Improving the Accuracy of Intersection Counts and Densities for Measuring Urban Street Network Compactness and Resilience

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Project Objective

In transportation planning, innumerable models, measures, and standards — from LEED-ND certification to resilience simulations — rely on intersection counts as input data. Yet intersections can be surprising difficult to count accurately, resulting in biased measures that propagate downstream. This project measures these biases then develops and validates better methods to overcome misrepresentations of intersections for data-driven, evidence-informed planning for sustainable transportation networks that support active and resilient travel.

Problem Statement

Intersection counts are ubiquitous in transportation planning practice and research. In particular, they are frequently normalized by area to calculate intersection density, the most common measure of compact street network design in planning practice for sustainable transport, active travel, and (alongside connectivity) networks resilient to disruption. However, due to the nature of typical street network data (centerlines) and the typical tools used to count intersections (desktop GIS), recent research suggests that traditional methods of counting intersections overcount them substantially. Worse, they do so unevenly in different kinds of places. The nature of this bias means that individual neighborhoods with the most car-centric complex intersections are often the most misrepresented as being more compact and fine-grained than they are in reality. Researchers and practitioners rely on intersection counts and densities as foundational inputs and require accurate measurements to represent the real world accurately to plan resilient and sustainable transportation infrastructure accordingly.

Research Methodology

This project 1) develops and distributes an algorithm to automatically and correctly calculate intersection counts and densities anywhere in the world, 2) conducts a worldwide empirical assessment of traditional intersection counting methods' bias to quantify the importance of measurement bias, and 3) assesses this bias's impact on resilience simulations. This project develops and validates an algorithm that consolidates the multiple network nodes representing complex street intersections. It merges network nodes within some design tolerance of one another and then reconnects network edges correctly to the merged node to maintain the network topology. For each urban area in the world, we assign the design tolerance value for consolidation using estimates of 1) the urban area's average road width and 2) the world median weighted road width from 1990-2015 using data provided by the Atlas of Urban Expansion. After stratifying 8,910 cities by world regions, population size, and intersection density, we validate the consolidation results of 32 cities. Next, using the original and consolidated networks, we measure the resilience of street networks focusing on how quickly networks become disconnected and how network disruption affects trip efficiency. We conduct the network disruption simulations by systematically attacking 1) nodes with the highest betweenness centrality, 2) nodes at the lowest elevations, and 3) random nodes. Then we measure how street network vulnerability differs across cities and describe how unconsolidated networks might lead to over or underestimation of such vulnerability. Finally, we identify the street network design characteristics that are most related to resilience.

Results

Our algorithm consolidates intersections with a true positive rate above 95% and true negative rate around 90% for both parameters. The validation reveals that the algorithm performed best in cities located in Land Rich Developed Countries and when correcting redundant nodes caused by divided roadways. Among the three disruption methods in our resilience simulation, our results demonstrate that attacking the nodes with high betweenness centrality (that is, the most "important" nodes in the network) may lead to particularly severe network disruption and longer trip distances. Our regression results reveal that street networks with lower node degrees, greater circuity, and an over-reliance on important nodes are more vulnerable to disruptions.

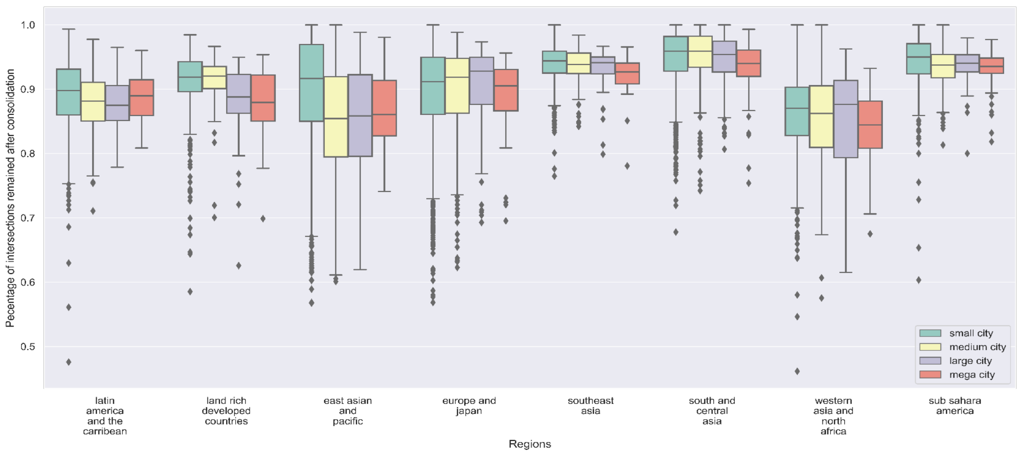

Figure 1. Percent intersections remaining after matched-width consolidation.

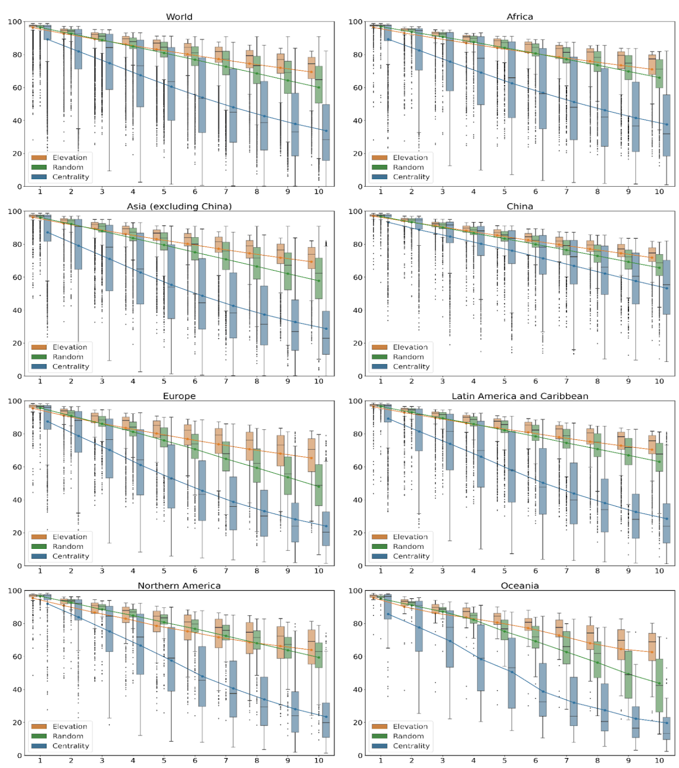

Figure 2. Robustness indicator distributions per region with trend lines tracking mean values.