Algorithms and Heuristics for Remote Food Delivery under Social Distancing Constraints

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Community Problem: *The COVID19 pandemic has created unique food insecurity problems*

- School closings have eliminated school lunch programs
- Seniors have lost access to food pantries due to isolation

Objective: Formulate & solve the meal delivery problems created by these circumstances, and transition into use

Intellectual Merit

- Constraints imposed by public health and social distancing concerns pose a novel class of vehicle routing problems
  - Project will formalize these problems, and provide benchmark solutions/results
- Solutions to these problems will be key to improving the well-being of low-income children and adults, both during and post pandemic

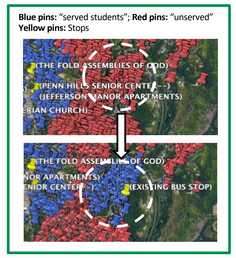
Project Activities to Date

Initial Focus: Penn Hills School District Summer Meal Program

- **Input Data:** Home location for each student, school bus stops; underlying road network
- **Problem:** Generate a set of vehicle delivery routes that maximize the number of meals delivered

Solution Approach

1. Determine set of delivery stops



2. Generate vehicle routes

Variable	Definition
S	the set of delivery stops to be covered; $\|S\| = s$
V	the set of delivery vehicles; $\|V\| = v$
$Meals_k, k = 1,...,s$	the number of meals required at delivery stop k
$TDur_{a,b}, a,b \in S$	travel time from delivery stop a to delivery stop b
$SDur$	the fixed duration of any delivery stop
$VehicleCap_i, i = 1,...,v$	the maximum number of meals that vehicle i can carry
est	the earliest time that delivery can start at a given stop
lft	the latest time that delivery can finish at a given stop
$Assigned_{i,k}, i = 1,...,v; k = 1,...,s$	1 if vehicle i has stop k in its itinerary; Otherwise 0
$Succ_k, k = 1,...,s$	the next stop after k in the route k has been assigned to
$Start_k, k = 1,...,s$	the (earliest) start time of stop k in its route
$End_k, k = 1,...,s$	the (latest) end time of stop k in its route

$$\max \left(\sum_{i=1}^{v} \sum_{k=1}^{s} Assigned_{i,k} \times Meals_k \right)$$

Subject to:

$$\forall i \in V \left(\sum_{k=1}^{s} Assigned_{i,k} \times Meals_k \leq VehicleCap_i \right) \quad (1)$$

$$\forall k \in S \left(\sum_{i=1}^{v} Assigned_{i,k} \leq 1 \right) \quad (2)$$

$$i \in V \left(\sum_{j=1}^{s} \sum_{k=1}^{s} Assigned_{i,j} \times Assigned_{i,k} \Rightarrow (End_j < Start_k \vee End_k < Start_j \right) \quad (3)$$

$$\forall i \in V \left(\sum_{k=1}^{s} Assigned_{i,k} \times (SDur + \sum_{k=1}^{s} Assigned_{i,Succ_k} \times TDur_{k,Succ_k}) \leq (lft - est + 1) \right) \quad (4)$$

$$\forall k \in S \left(\sum_{i=1}^{v} Assigned_{i,k} = 1 \right) \Rightarrow (Start_k \geq est) \quad (5)$$

$$\forall k \in S \left(\sum_{i=1}^{v} Assigned_{i,k} = 1 \right) \Rightarrow (End_k \leq lft) \quad (6)$$

Results

- Scalable, near-optimal meal delivery routing procedure
- Implementation of routes produced from Penn Hills data for summer meal delivery
- Meal delivery has continued through the 20-21 school year, and has now expanded to two additional school districts

Broader Impact (Immediate):

July 1, 2020 start Penn Hills

Nearly 6,000 meals are delivered monthly

October 28, 2020 start McKeesport

Over 1,000 meals are delivered monthly

Over 50,000 meals delivered

December 1, 2020 start Sto-Rox

Nearly 1,600 meals are delivered monthly

Broader Impact (Sustainability):

- Remote meal delivery needs will persist after the pandemic
  - Delivery of excess food (grocery stores, restaurants) to food banks
- Application to other delivery problems
  - Delivery of vaccine to those lacking access

Next Steps:

- Formalization and solution bench-marking of other food delivery problem variants
- Establishment of meal delivery programs in additional school districts, municipalities, and cities

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