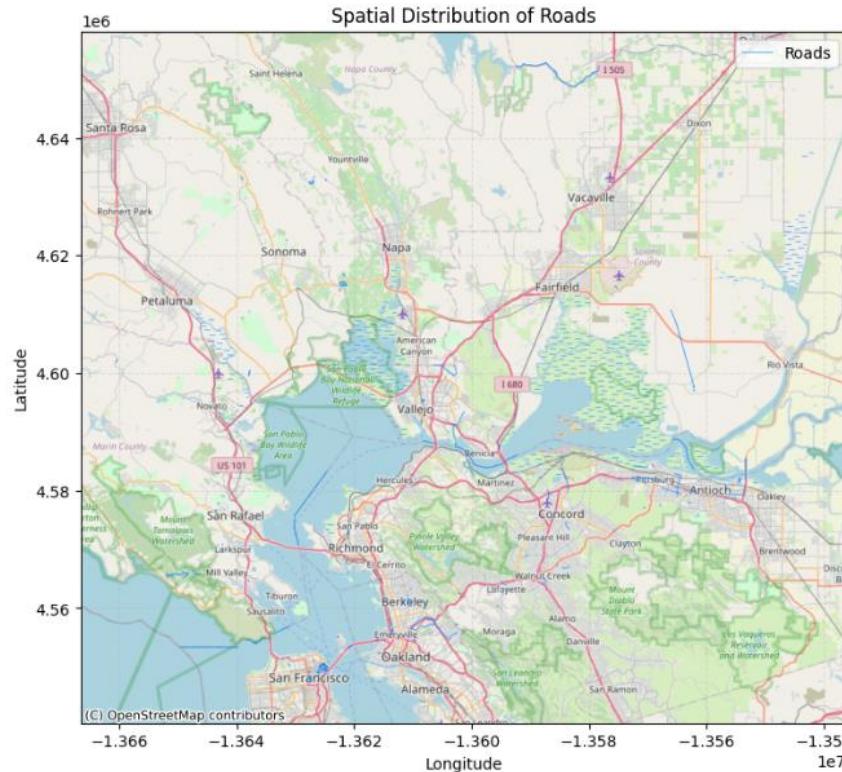


This is the Road Network Graph visualization.

[DOWNLOAD IMAGE](#)

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Spatial Distribution Graph



This is the Spatial Distribution Graph visualization.

[DOWNLOAD IMAGE](#)

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Exploration Workflow for planet_nodes Table

- **Visualization Details:**

- Each red dot represents a node, which could be an intersection, point of interest, or part of the road network.
- The map showcases the spatial layout of road networks worldwide using latitude and longitude.

- **Key Insights:**

- Dense clustering of nodes in regions like Europe, North America, and parts of Asia reflects high urbanization and detailed mapping.
- Sparse node distribution in certain areas like deserts and oceans is expected due to less mapping activity or geographical constraints.

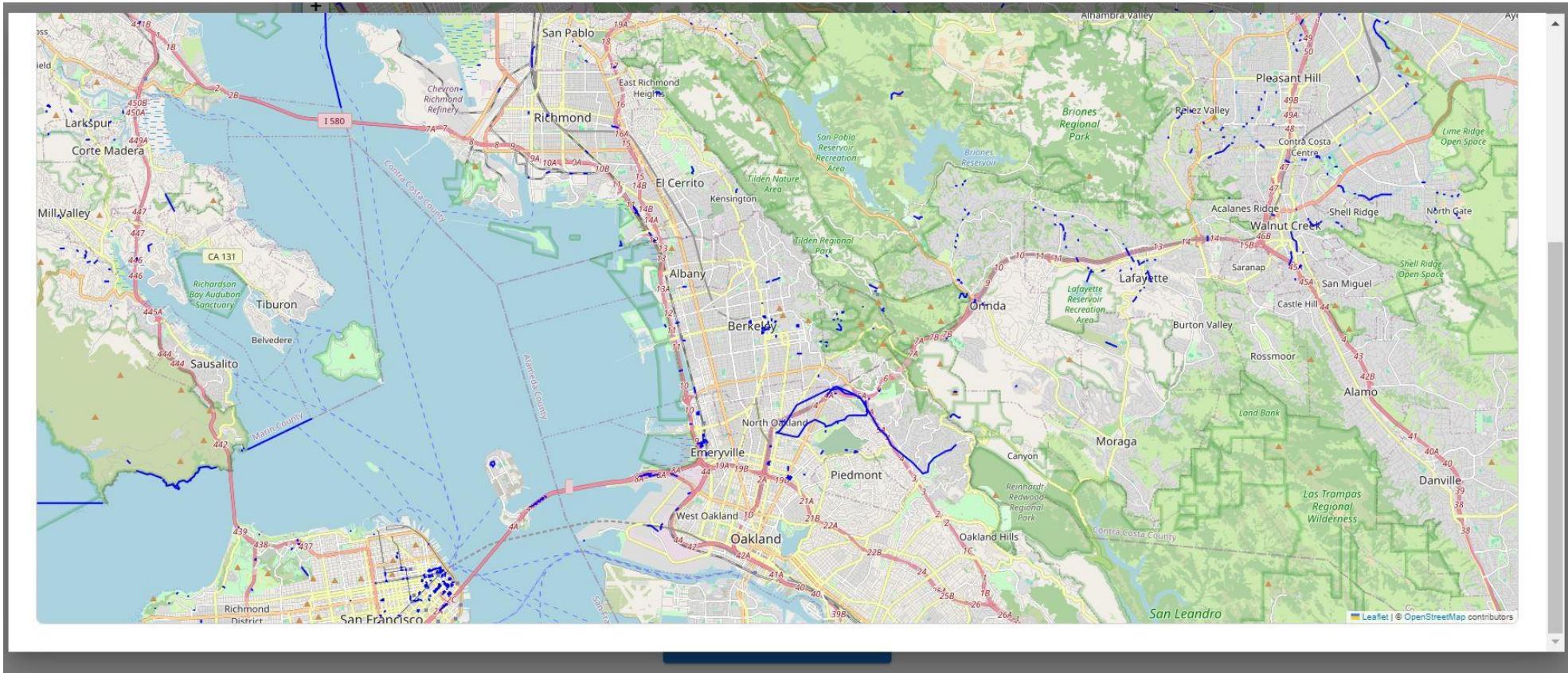
- **Use Cases:**

- **Urban Planning:** Identifying high-density areas to optimize traffic flow.
- **Mapping Accuracy:** Highlighting regions with sparse node data for future mapping efforts.

Spatial Distribution of Roads from planet_ways table

- **Visualization Details:**
 - The map shows roads as red lines plotted over a base map.
 - Roads are distributed spatially using Longitude and Latitude values from the planet_ways dataset.
- **Key Insights:**
 - Highlights major road networks, intersections, and connectivity in the region.
 - Provides a detailed view of urban and rural road infrastructure.
- **Use Cases:**
 - **Infrastructure Planning:** Helps city planners identify regions with dense or sparse road networks.
 - **Traffic Analysis:** Supports analysis of potential bottlenecks in the road layout.
 - **Urban Development:** Assists in optimizing future road construction.

Spatial Distribution of Roads from planet_ways



Visualizing Key Features: Insights from planet_features table

- **Visualization Details:**

- The map overlays various geographic features, including roads (red lines), water bodies (blue), and green zones (parks or natural reserves).
- Represents a highly detailed view of a specific region's infrastructure.

Key Insights:

- The visualization helps identify connections between urban areas, natural reserves, and transport networks.
- Highlights the spatial relationships between features, such as roads intersecting park boundaries or connecting urban centers.

Use Cases:

- **Environmental Planning:** Identifying green zones and their interaction with urban development.
- **Infrastructure Design:** Optimizing road layouts based on surrounding features.
- **Urban Analysis:** Analyzing connectivity and accessibility between key points of interest.

Thank You!!!
