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Problem:

A small business seeks to expand current market alternatives by providing fresh and sustainable organic food in a fast food setting. The State of Maryland has been selected as a pilot location, and ten possible restaurant sites within the state are considered for initial build sites. The business has enough capital to initially construct three sites among the ten possible locations. The Maryland State Department of Agriculture provides ample data on all registered organic farms in the state, to include location, production level and types of food available. Each restaurant requires a supply of produce, meat/poultry and dairy.

It is supposed that, in the long run, the cost of the business will be a function of the total transit time of the food supply to the restaurants (since they are marketing fresh, organic, locally grown food).

A network is then constructed from the complete bipartite graph seen in Figure 1. The franchise seeks to minimize time across all arcs. The locations have been abstracted to zip codes, and the arc lengths are labeled as travel times in seconds over state roads as computed by Google Maps.

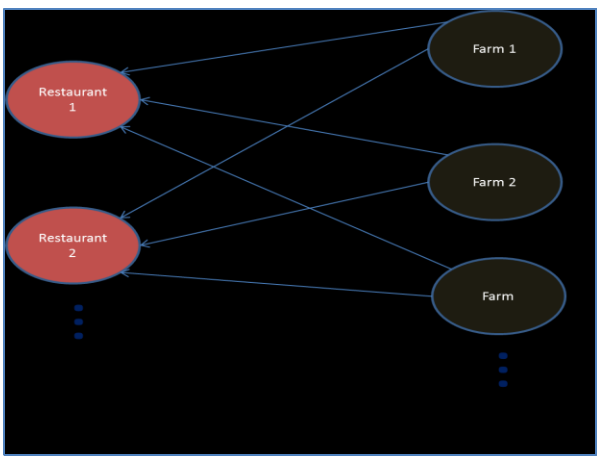

Figure 1 A section of the network showing 2 of 10 restaurant nodes and 3 of the 76 farm nodes.

As a reaction to potential intrusion on profits, a corporate fast food industry leader has successfully lobbied state and federal governments to institute organic food inspection stations for all food shipments leaving certain farms. Though inspections are certain, their location, number and duration are not known. It is assumed that inspections will be placed within the network to impose maximum delay to operator transit time.

In general, a model analyzing the network is formulated as an inner problem, defining the franchise choice for build sites, and an outer problem, defining the attacker actions against the franchise.

- Inner Problem
  - Minimize the total transit time of the supply network.
  - Subject to:
    - The total number of restaurants that can be built within budget.
    - Each restaurant must receive a supply of each type (produce, meat/poultry and dairy).
- Outer Problem
  - Maximize the solution to the inner problem.
  - Subject to:
    - There is a maximum of one inspection station for each farm.
    - The total number of inspection stations must not exceed a certain number.

Both the outer and inner problems are mixed integer problems; or more precisely, pure linear binary variable programs. The problem is solved via Benders decomposition. This approach is very useful in optimal placement problems containing several possible arc node combinations.

Results:

The algorithm was run iteratively, attack sites increasing from 0 to 12 and duration increasing from 0 to 8 hours, to attain the most frequently recommended build sites.

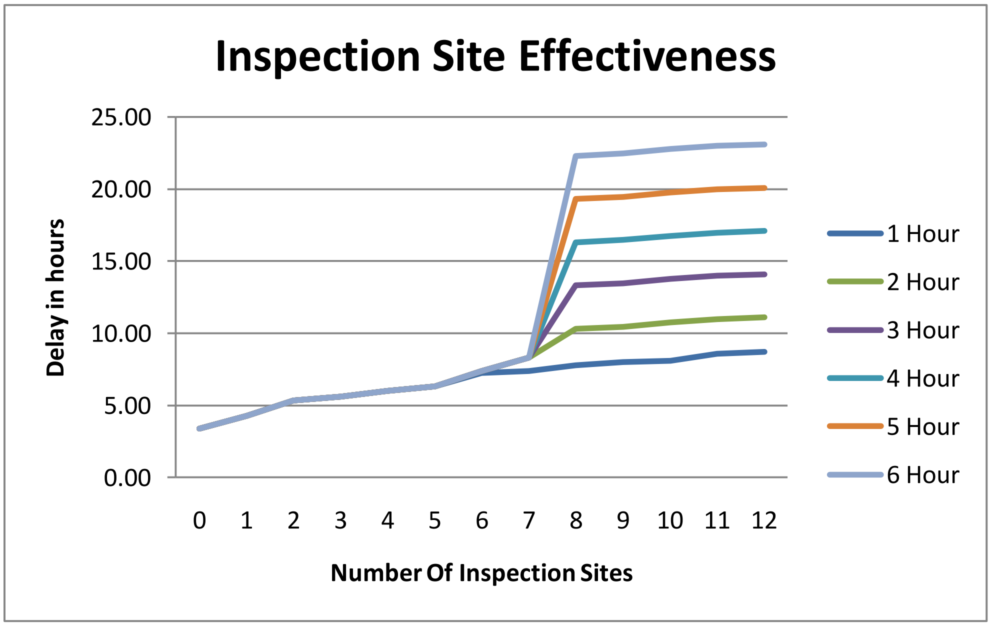

Figure 2 Operator resilience curve illustrating attacker effectiveness. Notice the maximum delay incurred is approximately 24 hours with 6 hour inspection duration. The jump in delays occurring from 7 to 8 attacks occurs as a result of drawing products from a farm being inspected.

The most frequent build sites though the entire span of the algorithm's iterative run are summarized in Figure 3.

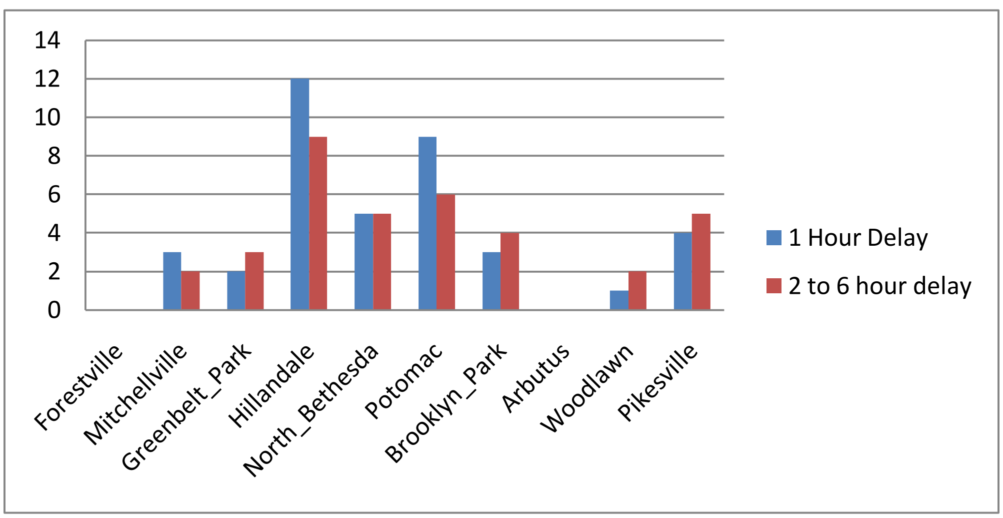

Figure 3 The build site frequencies for the 10 locations under consideration. Hillandale, North Bethesda and Potomac are the most frequently recommended locations under the complete run of the algorithm.

To expand the scenario, consideration was given to simulating varying profit of potential locations as an offset to their computed arc distance. Arc data for Forestville, Artibus and Woodlawn was reduced by

1000, 750 and 500 seconds respectively. The results to the change in build site recommendations for a single run for a 3 hour delay are illustrated in Figure 4.

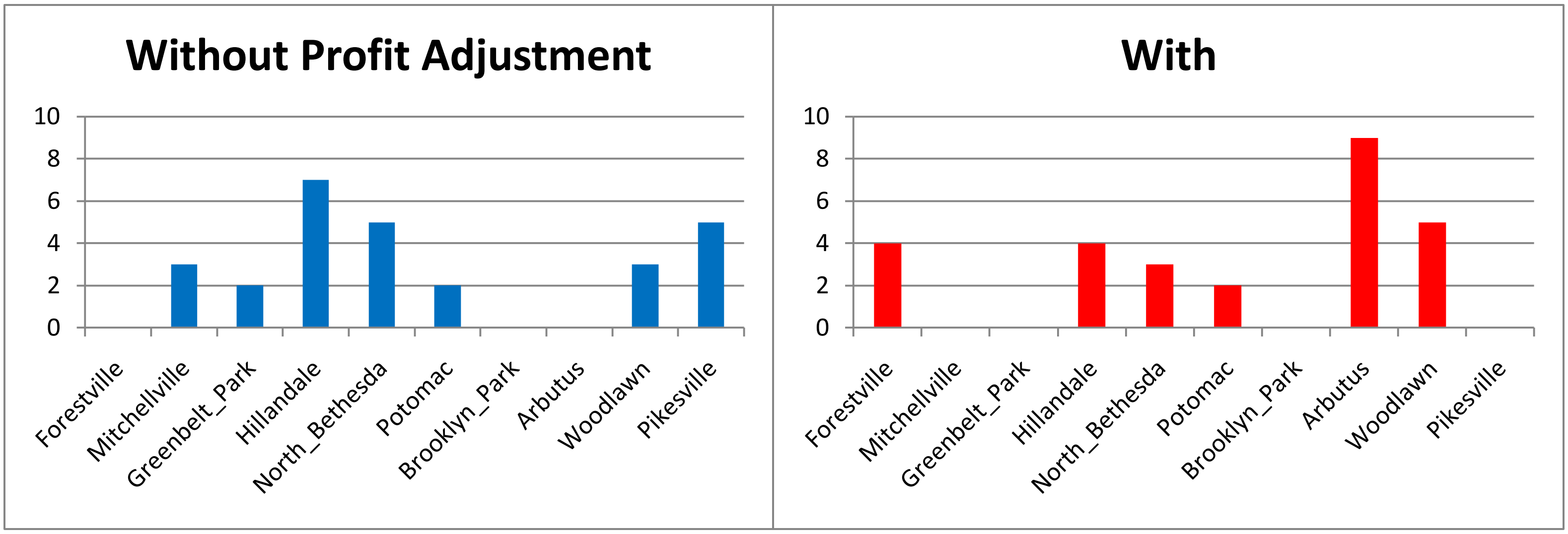

Figure 4 The difference of build site frequency in an algorithm run changing inspection sites from 0 to 8 inspection sites when arc length s are offset by potential profit. Notice that the Artibus becomes the most prominent location.

Conclusions:

The Network provides an adequate abstraction to study respective transit times between organic farms and potential restaurant locations in the State of Maryland. The algorithm solutions are sensible, recommending sourcing from farms providing more than one product. The optimal attacker response imposes inspection delays on those nearby farms that are multi-item providers; The operator should seek to protect multi-product farms.

Additionally, the model is adaptable to study the fluctuation of build site recommendation frequency based upon market research and profitability, though such offsets would have to be carefully calculated as a function of time. Manipulating the arc data in this manner, however, impedes the use of time as a sensible metric otherwise.

As continued research into the characteristics and feasibility of this network continue, it is recommended that the constraints be expanded to include minimums delivery times for the respective meat, produce and dairy products. Furthermore, the problem should be reformulated into a Min Cost Flow network to account for the varying ability of farms to produce their respective products. It is also recommended that the adjacency of build site solution be addressed to preclude intra-competition and potential profit loss.