Transportation Network Analysis Report

1. Introduction

This report presents the results of the transportation network analysis. The analysis identifies critical intersections, routes, and hubs within a transport graph using network science metrics and visualizations.

2. Data Preparation

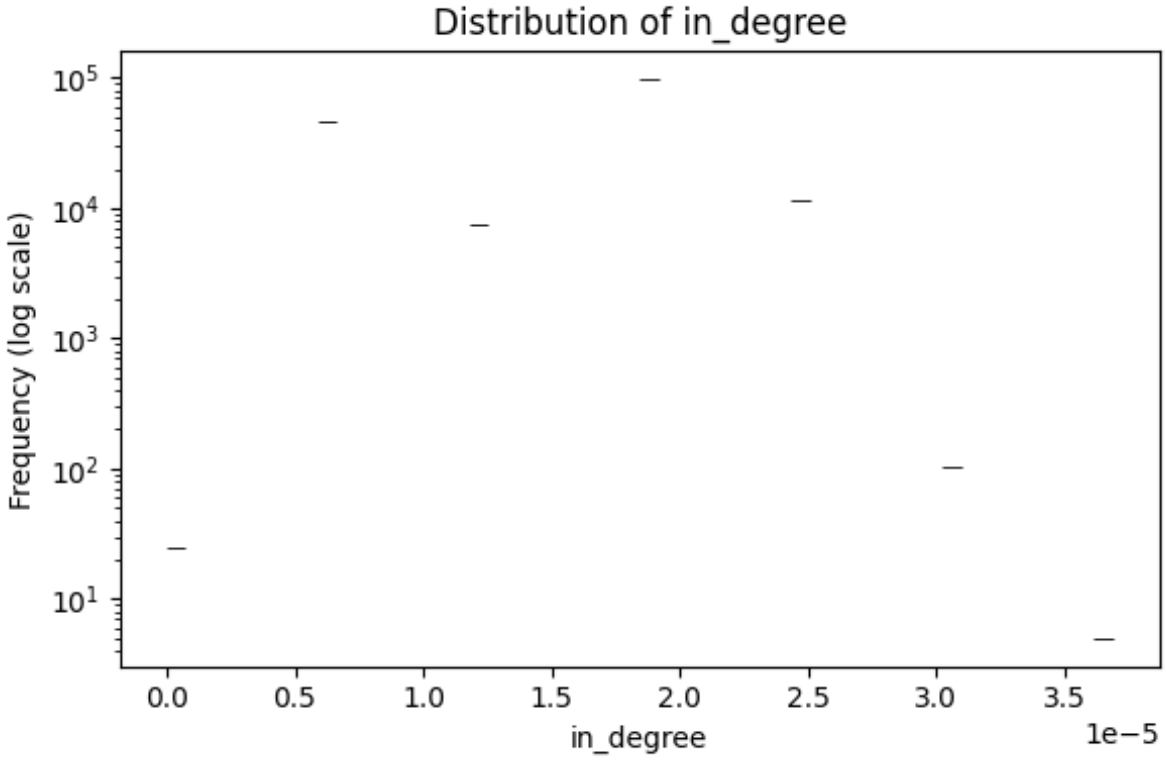
We modeled a transportation system as a directed graph where nodes represent intersections or stations and edges represent routes or connections. Key objectives included computing centrality measures to identify high-traffic nodes, analyzing connectivity, and visualizing structural patterns in the network.

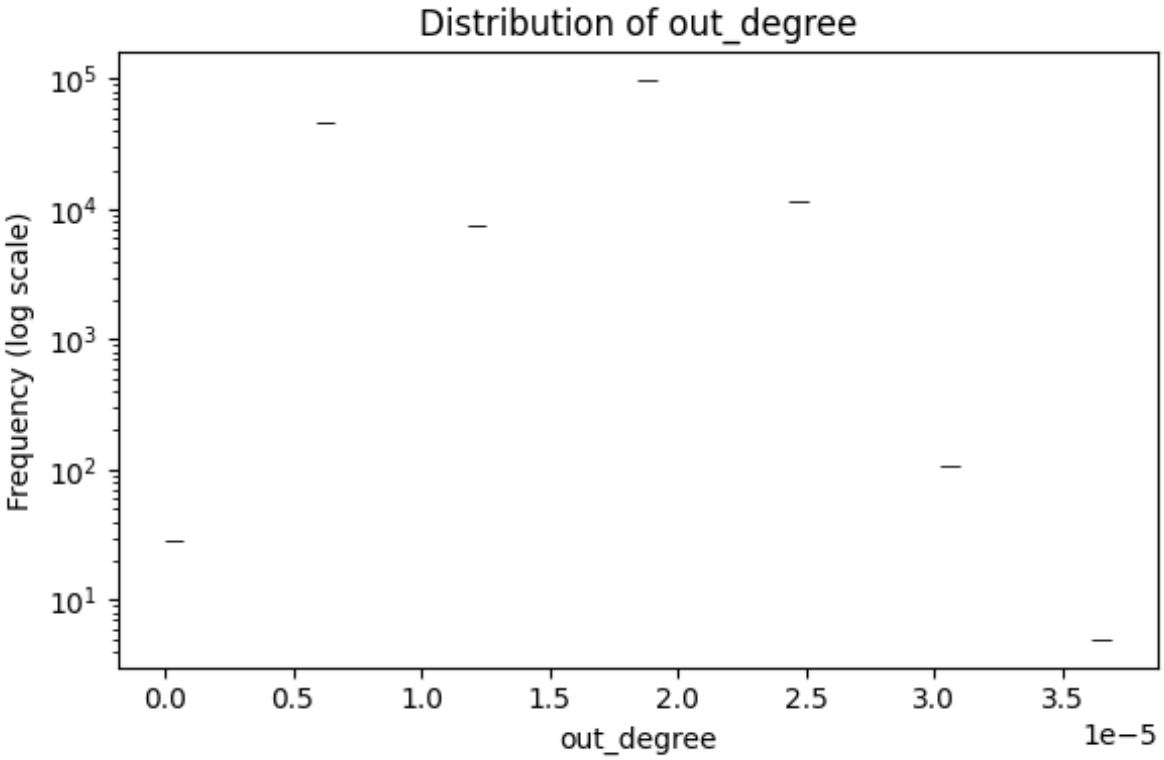
3. Centrality Analysis

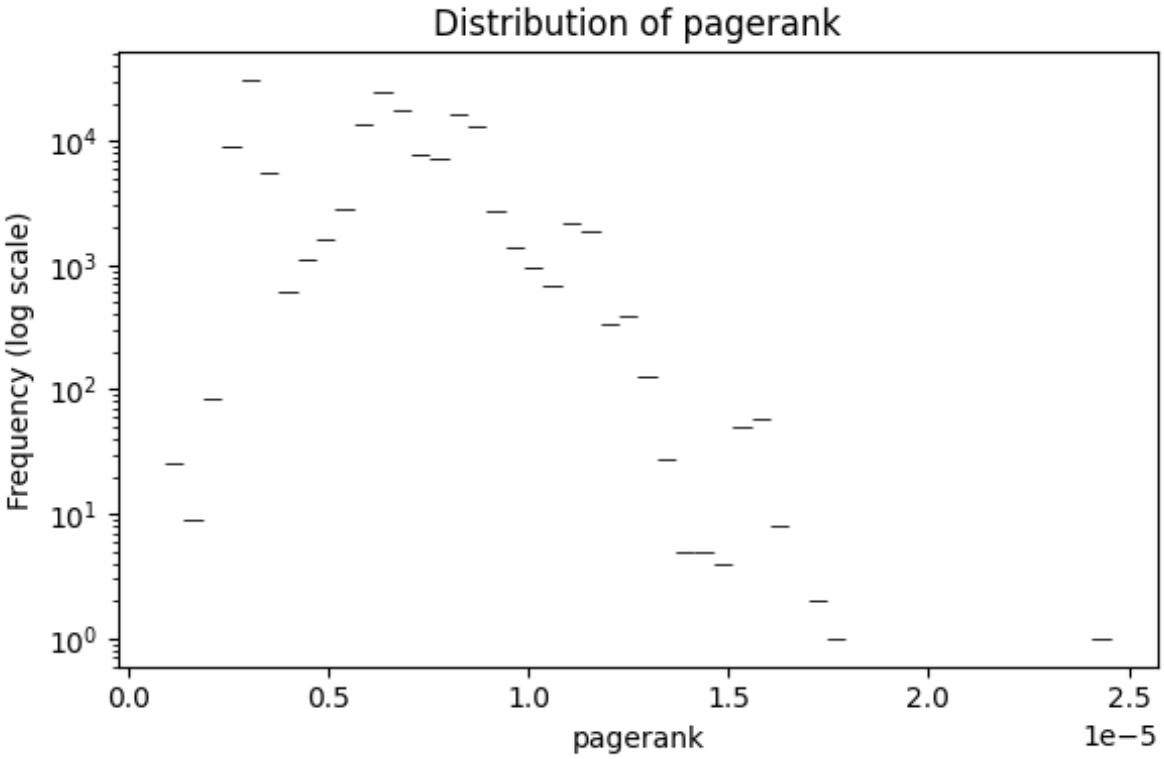
To identify influential papers, several centrality measures were computed, including In-Degree, Out-Degree, PageRank, Betweenness, Hub, and Authority scores.

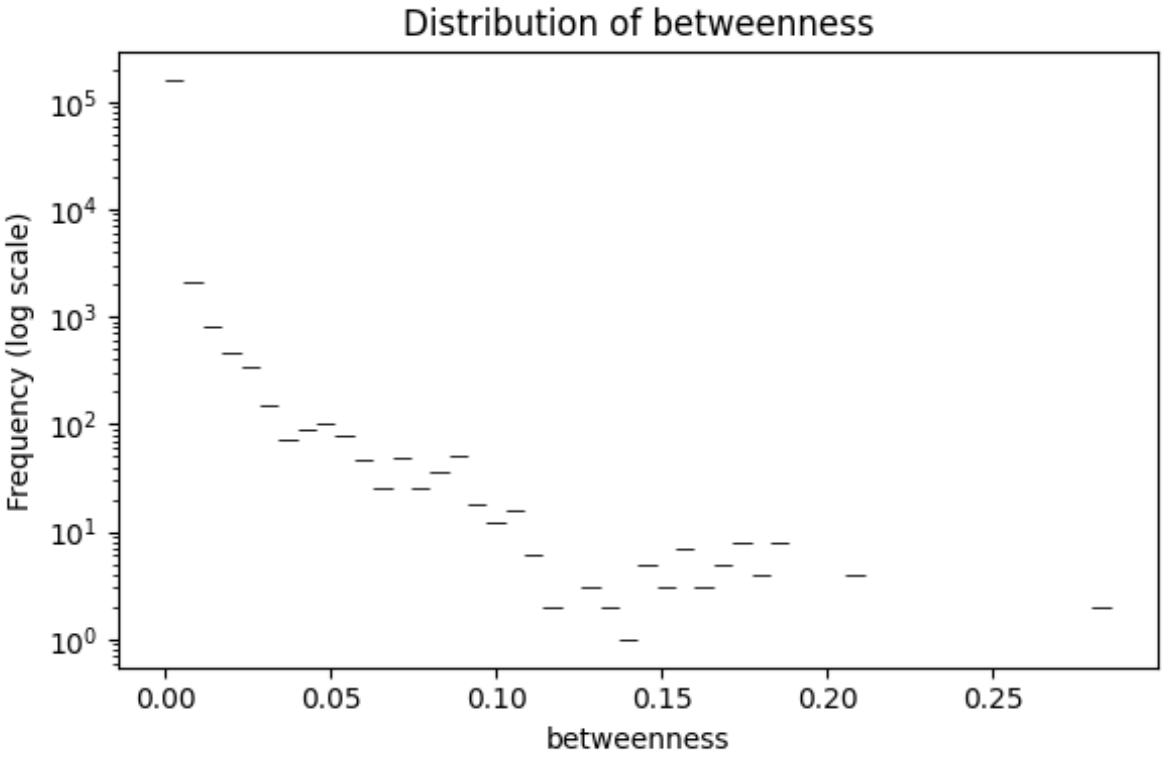
3.1 Centrality Visualizations

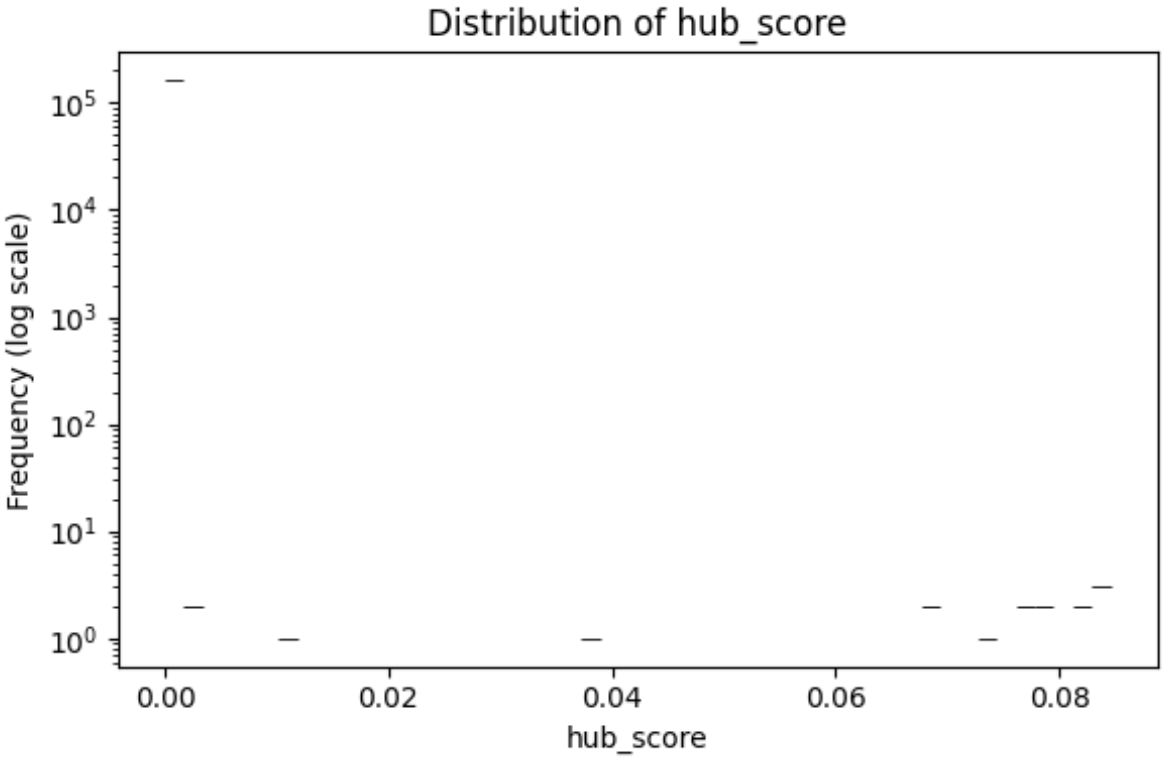
The figures below illustrate network properties, centrality distributions, and relationships between metrics such as PageRank, betweenness, hub and authority scores.

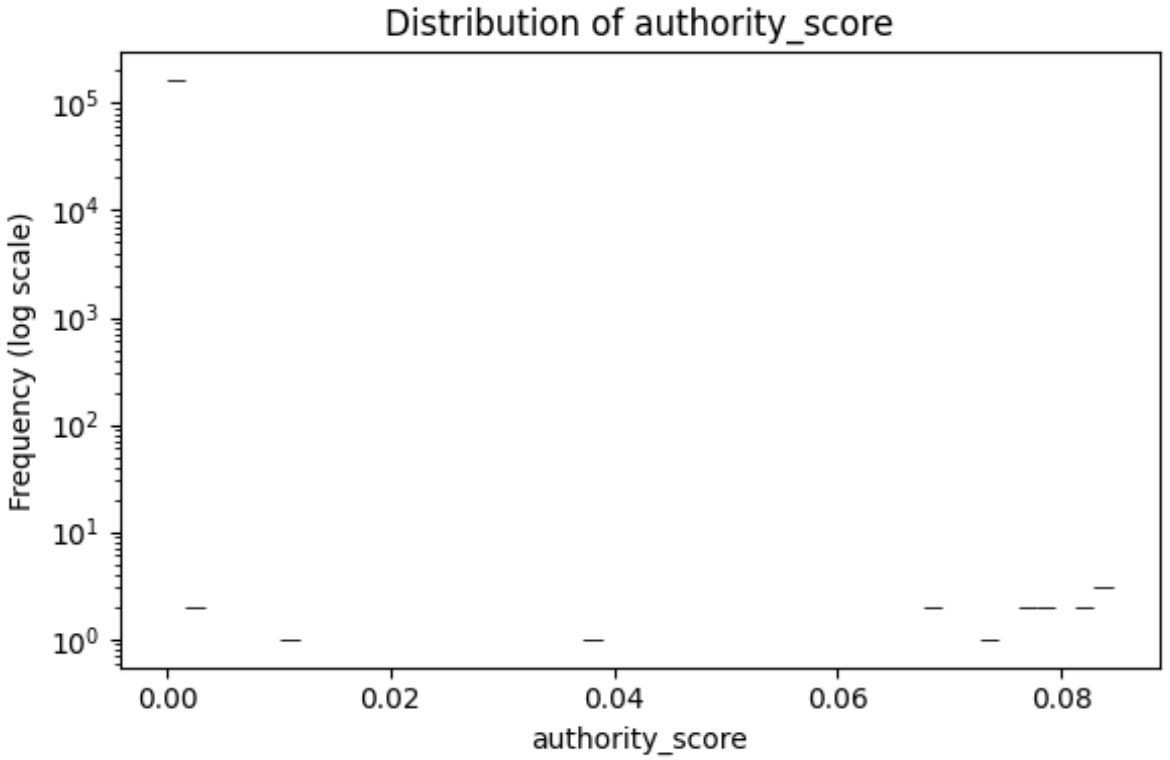


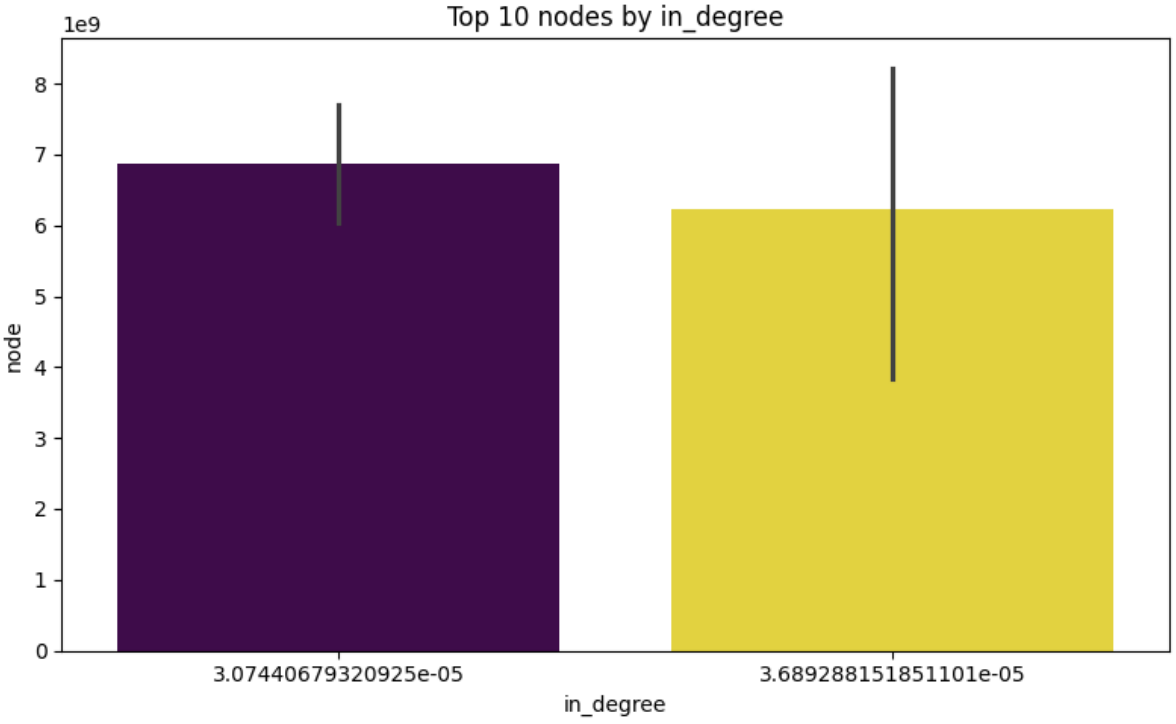

Distribution of out_degree
Frequency (log scale)
10^5
10^4
10^3
10^2
10^1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
out_degree
1e−5

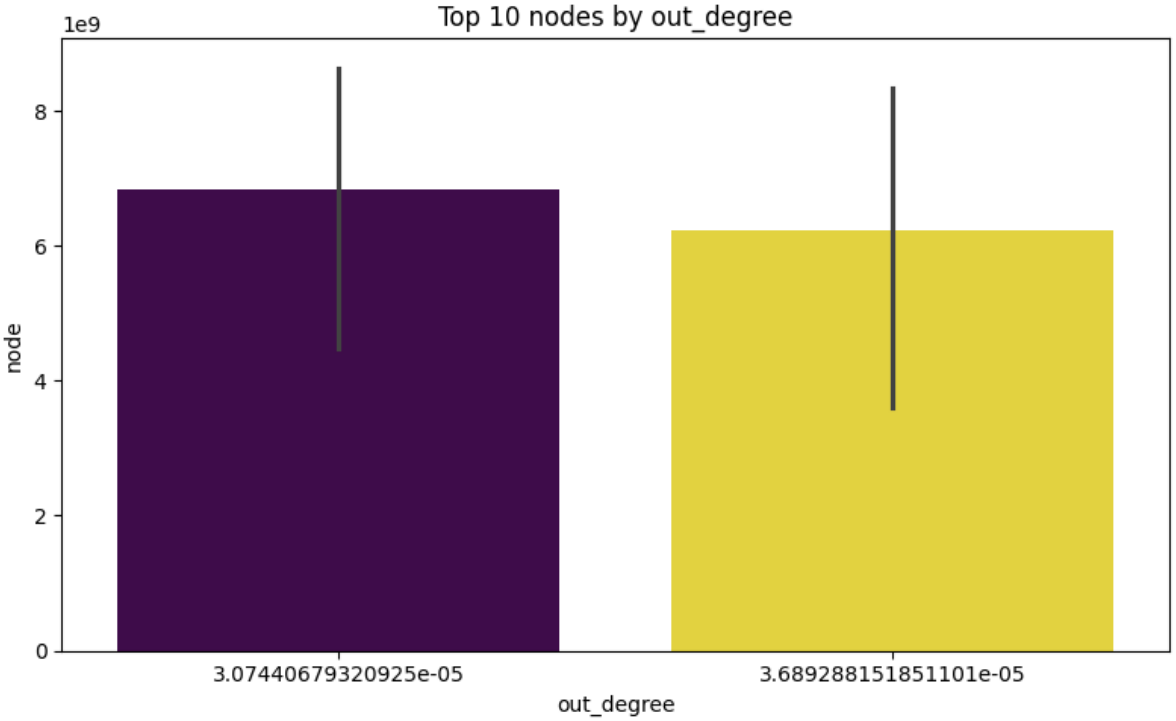

Distribution of pagerank
Frequency (log scale)
10^4
10^3
10^2
10^1
10^0
0.0
0.5
1.0
1.5
2.0
2.5
pagerank
1e−5

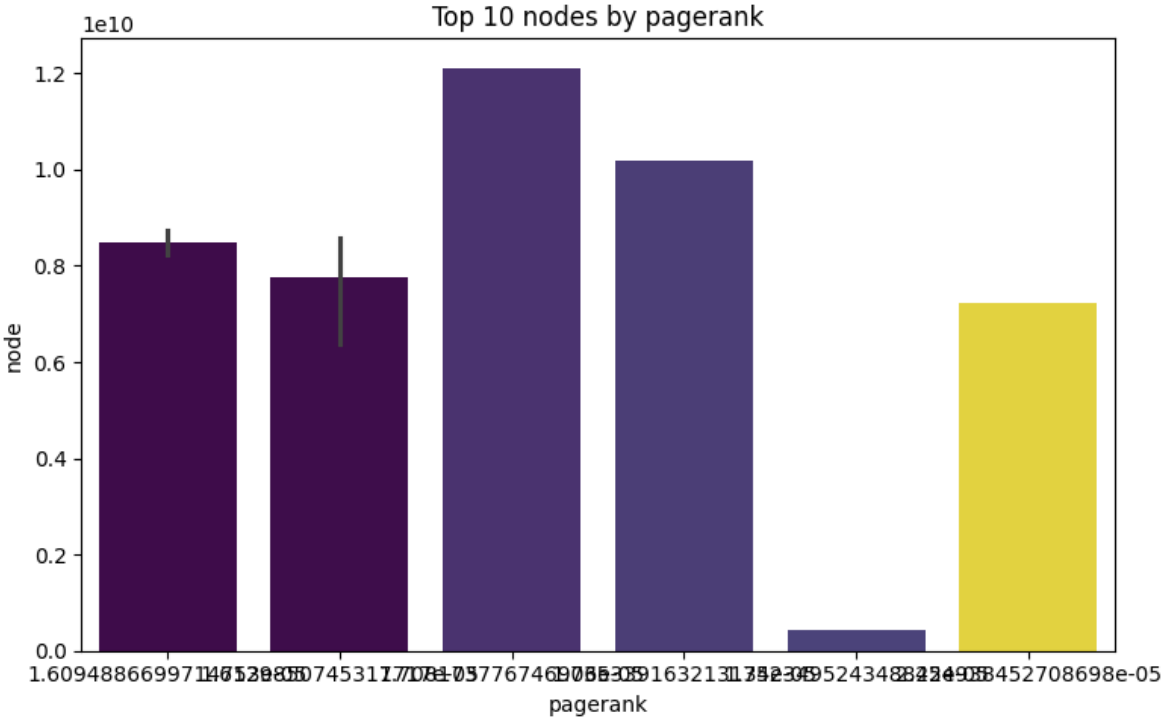

Distribution of betweenness
Frequency (log scale)
10^5
10^4
10^3
10^2
10^1
10^0
0.00
0.05
0.10
0.15
0.20
0.25
betweenness

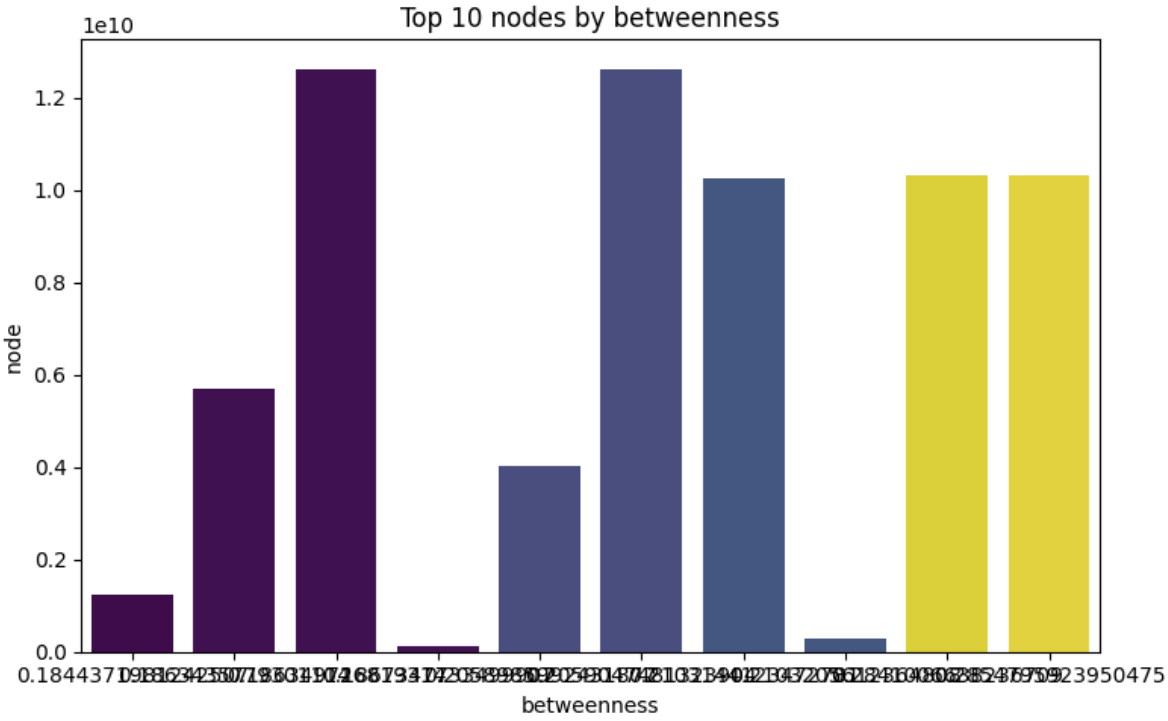

Distribution of hub_score
Frequency (log scale)
10^5
10^4
10^3
10^2
10^1
10^0
0.00
0.02
0.04
0.06
0.08
hub_score

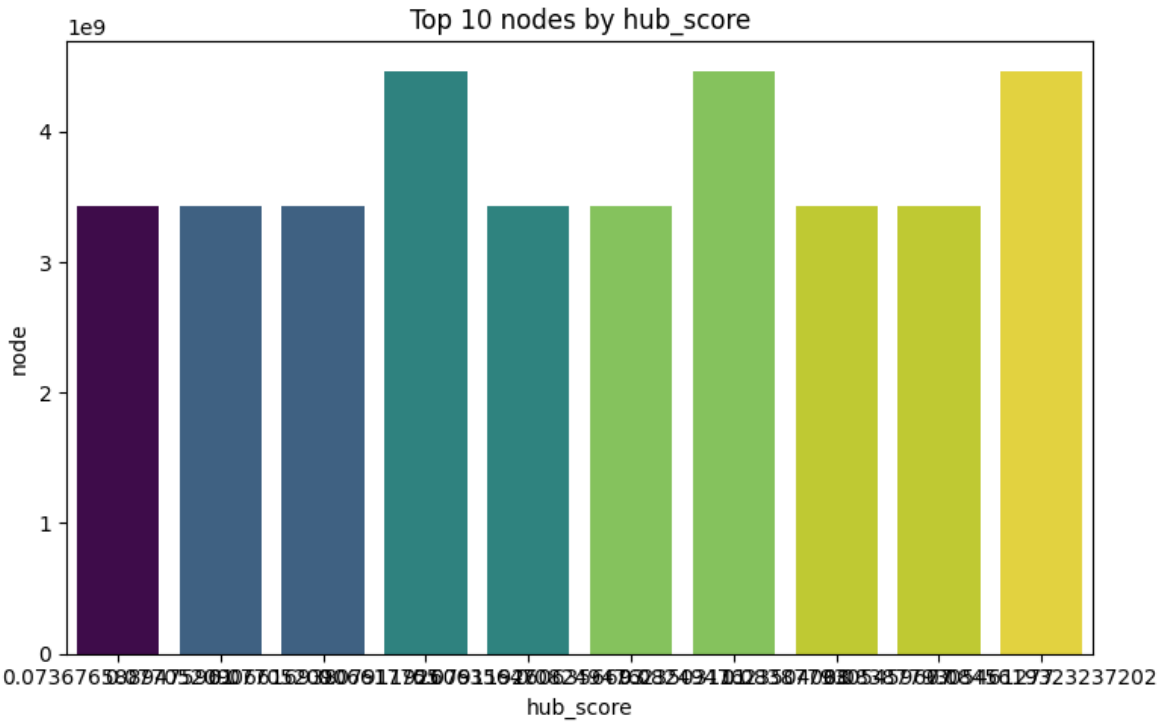

Distribution of authority_score
Frequency (log scale)
10^5
10^4
10^3
10^2
10^1
10^0
0.00
0.02
0.04
0.06
0.08
authority_score

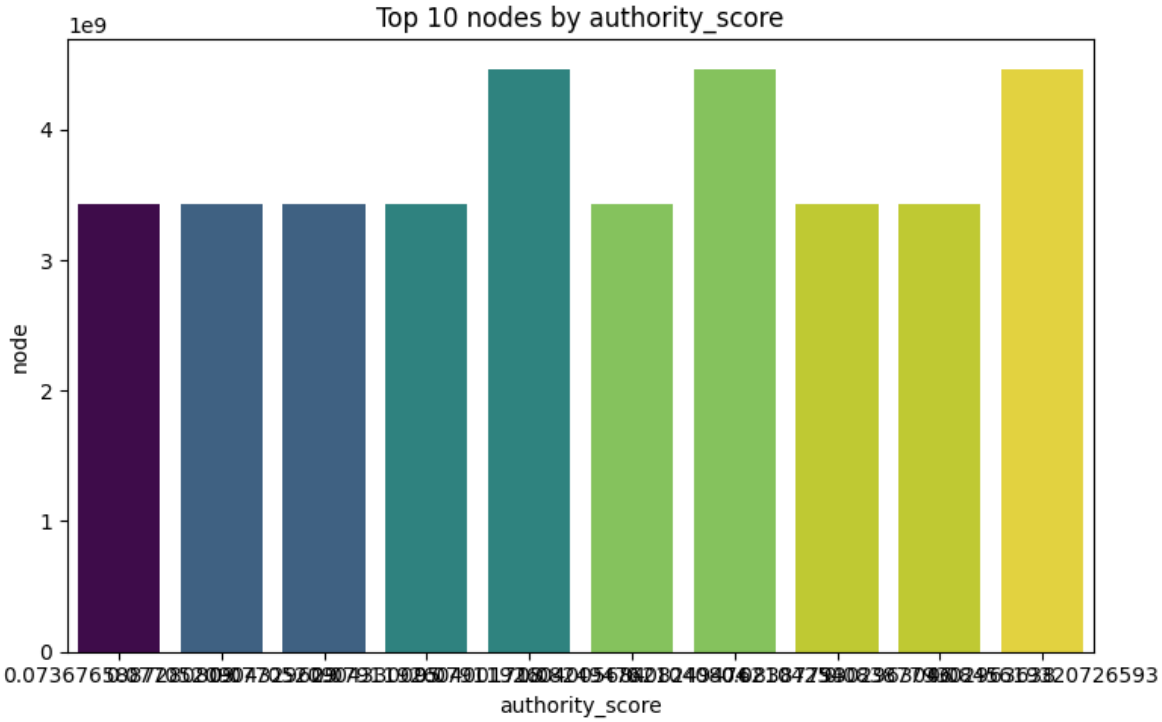

Top 10 nodes by in_degree
1e9
node
8
7
6
5
4
3
2
1
0
3.07440679320925e-05
3.689288151851101e-05
in_degree


Top 10 nodes by out_degree
1e9
8
6
4
2
0
node
3.07440679320925e-05
3.689288151851101e-05
out_degree


Top 10 nodes by pagerank
1e10
1.2
1.0
0.8
0.6
0.4
0.2
0.0
node
pagerank


Top 10 nodes by betweenness
1e10
1.2
1.0
0.8
0.6
0.4
0.2
0.0
node
betweenness


Top 10 nodes by hub_score
1e9
4
3
2
1
0
node
hub_score



Top 5 by In-Degree:

Node 8609853337.0: 0.000037
Node 4813567397.0: 0.000037
Node 7488855891.0: 0.000037
Node 1905643476.0: 0.000037
Node 8341138742.0: 0.000037

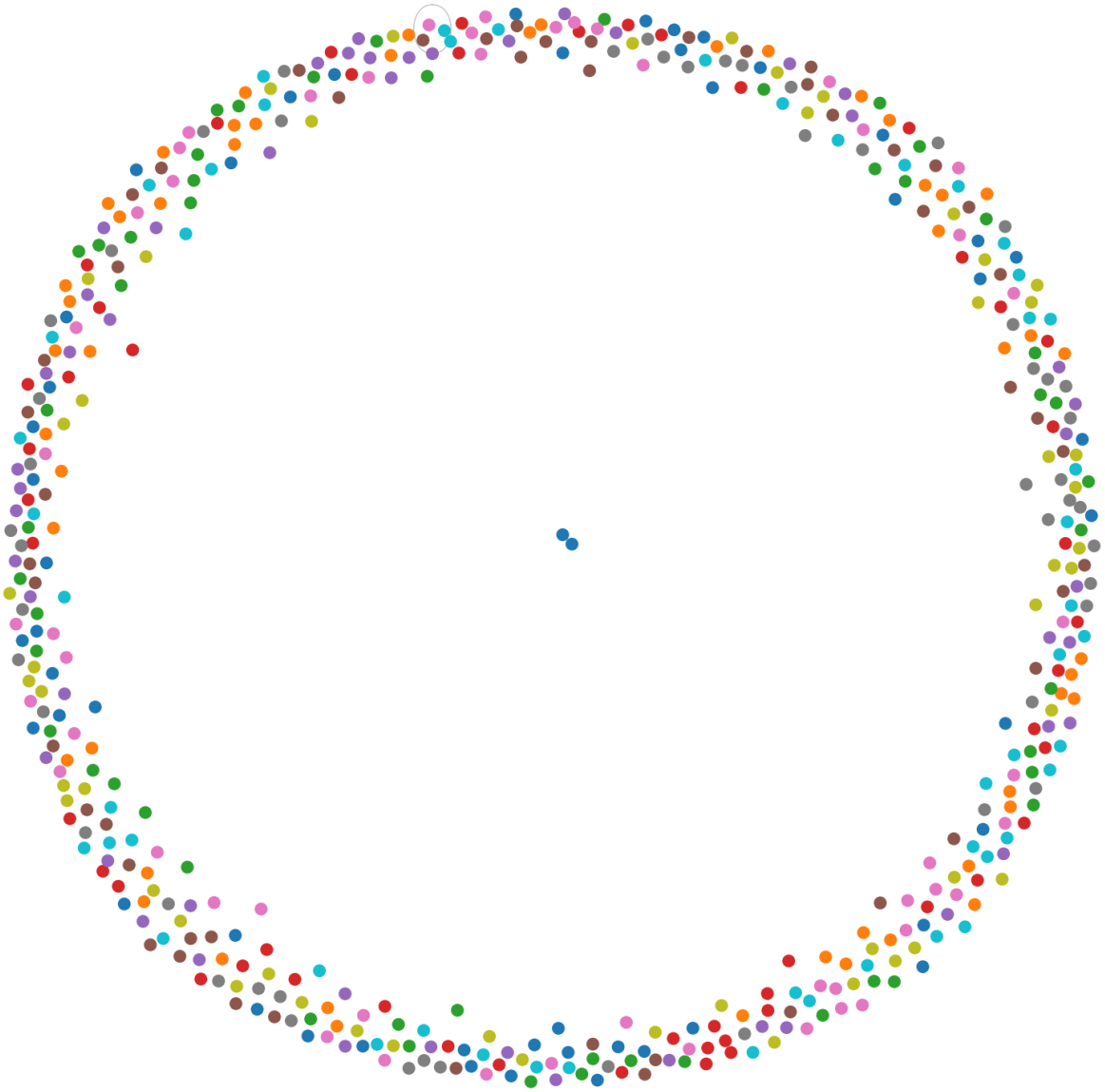
Top 5 by PageRank:

Node 7226570628.0: 0.000025
Node 445252475.0: 0.000018
Node 10183503218.0: 0.000017
Node 12116337047.0: 0.000017
Node 8332773638.0: 0.000016

These results highlight the intersections that serve as major hubs in the transportation network. Nodes with higher PageRank values are more likely to receive or distribute traffic efficiently, indicating their strategic importance in maintaining overall network connectivity.

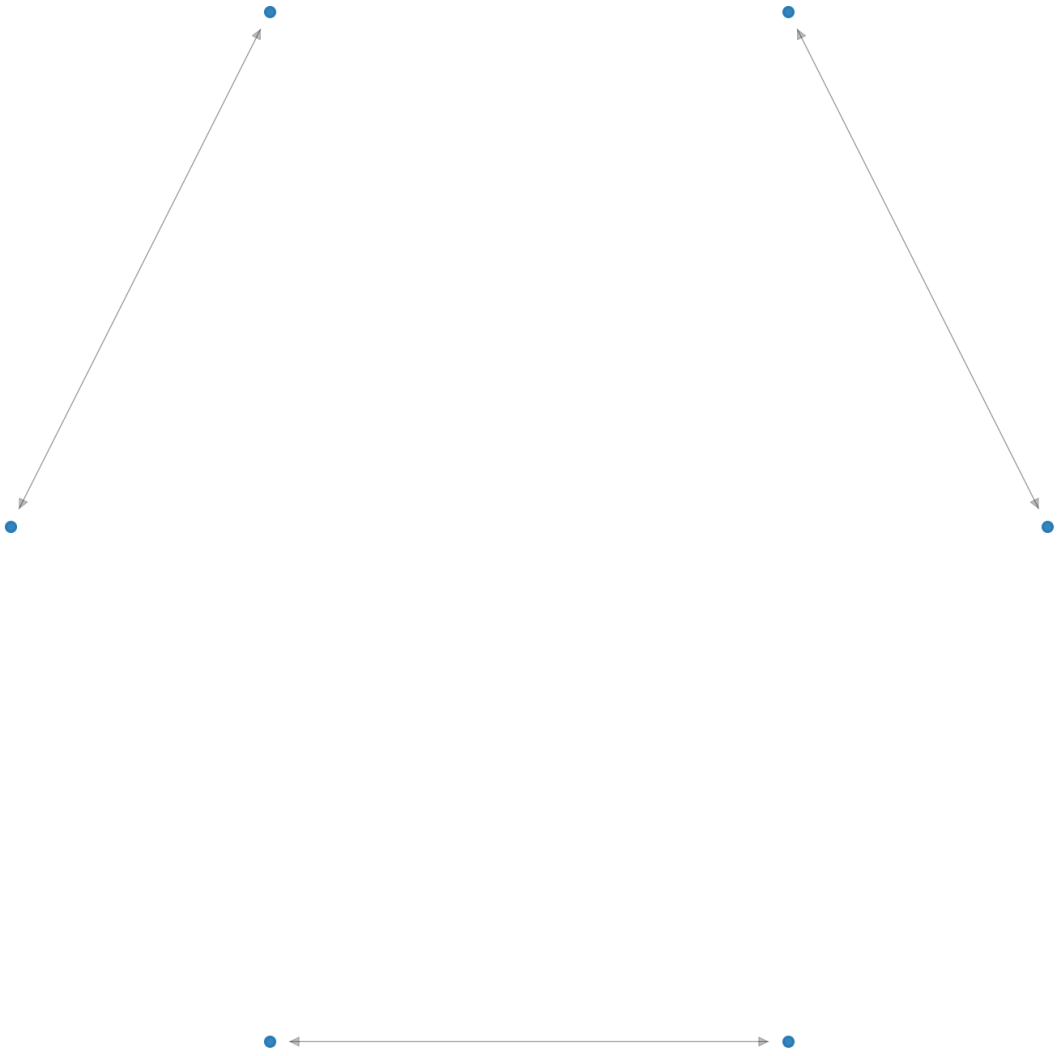
4. Community Detection

The Louvain algorithm was applied to the undirected version of the transportation graph to detect communities. Each community represents a cluster of intersections that are more densely connected to each other than to the rest of the network.



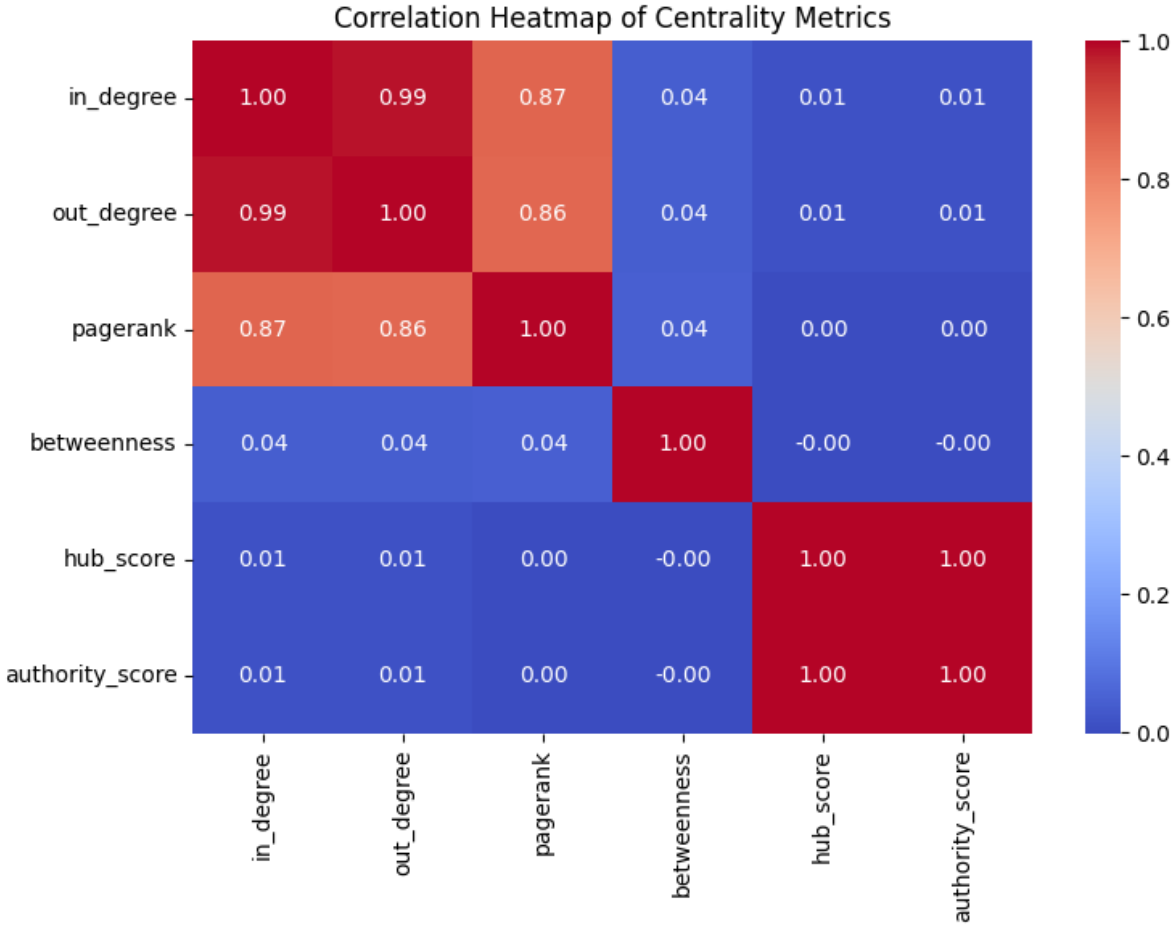
5. Network Visualization

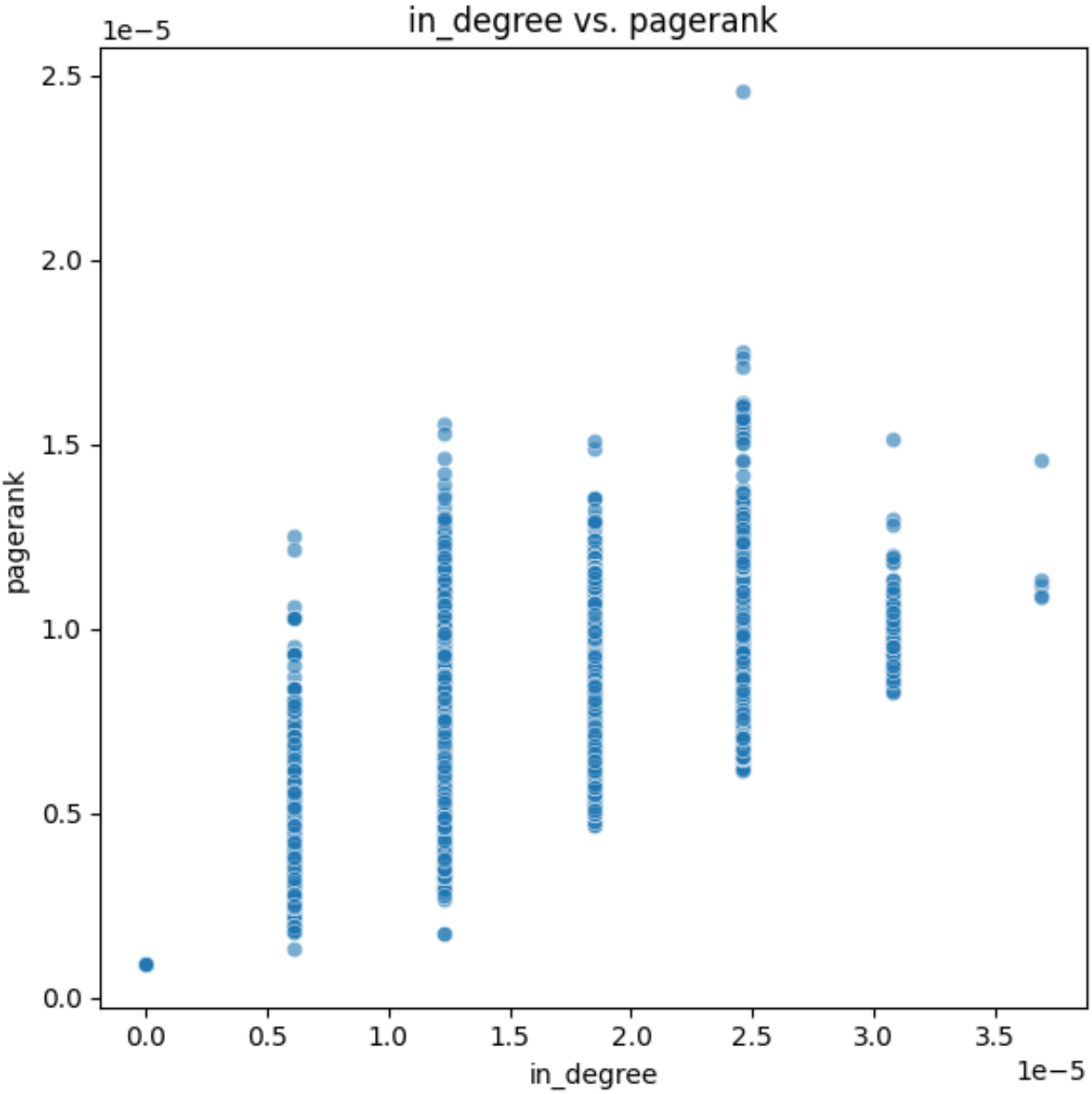
The largest weakly connected component was visualized using a spring layout. Nodes with higher centrality appear more central and communities are visible as clusters of color.

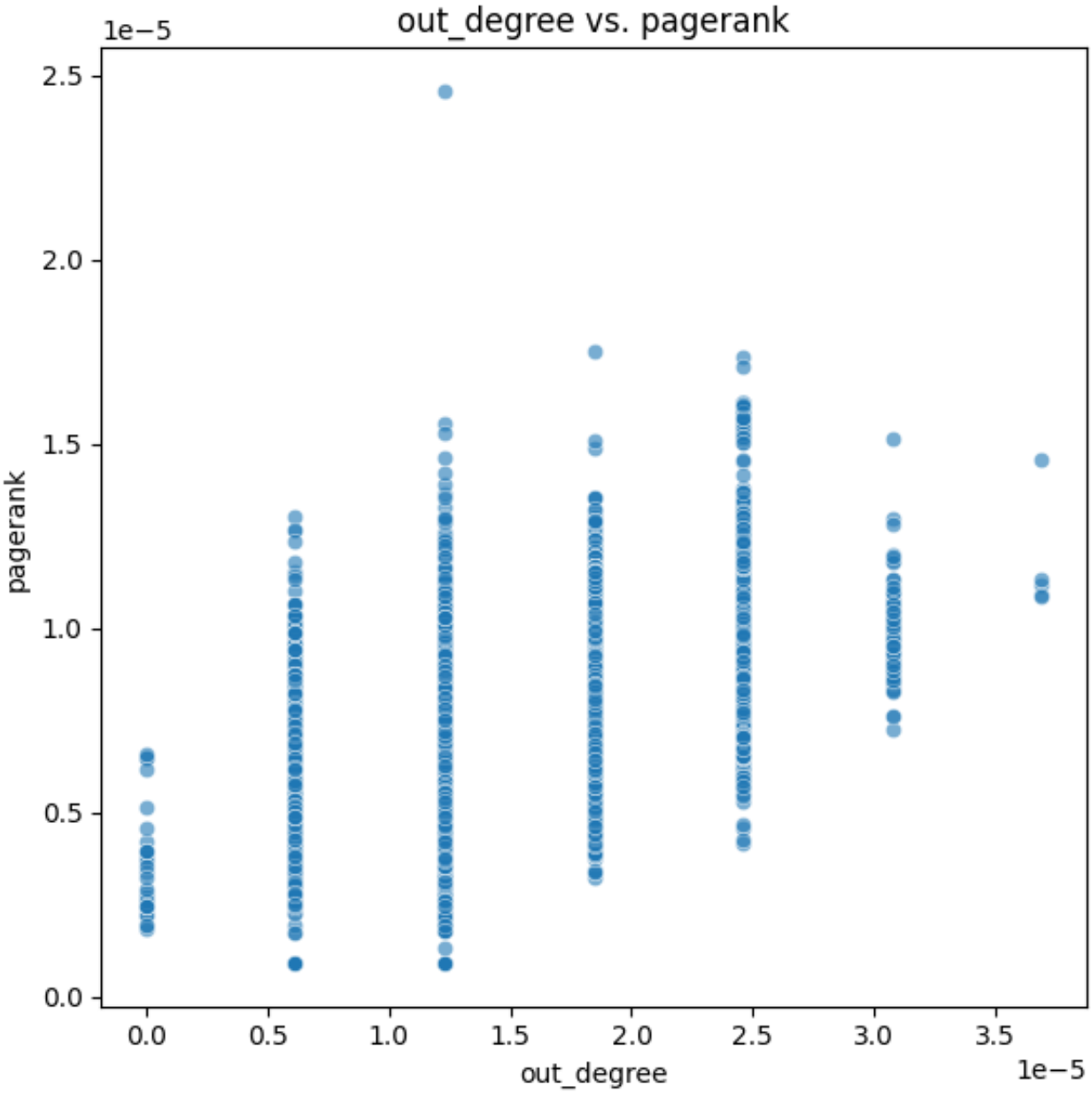


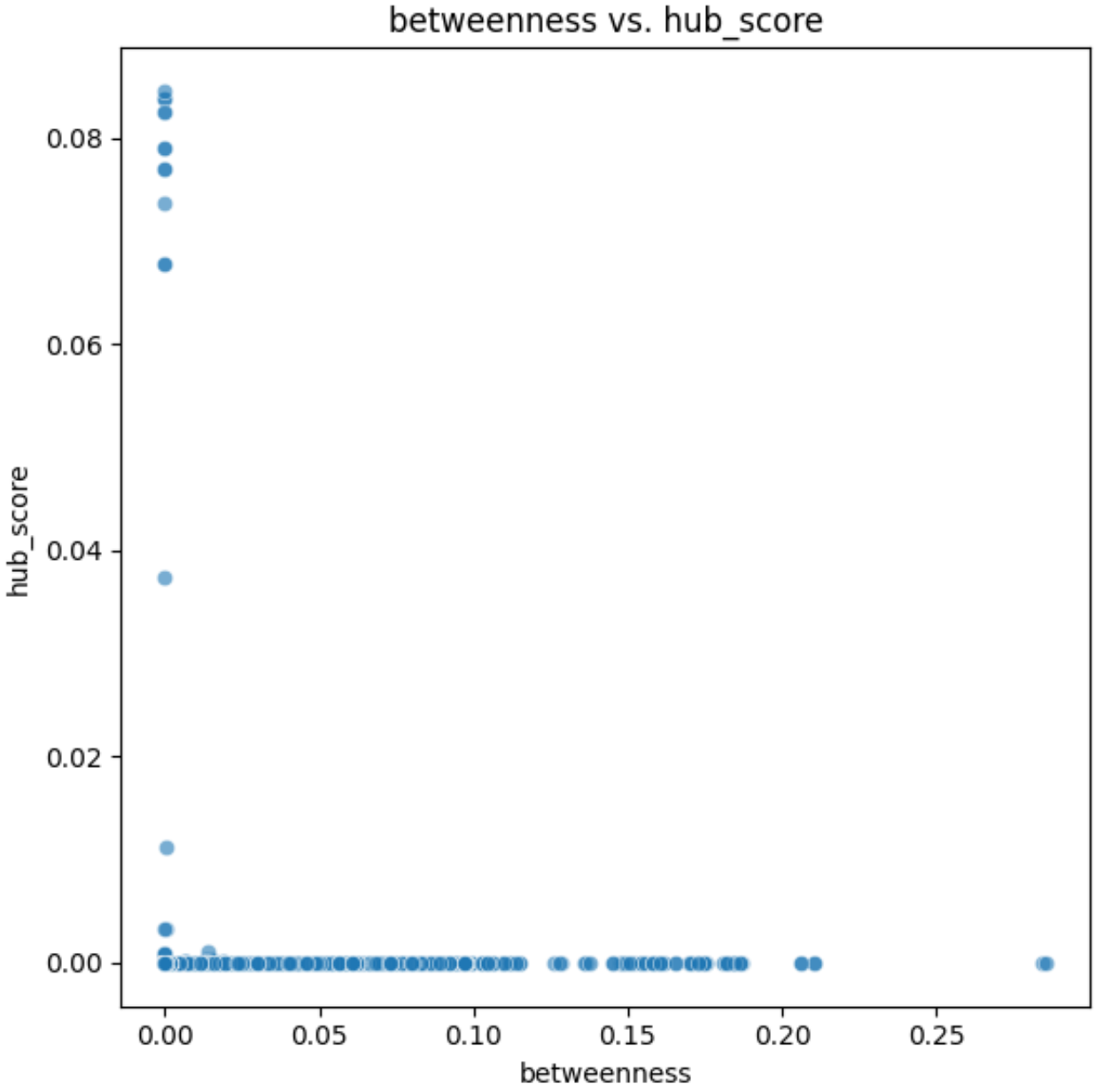
6. Correlation Analysis

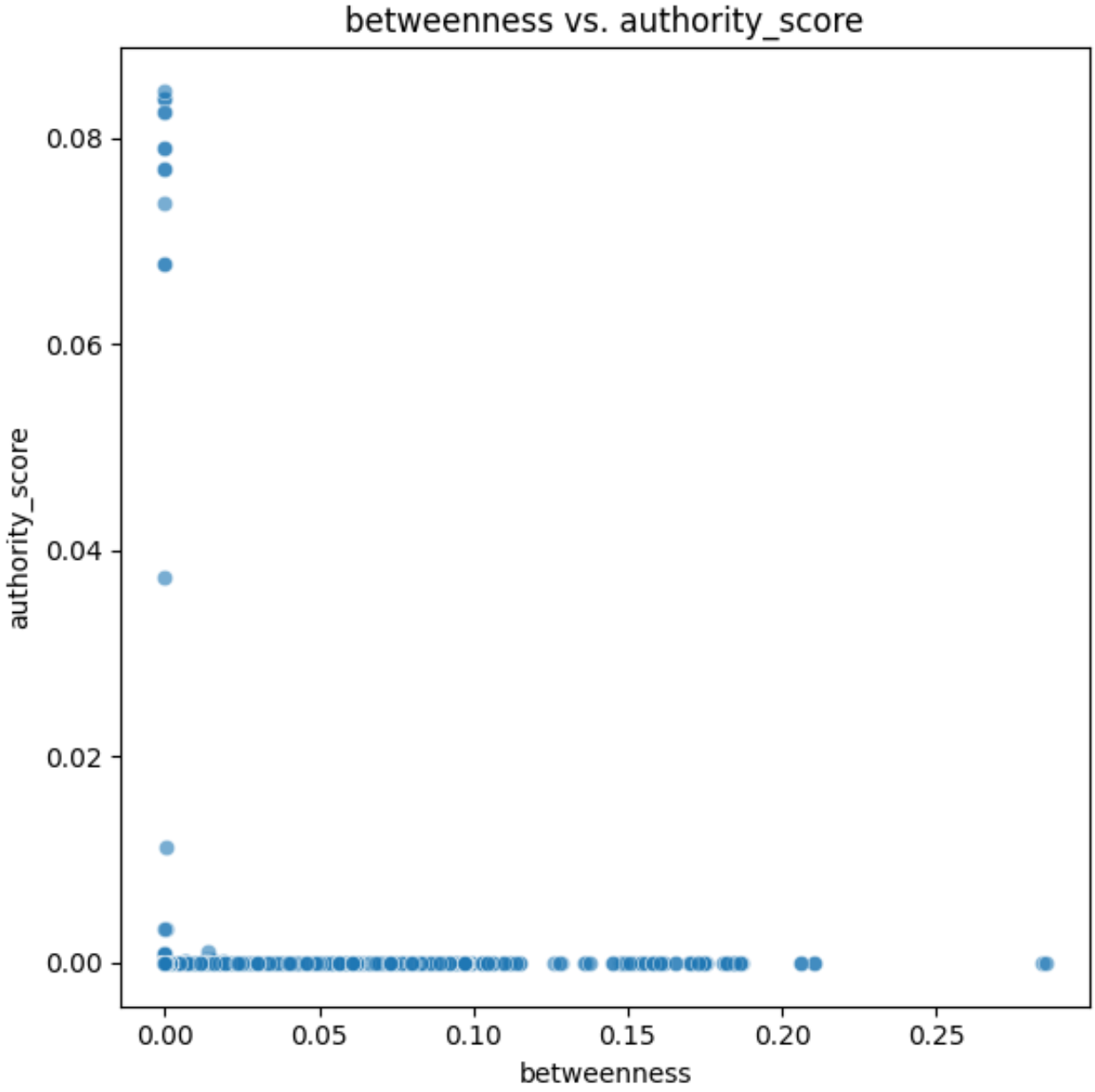
Scatterplots and heatmaps were used to explore relationships between centrality measures. These visualizations reveal how different metrics highlight key intersections that influence overall traffic flow or connectivity in the network.


Correlation Heatmap of Centrality Metrics
in_degree
out_degree
pagerank
betweenness
hub_score
authority_score
1.00 0.99 0.87 0.04 0.01 0.01
0.99 1.00 0.86 0.04 0.01 0.01
0.87 0.86 1.00 0.04 0.00 0.00
0.04 0.04 0.04 1.00 -0.00 -0.00
0.01 0.01 0.00 -0.00 1.00 1.00
0.01 0.01 0.00 -0.00 1.00 1.00
in_degree
out_degree
pagerank
betweenness
hub_score
authority_score
1.0
0.8
0.6
0.4
0.2
0.0


in_degree vs. pagerank
1e−5
2.5
2.0
1.5
1.0
0.5
0.0
pagerank
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
in_degree
1e−5


out_degree vs. pagerank
1e−5
2.5
2.0
1.5
1.0
0.5
0.0
pagerank
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1e−5
out_degree


betweenness vs. hub_score
hub_score
0.08
0.06
0.04
0.02
0.00
0.00
0.05
0.10
0.15
0.20
0.25
betweenness



7. Summary & Insights

The transportation network analysis reveals key insights into system efficiency and structure. Nodes with high betweenness centrality often act as critical transfer points or potential bottlenecks. High hub and authority scores indicate well-connected intersections, suggesting optimal areas for expanding capacity or rerouting flow. These results provide a data-driven foundation for future transport planning and optimization.

8. References

- NetworkX Documentation: https://networkx.org/documentation/stable/
- Louvain Method: Blondel, V.D. et al. (2008). Fast unfolding of communities in large networks.