**Spatial Optimization from a Student Perspective:**

**Modeling Optimal Interdiction Strategies for NSF Funded Research**

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### Introduction

Current Federal drug-control policy aims to reduce the flow of narcotics into the United States, in part, by interdicting narcotic shipments in Central America. Despite longstanding US presence, however, the volume and frequency of illicit trafficking through the region has continued to rise, and government-led interdiction forces intercept fewer than 6% of known trafficking events. Recent research has shown that interdiction contributes to the spatial fragmentation and proliferation of existing narco-trafficking networks and the ensuing propagation of collateral damages including violence, land seizures, and environmental degradation. Furthermore, maritime, airborne, and ground-based counterdrug operations are subject to temporary dynamic variation and demand, necessitating the development of alternative interdiction strategies. This paper presents two new models built on the established Maximal Covering Location Problem (MCLP): Maximal Covering for Interdiction (MCI) and Maximal Covering for Interdiction of Cartels (MCIC). These models identify the optimal interdiction – force package – locations given known drug flows and by differentiating among the illicit transit routes used by various drug trafficking organizations. These models were tested in a realistic interdiction scenario within the Illicit Supply Network (ISN) geography of Central America. The results demonstrate that location covering models can inform spatial decision making by counter-drug organizations by supporting the development of alternative interdiction strategies and improving the outcome-efficiency of interdiction operations in the transit zone.

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### Methods

**Maximal Covering for Interdiction (MCI)**

The Maximal Covering Location Problem (MCLP) formulated by [Church and ReVelle (1974)] finds the optimal facility locations for maximizing the sum of demand attributes at all facilities or resource constraints. The current literature, however, has not addressed expanding the MCLP to support spatial decision making by counterdrug organizations. This paper presents formulations of two interdiction models based on maximizing the disruption to narco-trafficking operations and solving those models on a realistic illicit supply network with a range of plausible data values. Maximal covering models can be applied to the problem of locating interdiction operations with the following formulation:

\[
\text{Maximize } \sum_{i \in P} \sum_{j \in J} x_{ij} y_j \\
\text{Subject To: } \sum_{i \in P} x_{ij} \leq 1 \quad \forall j \in J \\
y_j = \begin{cases} 
1 & \text{if flow is covered by interdicting at an end node, and otherwise} \\
0 & \text{if flow is not covered} 
\end{cases} \\
x_{ij} = \begin{cases} 
1 & \text{if flow is covered by interdicting at an end node, and otherwise} \\
0 & \text{if flow is not covered} 
\end{cases} \\
\sum_{k \in C} x_{ik} = p_k \quad \forall k \in K \\
x_{ij} \geq 0 \quad \forall i \in P, j \in J \\
y_j \geq 0 \quad \forall j \in J
\]

Where:
- \(i\) = the set and index of links where illicit goods are trafficked
- \(j\) = the set and index of end nodes (potential facilities/interdiction locations)
- \(x_{ij}\) = flow from link \(i\) to end node \(j\) covered by interdicting at end node \(j\), and otherwise
- \(y_j\) = special case of \(x_{ij}\) where \(y_j\) is the end node of link \(i\)’s coverage from flow from link \(i\)
- \(p_k\) = number of interdiction/facilities/force packages to be located

The classic MCLP can be cast in the context of interdiction, and the model is here termed the Maximal Covering for Interdiction (MCI) model. In this formulation, the objective (1) is to cover as many demands for interdiction services (links where illicit drugs are trafficked) as possible. These links are weighted by the amount of illicit goods that is known or estimated to be present on the links. Constraint (2) ensures that only the user specified resource (interdiction facilities/forces) are employed by interdicting agencies as “force packages” are located. Constraint (3) is a known covering constraint and ensures to satisfy that a demand can only be considered covered if a force package is located at the end node of the link. Constraints (4) and (5) require that at least one of the force packages should be located at a specific node and, similarly demands cannot be partially covered.

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**Maximal Covering for Interdiction of Cartels (MCIC)**

Interdiction forces are often coordinated collectively and are known as cartel. Therefore, the facility locations able to provide coverage to each demand link consist of the end node of that link. That node may be the end node of multiple links, in which case each of those links can be covered with the same force package. For example, in the hypothetical network shown in Figure 1, interdicting at node 4 would capture the flow on link \(a\) and \(b\) while interdicting at node three captures flow along link \(c\). For this analysis, the values assigned to each link are adopted from the Consolidated Countering Drug database (CCDB), a data repository maintained by the Joint Interagency Task Force South (JITF-S) to store interagency data on cocaine flow through the transit zone (Magliocca et al., 2019; McMenemy, 2020). The flow values are the CCDB 2018 estimates of cocaine movements and each link is assigned a value based on the country encompassing the end node of that link. Figure 2 (below) shows the study area and an example subset of nodes and links used in the analysis.

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### Results

Due to various limitations and constraints, the availability of, and demand for, counter-drug forces in Central America can change over time. Alternative policy actions, routine repair and maintenance, and the discovery of new intelligence can all necessitate the relocation or relocation of interdiction assets. The MCI was first tested to the ISN dataset for a range of values for \(p\) representing the varying number of force packages available at different times. Figure 3 shows the resulting force package locations and the percent coverage.

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### References

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