Using Traffic Data to Inform Transmission Dynamics for COVID19 in Southern California

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Project Objective

Without a vaccine or effective treatment, there is an urgent need for performing widespread COVID-19 testing to control disease spread. However, complete population testing is prohibitively challenging as testing supplies are limited and require trained health staff which could be better used in caring for those confirmed to be infected. It is therefore critical to focus testing in high-priority areas, where tests are likely to capture positive cases. Identifying infected individuals as tests become more widely available will provide crucial information on overall disease prevalence to inform future disease control efforts.

We can help identify areas of potentially high disease prevalence by synthesizing and using traffic patterns, as transportation patterns may shed light on possible transmission patterns in Los Angeles County. We propose using the USC Archived Data Management System (ADMS), which collects and synthesizes traffic data, to create an epidemic model informed by up-to-date origin-destination traffic data. We will use the model to identify which of the 26 health districts in Los Angeles (LA) county are at highest risk for unidentified cases and optimally locate testing sites within these regions. This allows our recommendations to incorporate change in transportation patterns due to social distancing recommendations.

This work uses methodology from infectious disease transmission models, network data, and facility location models together in a novel way. Not only will we provide much needed insight using empirical data into population flow dynamics in the context of social distancing recommendations, but we will shed light on infectious disease modeling more generally.

Problem Statement

Specifically, we will:

1. Develop a dynamic transmission network model of COVID-19 using LA transportation data and disease parameters from the medical literature.
2. Develop a location model to optimally place drive-through testing sites in these districts.

Research Methodology

We use a compartmental model of COVID-19 in Los Angeles County (LAC) that draws from origin-destination (OD) estimation outcomes using PEMS data. Our OD estimation process uses an optimization framework to provide our best estimate of traffic origins and destinations given observed highway volume data collected from PEMS sensors, as depicted in Figure 1. We use these OD estimations to approximate population movement during the COVID-19 lockdown, which can help us capture how COVID-19 spreads.

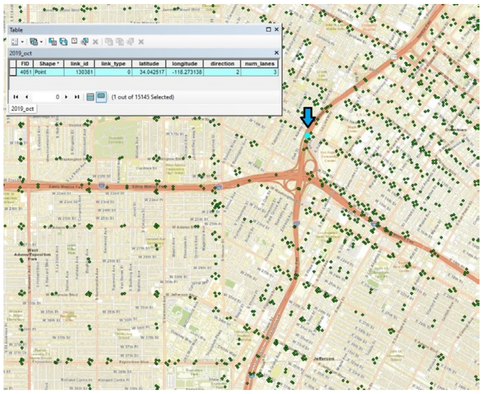

Figure 1: Example of road sensors that provide traffic volume data for our OD estimation.

Results

Our calibrated model of COVID-19 using the OD estimations as inputs is depicted in Figure 2. The model, which can be mathematically represented using a system of ordinary differential equations, models the number of individuals who are susceptible (S), exposed/have latent disease (E), identified and unidentified infected (I and U, respectively), hospitalized (H), recovered (R), dead (D), or vaccinated (V). In addition to relying on the OD estimation outcomes, which proxy population flow (and therefore transmission patterns), we draw from the medical literature to find rates of hospitalization, diagnosis, recovery, vaccination, and death. Model outputs around mortality, compared to empirically reported death counts, are shown in Figure 3, below. In general, the empirical measurements and simulated outcomes are close, indicating that the model is performing reasonably.

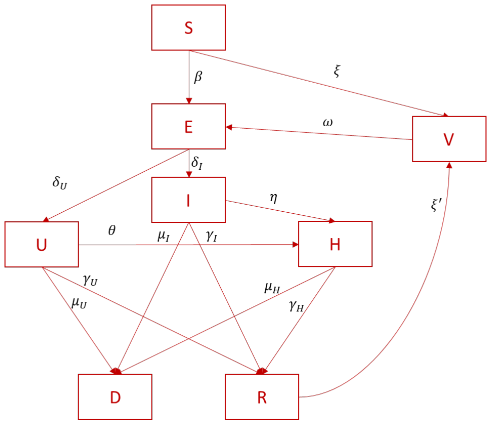

Figure 2: Model Schematic

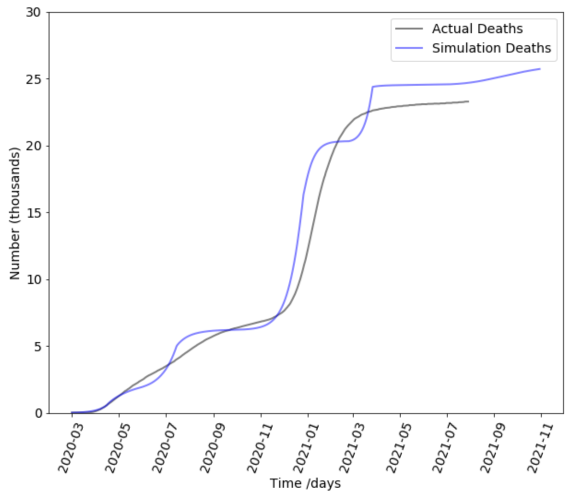

Figure 3: Model outcomes (compared to empirical values)

We use another optimization procedure to estimate optimal vaccine distribution center locations, which also uses the OD estimation outcomes to inform commuting patterns (which can change the term in the objective value that captures transportation costs). We find that, in general, such an optimization process can identify sets of vaccine distribution locations that outperform what was implemented in LAC in 2020, when vaccines first became available and were distributed only at limited distribution centers. The optimization process generally identifies center locations that are relatively more dispersed than those used empirically, allowing for greater population coverage.