

Component Structure and Robustness Analysis of the Air Transportation Network

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The air transportation network is critical for global integration and economic development, connecting millions of people and facilitating the movement of goods. This study focuses on the robustness of this network by examining how it withstands targeted attacks on critical airports. While many studies have explored the robustness of air transport networks, few have considered its mesoscopic organization. This work relies on the component structures to disentangle regional and interregional infrastructure [1,2]. Local components are dense parts of the network, while global components interconnect the local components. We use the weighted Louvain community detection algorithm to identify dense parts of the network. We identify five large components representing major regions (North America-Caribbean, Europe-Russia, East and Southeast Asia-Oceania, Africa-Middle East-Southern Asia, and South America) and one global component linking these regions. The local components correspond to geographically, economically, and culturally distinct areas, while the global component encompasses the major interconnections between these regions.

We evaluate the impact of removing critical nodes (airports) based on three centrality measures: strength, betweenness, and PageRank [3]. The analysis focuses on how these removals affect both regional and global connectivity [4]. The robustness analysis reveals that removing airports based on weighted betweenness centrality is the most effective strategy for isolating regional components from the global network. This approach requires fewer removals to disrupt connectivity. Despite high perturbations at the global network level, local travel within separated regions remains feasible. However, strength and PageRank attacks significantly reduce the size of isolated local components, making local travel more challenging. The global component's diameter and average path length suggest that interregional connections are not drastically different from regional ones, indicating a high degree of interconnectedness. Local components exhibit differences in vulnerability and resilience. For instance, domestic networks like Australia, Canada, India, and the US are more vulnerable to targeted attacks than other global regions. This study's unique approach, focusing on the component structure, provides new insights into how global perturbations affect regional infrastructures.

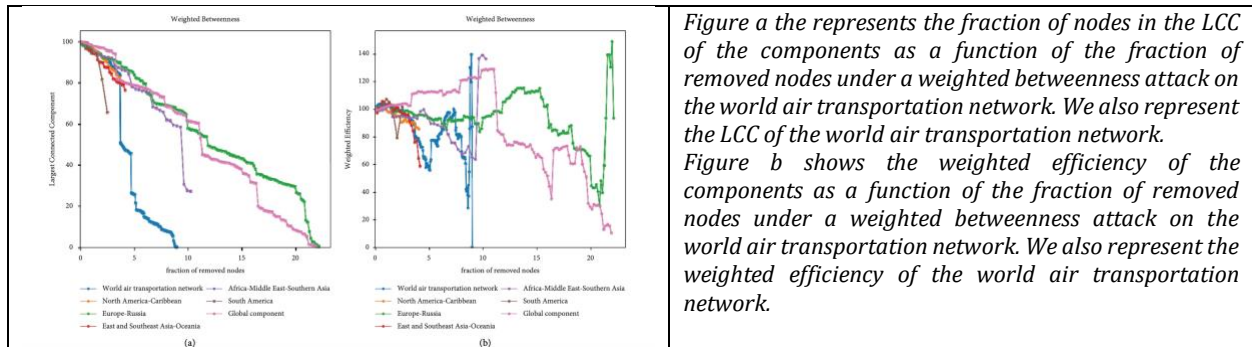


Figure a represents the fraction of nodes in the LCC of the components as a function of the fraction of removed nodes under a weighted betweenness attack on the world air transportation network. We also represent the LCC of the world air transportation network. Figure b shows the weighted efficiency of the components as a function of the fraction of removed nodes under a weighted betweenness attack on the world air transportation network. We also represent the weighted efficiency of the world air transportation network.

- [1] Diop, I.M., Cherifi, C., Diallo, C. et al. Revealing the component structure of the world air transportation network. *Appl Netw Sci* 6, 92 (2021). <https://doi.org/10.1007/s41109-021-00430-2>.
- [2] Issa Moussa Diop, Cherif Diallo, Chantal Cherifi, Hocine Cherifi, " Exploring the Regional Structure of the Worldwide Air Traffic and Route Networks", *Complexity*, vol. 2023, Article ID 3411799, 29 pages, 2023. <https://doi.org/10.1155/2023/3411799>
- [3] Rajeh, S., Savonnet, M., Leclercq, E. et al. Comparative evaluation of community-aware centrality measures. *Qual Quant* 57, 1273–1302 (2023). <https://doi.org/10.1007/s11135-022-01416-7>
- [4] Issa Moussa Diop, Cherif Diallo, Chantal Cherifi, Hocine Cherifi, " Robustness Analysis of the Regional and Interregional Components of the Weighted World Air Transportation Network", *Complexity*, vol. 2022, Article ID 6595314, 17 pages, 2022. <https://doi.org/10.1155/2022/6595314>.