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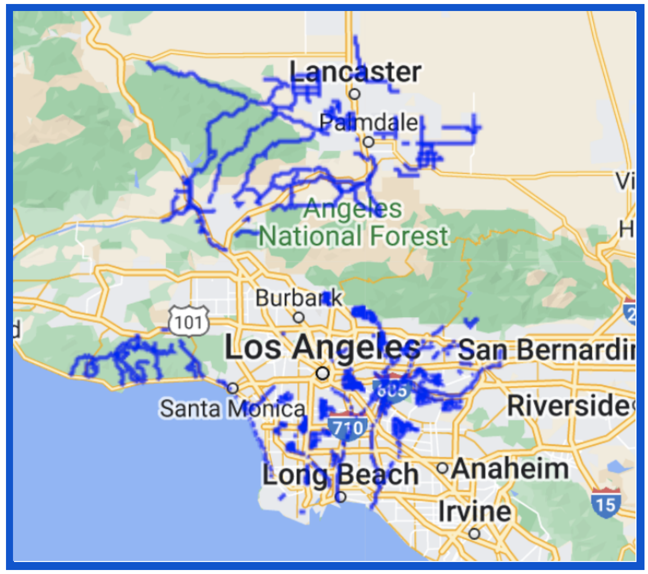
Rewriting L.A. County bikeways to create a more efficient and happier system

Abstract - We present a method to rewrite the existing bikeway network connections of Los Angeles county to encourage growth in the percentage of transportation by bicycle. We found that using an easy-to-praxis method of joining smaller connected components to one another to create a larger network. Our method reduces the current 152 distinct connected components in the bike network to 27 connected components. This has massive benefits for the bikeway network: bikers are able to freely travel all over the city through near-optimal connected roads.

Motivation and Overview - I have recently become interested in a future world in which bikes are the main method of transportation. But the United States has a long way to go in reversing the large network of roads that makes it hard to create safe, efficient networks of bikeways. Using openly published data from Los Angeles County, I was able to study the bikeway network of the entire country, from existing, to funded, to planned. I first was interested in the currently existing characteristics of the bikeway network. I was hoping there were already characteristics about the network that made it good, but there were none. I then wanted to figure out a method to determine the optimal strategy to transform this bicycle network into something that is able to naturally grow on its own.

The bikeway network analyzed in this paper is a graph with 681 nodes and 544 edges. Nodes of this network represent streets that a bikeway runs alongside of it and can also represent smaller recreational paths that would exist in perhaps a national park. The edges of this graph represent the existence of a bikeway *between* two streets. In other words, riding a bike along the edges of this graph corresponds to the sequence of streets taken in order to bike from point A to point B. Choosing edges this way simulates the experience of a rider commuting or traveling throughout the city. This network is undirected, because bike paths are bidirectional by nature. The paths are also unweighted. I live in an outer part of LA county where there is a lot of bikeway infrastructure (existing or planned), but there is not a population large enough to incorporate the flow of the bikeways into the weighting of the network. An important quality of the LA County bikeway data is that there are 152 distinct connected components that do not share any edges between them. A highly fragmented network is not desirable for a bikeway network because bikes have no way of moving from one connected cluster to another. What is desirable in bikeway networks is the small-world property to efficiently handle bikeway traffic flow. Therefore, the method I am using to approach the central problem of efficiently taking the next steps to improve LA County bikeways involves a strategy to connect the disjoint components and reduce the total connected components from 152 to around 20. With a calculation, it can be determined that the total length in kilometers of funded roads is 50 kilometers. For the



calculations performed in this paper, each policy strategy was given a budget of 50 kilometers of road that must be effectively allocated for a successful rewrite strategy.

Data and Methods - My dataset is courtesy of the County of Los Angeles' open data repository located at data.lacounty.gov. It is titled on the website as "LA County Bikeways," and I downloaded the csv.

The dataset also contains geospatial data, which I used for spatially plotting the nodes of the network for the purposes of visualization. For my analysis, I chose to remove any dependence on the exact geospatial conditions of the nodes, and focused on the underlying topological structure of the bikeway data. It is sufficient to consider only the sequence of nodes that takes you from point A to point B to plan a successful bikeway network, so for my purposes the exact location of bikeway clusters is secondary to the goal of my analysis.

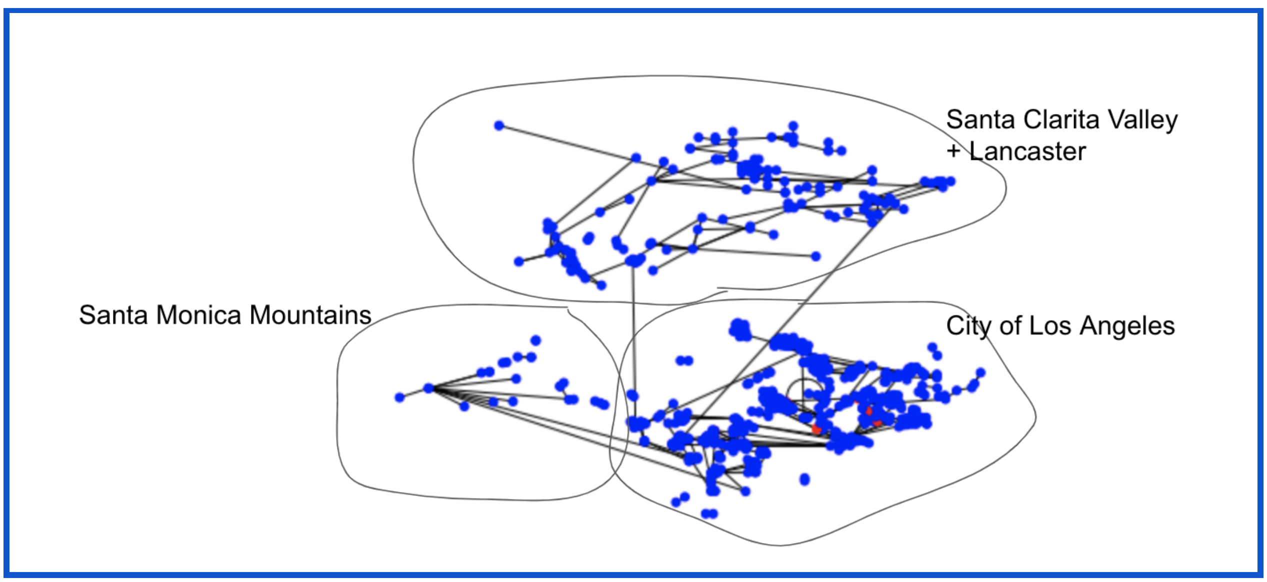


Figure. Topological plot of LA County bikeways network

I analyzed the network with the following three methods:

(1) Betweenness centrality

For betweenness centrality I decided to use this metric to analyze all 152 connected clusters of biking lanes because there are large enough subnetworks where betweenness centrality plays a relevant role in their dynamics. I will iterate through all of the graphs and plot their betweenness centrality by their number of nodes and then label each node on the graph by the street.

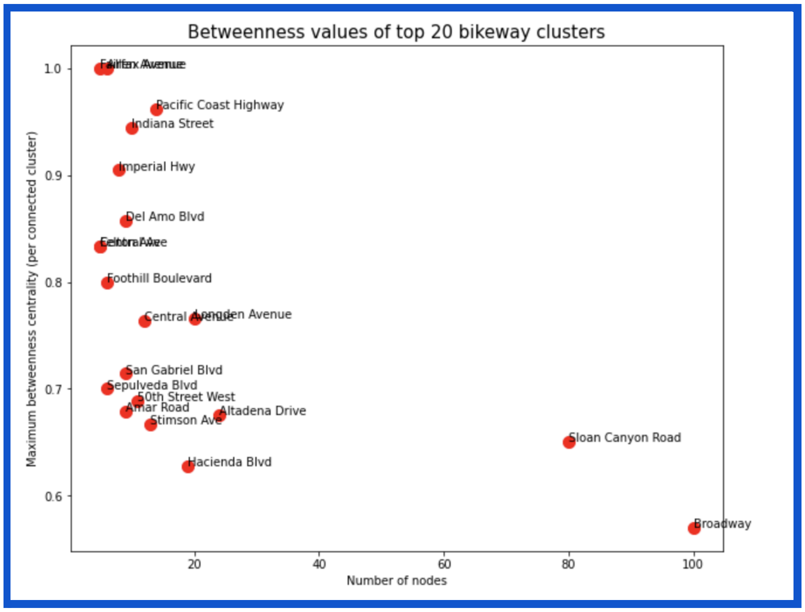


Figure. This plot shows the top 20 largest bikeway connected components and the maximum betweenness centrality score in each component.

(2) Clustering

Clustering the data bike path data with many of the other columns of data could reveal some interesting patterns in bikeway construction, particularly how likely they are to succeed and which ones are structurally doomed to fail.

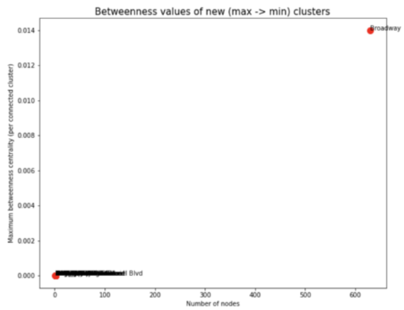
(3) Small world

A small world network is characterized by a small average shortest path length and clustering coefficient much larger than than the clustering coefficient of a random graph. After testing for these conditions on the set of connected components of the network, it was discovered that none of the bikeways are small world networks, even with the unfunded path incorporated. This reveals something very interesting about the way bikeway infrastructure is created in the United States: we are either in a stage where bike paths are trying to expand and cover as much distance possible, therefore trading off the ability to create small world networks, or by trying to connect different areas of Los Angeles with bikeways it reveals how the current ways cities are set up is not conducive to a small world way of living.

Inspired by a November 2020 article titled "Data-driven strategies for optimal bicycle network growth" by Guillermo Natera Orozco et al., published in Royal Society Open Science, that argued:

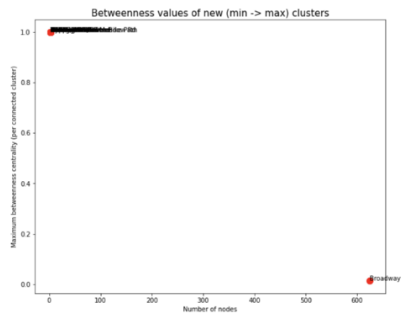
"In our algorithms, each new link works as a bridge between components, potentially having large betweenness centrality. Such high-betweenness segments could become overused and create bottlenecks in practice. To improve this situation, it would be necessary to create links in the network that act as redundant paths. In doing so, directness and coverage would also be improved, along with the network's robustness to interruptions."

This idea inspired me to design the most effective method of adding edges between the nodes of highest betweenness centrality in the 152 connected components. I experimented with many different strategies to choose which nodes to link from this 152 with the added budget constraint of 50 kilometers of road to use. The four methods attempted as as follows: (1) connect betweenness nodes in order of maximum betweenness to minimum, (2) connect betweenness nodes in order of minimum betweenness to maximum, (3) randomly connect betweenness nodes until budget is exhausted, and (4) weight each betweenness node by the number of nodes in the connected component and connect nodes in order of maximum to minimum weight. The first three methods were unsuccessful, but the fourth method was successful.



Policy: max -> min

Notice: this policy is biased towards already large bikeway hubs



Policy: min -> max

Notice: this policy may give new networks better betweenness, but Broadway still contains 600+ nodes

Policy: random edges

Notice: this is kind of somewhere in the middle between the two prev options.

Results - Using the weighted betweenness clustering value as a heuristic strategy for determining the most effective candidate edges, I have designed a method that repairs the existing bikeway structure by greatly reducing the number of separate connected components from 152 to 27. These clusters were automatically determined through the computation which means this method can be easily transferred to other bike networks and problem spaces. The distribution of the number of nodes of each cluster and the maximum betweenness centrality score also had excellent qualities. The resulting clusters and their betweenness scores are displayed below.

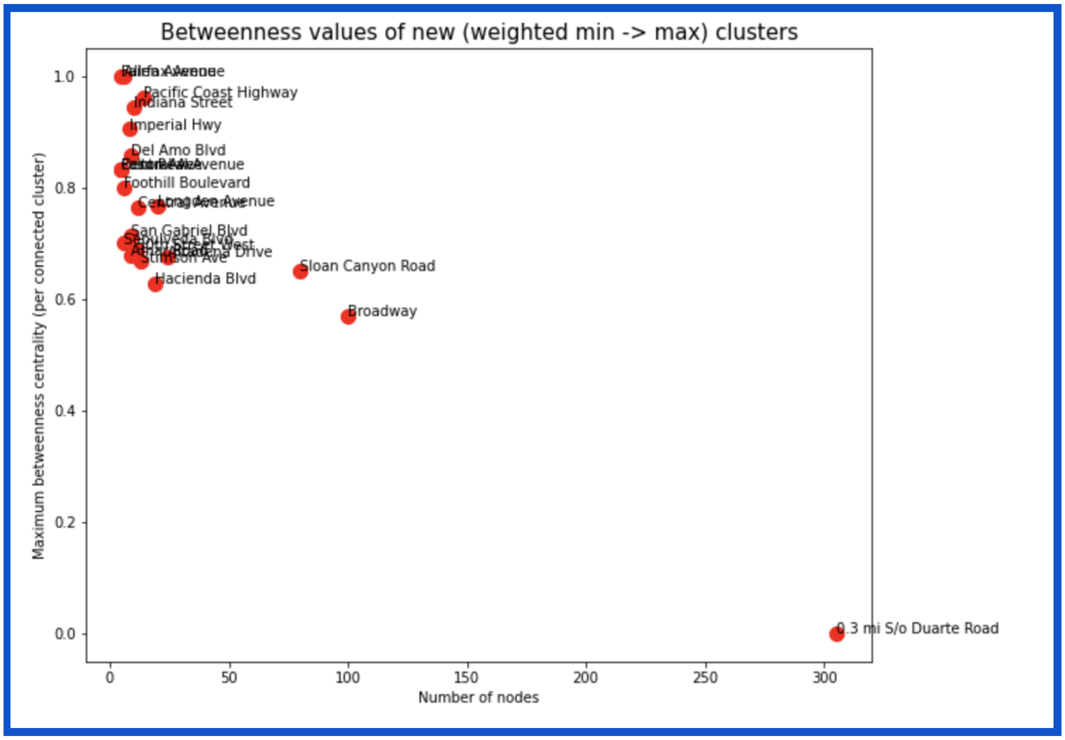


Figure. Weighted betweenness node rewriting scheme results.

Future Work and Conclusions - My paper clearly demonstrates there is something fundamentally wrong with the current topological structure of Los Angeles's bikeway network. There are way too many disconnected network clusters, and my paper also demonstrates a simple to use network rewriting method that reduces the network into 27 desirable bikeway clusters within an allocated budget. Future work could include further optimizing the overall network to ideally create one fully-connected, small-world network that can handle large bike flows. It would also be interesting to investigate what the optimal network would look like using this information gathered here. Maybe creating a network from the ground up that had very high minimum betweenness centrality with a maximum betweenness centrality not much larger while also keeping a small world property.

Sources and similar work:

[Data-driven strategies for optimal bicycle network growth]

[A Micro-Scale Analysis of Cycling Demand, Safety, and Network Quality]