Analysis of Robustness and Efficiency of the Transport Network in Downtown Mexico City using a directed graph theory approach. Identification of key urban nodes

Keywords: Urban networks, Transport networks, Graph-theory, small-world coefficient, centrality measures, Global and Local efficiency

Extended Abstract

Graph theory and complex network analysis have emerged as powerful mathematical and computational frameworks for quantitatively analyzing the structure, dynamics, and stability of complex systems across diverse fields, including molecular biology, social sciences, and urban transportation systems. This study presents a graph-theoretic approach to investigate the stability and robustness properties of the urban transportation network in Mexico City's central district, one of the most congested and busiest traffic areas in one of the world's largest metropolitan regions. The study area encompasses approximately 1,130 streets and avenues of varying sizes and about 580 intersections, forming the central hub of Mexico City's cultural, economic, and governmental activities. We constructed a directed graph $\mathscr{G}$ based on the actual road map of downtown Mexico City, where $N = 581$ nodes represent street intersections and $E = 1,123$ directed edges correspond to road segments between intersections. The directed nature of the graph captures the often asymmetric traffic flow patterns inherent to urban road networks, see Figure (1).

We computed multiple centrality measures—including closeness centrality (C_c), eigenvector centrality (C_e), and particularly betweenness centrality (C_b)—to characterize both global and local connectivity patterns and identify critical nodes within the network. Additional analyses focused on the giant component and network robustness to identify crucial edges and nodes. Finally, we evaluated edge-centrality based metrics and global efficiency to provide comprehensive insights into the network's functional performance.This methodology offers a paradigm for studying traffic flow dynamics and identifying critical infrastructure elements in large urban conglomerates worldwide, with potential applications for urban planning and transportation management in other large urban conglomerates.

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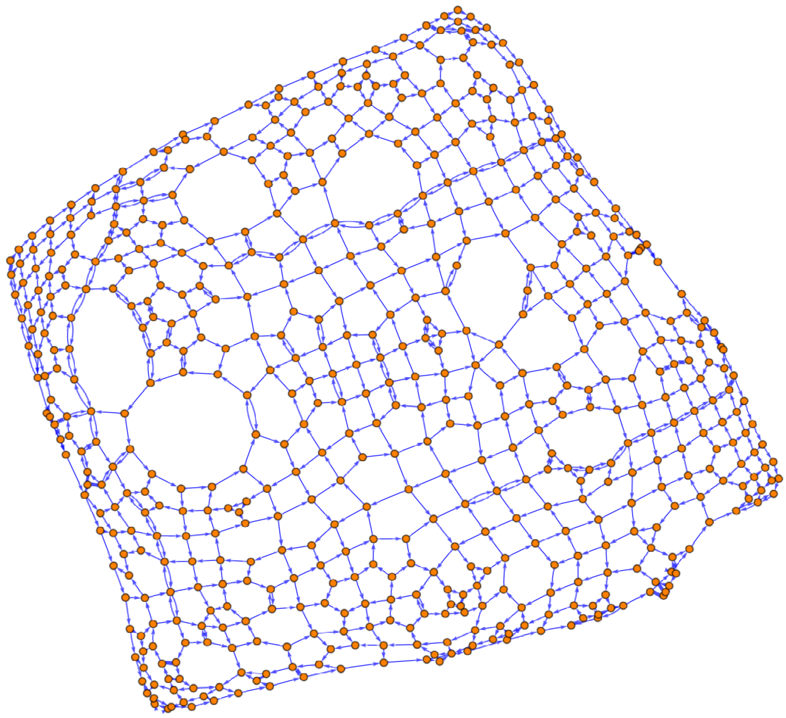

Figure 1: **Directed network representation of the main motor vehicle transportation network in Mexico City downtown.** Each node represents a given intersection between any pair of streets while an edge represents a road in which motor vehicles can go in one direction or another. The network has $N = 581$ nodes and $E = 1123$ edges which correspond to segments of different sizes of a given road or street.