COST-EFFECTIVE LOCATION ALLOCATION FOR COVID-19 PATIENT ASSIGNMENT IN FLORIDA: A DATA-DRIVEN APPROACH

Alexander DeLise[1], Seyedreza Abazari[2], and Arda Vanli[2]

[1] Department of Mathematics, Florida State University, Tallahassee, FL | [2] Department of Industrial and Manufacturing Engineering, FAMU-FSU College of Engineering, Tallahassee, FL

Abstract

This research presents a mathematical model to decide the best location of healthcare facilities (HCFs) in Florida to minimize demand during the COVID-19 pandemic. The model proposes a hybrid approach to minimize the cost of establishing the healthcare facilities at the candidate locations and the cost of travel to the healthcare facilities. To estimate the demand for the healthcare facilities, the study incorporates hospital data from all 67 counties of Florida. Budgetary constraints ensure that the optimal solution does not exceed a threshold of money spent to establish the healthcare facilities, and travel constraints ensure that demand does not exceed a threshold for money spent to travel to the candidate locations.

Introduction

Since 2020, the COVID-19 pandemic has taken an unprecedented toll on human life due to its contagiousness and ability to cause severe illness and death, including over one million US deaths [1]. Due to the rapid transmission rate of the virus and disruptions in the supply chain, HCFs were forced to turn away critically ill patients as the demand for ventilators, personal protection equipment, and intensive care unit beds exceeded that which the HCFs provided [2]. Residents in northwest and southern Florida have lower access to HCFs than other parts such as central Florida (Orlando, Tampa, etc.) [3] and thus receive worse care [4]. We employ a mixed-integer mathematical linear programming model that takes a hybrid approach to determine the optimal location for establishing new HCFs based on models from [5]. Our data consists of daily COVID-19 release data in Florida from each of its sixty-seven counties.

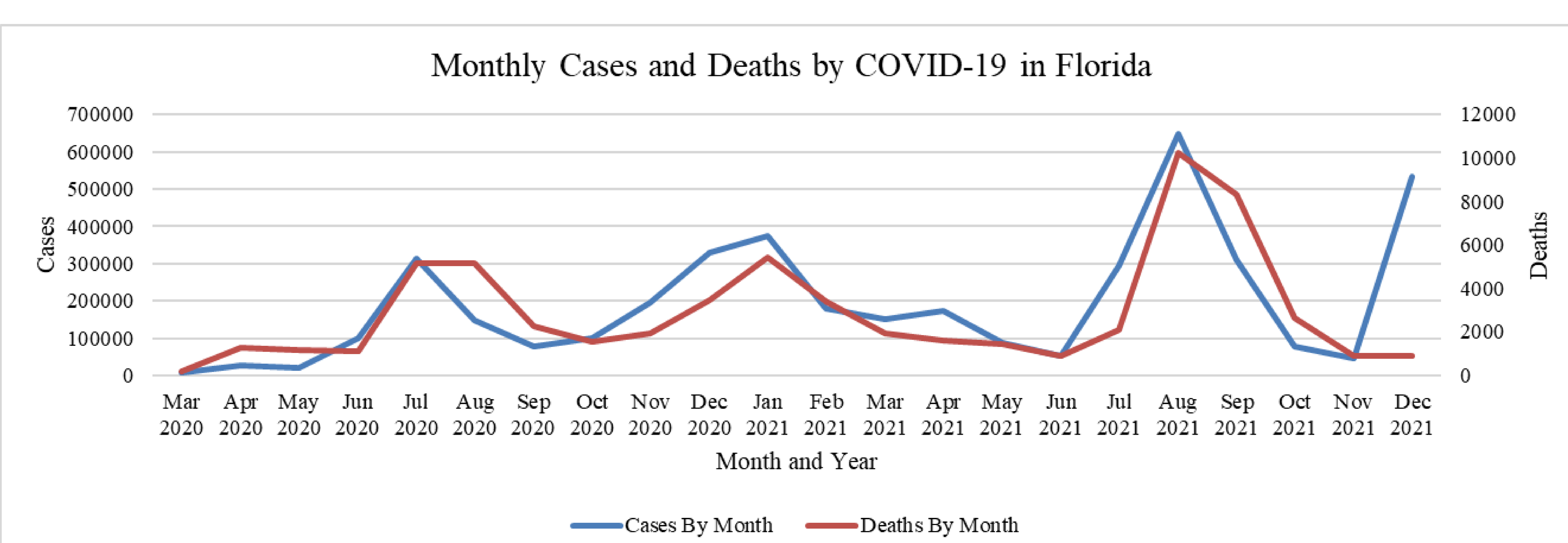

Figure 1: Monthly Cases and Deaths by COVID-19 in Florida [6]

Methods

Sets	
I	Set of demand points $i \in \{1, 2, \ldots, 67\}$
J	Set of candidate locations $j \in \{1, 2, \ldots, 67\}$
Input Parameters	
f_j	Fixed cost to establish an HCF at candidate location j.
t	Fixed cost to travel per mile by car[7].
d_{ij}	Distance between demand point i and candidate location j.
w_i	Demand associated with demand point i.
Decision Variables	
x_j	1, if a facility is established at candidate location j; 0 otherwise.
y_{ij}	1, if demand point i is assigned to an HCF at candidate location j; 0 otherwise.
s_{ij}	The satisfied demand from i at candidate location j.
dist_{ij}	The distance travelled from i to established facility j.

- (1) minimizes the explicit fixed cost of establishing a new HCF and the implicit cost of traveling to the HCF.
- (2) ensures that a demand point is only assigned to one location.
- (3) limits the number of people assigned to a candidate location to not exceed its capacity.
- (4) institutes the budgetary constraint such that the total cost of establishing the HCFs does not exceed the threshold.
- (5) and (6) determine the range of the number of candidate locations to be established.
- (7) places an upper bound on the total travel cost to the candidate locations.
- (9) ensures that a demand point's entire population is assigned only to one hospital.
- (10) outputs the distance travelled by a demand point to an established HCF.
- (11) and (12) are integrality constraints.

Model Formulation

$$\min \sum_{j\in J} f_j x_j + t \sum_{i\in I}\sum_{j\in J} d_{ij} y_{ij} \tag{1}$$

Subject to

$$\sum_{j\in J} y_{ij} = 1 \quad \forall\, i \in I \tag{2}$$

$$\sum_{i\in I} w_i y_{ij} \le \text{cap}_j \quad \forall\, j \in J \tag{3}$$

$$\sum_{j\in J} f_j x_j \le B \tag{4}$$

$$\sum_{j\in J} x_j \le P \tag{5}$$

$$\sum_{j\in J} x_j \ge 1 \tag{6}$$

$$\sum_{i\in i}\sum_{j\in J} d_{ij} y_{ij} \le D \tag{7}$$

$$y_{ij} \le x_j \quad \forall\, i \in I,\ j \in J \tag{8}$$

$$w_i y_{ij} = s_{ij} \quad \forall\, i \in I,\ j \in J \tag{9}$$

$$\text{dist}_{ij} = d_{ij} y_{ij} \quad \forall\, i \in I,\ j \in J \tag{10}$$

$$x_j \in \{0, 1\} \tag{11}$$

$$y_{ij} \in \{0, 1\} \tag{12}$$

Results

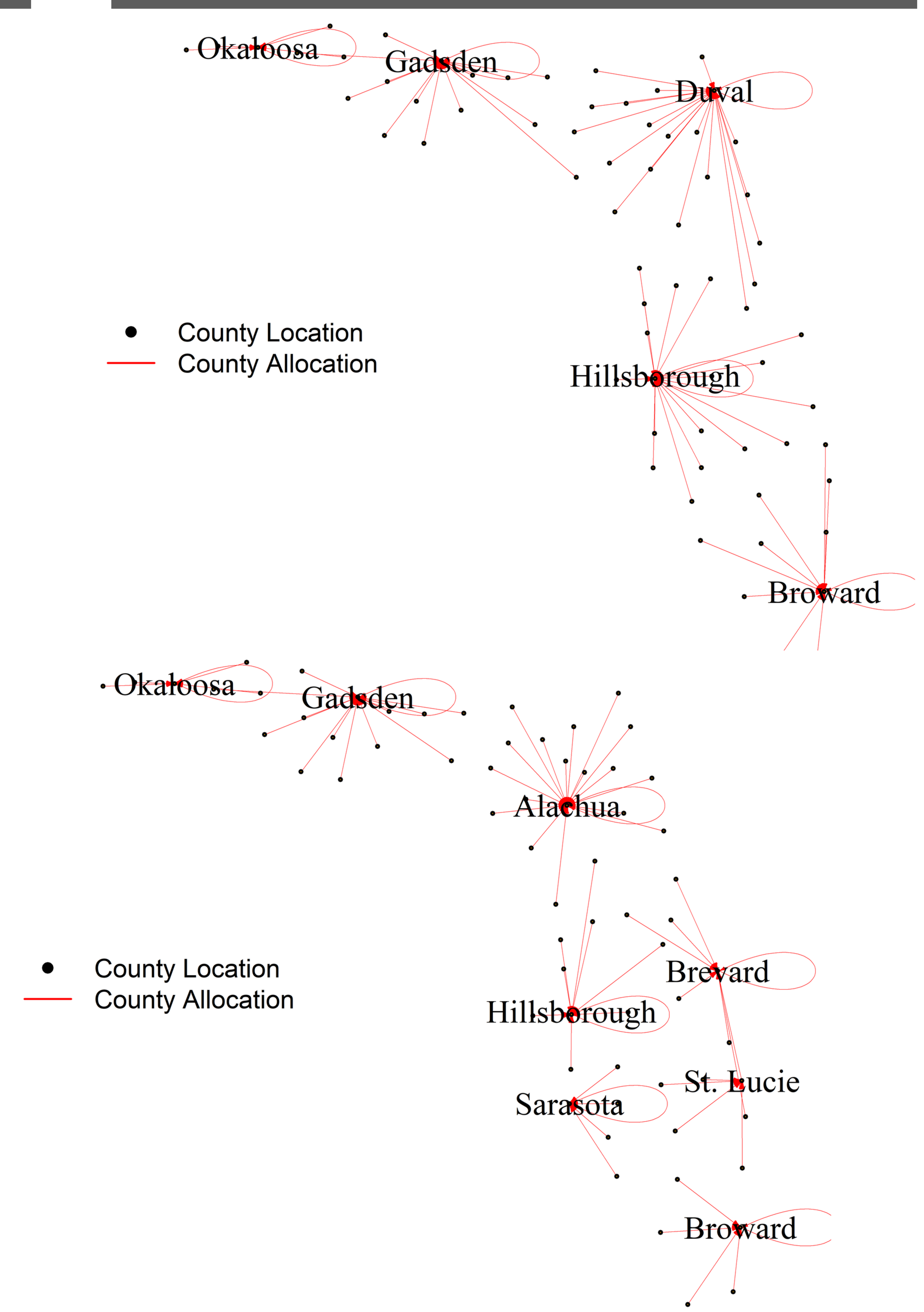

Figure 2: Optimal Location and Assignment of Patients Under Five and Eight HCF Scenarios

References

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