**Social Network Analysis Project**

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DS 745: Visualization and Unstructured Data Analysis

November 6th, 2024

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The goal of this analysis is to investigate the structure of global airline networks, focusing on identifying critical hubs and understanding the flow of connectivity between airports. By applying Social Network Analysis (SNA) techniques, we aim to highlight key nodes (airports) and edges (routes) that contribute to the efficiency of the global airline industry.

The airline industry is a cornerstone of the global economy, tourism, and cultural exchange. By analyzing the network structure, we can uncover insights that help improve operational efficiency, reduce congestion, and enhance customer satisfaction. Furthermore, this analysis aids in disaster recovery planning.

**How can SNA apply to airlines? How does it affect decision making?**

Social Network Analysis can help understand complex transportation systems like airline patterns. Understanding the centrality of critical nodes (airports) code help optimize scheduling and reduce delays. Identifying redundant or underutilized routes would allow airlines to optimize their networks. Airports with high betweenness centrality are important for connectivity; any disruptions to these nodes could impact global travel and alternative routes or hubs can reduce risks.

Moreover, SNA could help improve capacity and efficiency at high-degree airports, create strategic partnerships at keys hubs to maximize connectivity and revenue, and strengthen operations at airports with high betweenness to handle rerouted traffic.

**Methodology**

The Open Flights dataset was used as it contained information on airports, routes, geographic coordinates. The data was processed using Python’s NetworkX and Plotly libraries to build and visualize the network.

In this case: degree centrality refers to identify airports with the most direct connections, betweenness centrality highlights airports that act as bridges in the networks, and closeness centrality measures how efficiently an airport can reach others.

**Analysis and Results**

The analysis of the airline network reveals critical insights into how global air traffic is structured. The graph below is a holistic social network visual developed including every airport and route.

A network diagram of blue dots

Description automatically generated

The complete network visualization shows a dense core surrounded by sparsely connected nodes. Major hubs dominate the center, reflecting their important role in global connection. However, this social network is very hard to interpret on its own and doesn’t capture the nuances of the crucial hobs around the world.

A table with black text

Description automatically generated A graph with numbers and a number of degrees

Description automatically generated with medium confidence

On another note, the degree distribution plot above indicates that most airports have a small number of direct connections, while a few major hubs dominate the network with an extremely high number of connections. The table on rights displays the top 5 airports in degree centrality, betweenness centrality, and closeness centrality.

Airports like FRA, CDG and AMS rank at the top in degree centrality, emphasizing their roles as primary hubs facilitating a large volume of direct flights.

The betweenness centrality measure highlights airports that act as intermediaries in the network. For example, ANC and LAX, may not have the top direct connections, but they are vital at connecting geographically distant regions. Similarly, DBX is important as a bridge between Europe, Asia, and Africa.

In contrast, Closeness Centrality evaluates how efficiently an airport can reach other airports. FRA, CDG, and LHR (London Heathrow) excel in this metric, indicating that these airports are well-positioned within the network to minimize travel distances, which is crucial for passenger convenience and operational efficiency.

Furthermore, the visual below highlights the top 50 airports by degree centrality. The top 50 airports form a densely connected sub-network, with major hubs such as FRA, CDG, AMS, LHR, and ATL positioned at the core.

A map of different colored circles and lines

Description automatically generated

These airports are highlighted not only by their high degree centrality but also by their significant betweenness centrality, indicating their pivotal role in facilitating global connectivity. The central cluster of the network consists of European and North American airports with frequent direct routes between them. This underscores the importance of transatlantic travel, a cornerstone of global air traffic. Airports such as BKK, SIN, and PEK, while slightly farther from the core, still maintain strong connections to both core airports and other peripheral nodes. This positions them as growing hubs in the Asia-Pacific region, reflecting the region’s increasing importance in global travel.

Lastly, in an effort to add more context and visualize the social network in a real-world sense the visual below captures the top 25 airport’s social network on a globe.

A map of the earth with lines and dots

Description automatically generated

The visualization clearly shows the transcontinental routes and the role of major hubs in connecting different regions. Airports in Europe and North America dominate the network, reflecting their high traffic volumes and central positions in global air travel. However, emerging hubs in the Middle East and Asia, like DXB and PEK, are becoming increasingly critical in connecting eastern and western hemispheres. (The globe is interactive on the jupyter notebook file)

**Interpretation, Recommendations, Conclusion**

The combination of these visual and quantitative analysis provides a comprehensive understanding of the airline network. The dominance of certain hubs indicates a potential issue where disruptions at these airports could have widespread impacts on global connectivity. Therefore, airlines and policymakers should consider strengthening secondary hubs, such as ANC and LAX, to enhance network resilience.

In addition, the analysis suggests opportunities for optimizing routes. Airports with high betweenness but low degree centrality might benefit from additional direct connections to reduce network congestion and improve passenger experience. Similarly, enhancing the capacity and efficiency of highly central airports could streamline global operations and minimize delays.

In conclusion, this study highlights the intricate dynamics of the global airline network and provides actionable insights for improving operational efficiency, resilience, and customer satisfaction.