

EXECUTIVE SUMMARY

Backstory

The tragedy at the World Trade Center on Sept 11, 2001 is considered the worst terrorist attack in our nation's history. Unparalleled in nature and magnitude with loss of life of 2,823 people, it brought to light the real threat to the security of our nation. In the aftermath of this heinous act, there was enormous heroism displayed by the members of New York City's Fire Department where 343 personnel lost their lives in the struggle of two catastrophically damaged high-rise buildings. This taxing battle began almost immediately after the first tower was struck, and would last for several more days, yet none can question that the moments just after the start of this atrocity were the most chaotic and hectic. 9-1-1 Dispatch was almost immediately swamped with calls and alarms about the attack, and would continue to face this turmoil for a long time after as they directed selected fire crews to the scene. They faced not only the need to combat the problem at hand, but also had to maintain fire protection for the rest of the city. Multiple fire crews around the city continuously requested to be dispatched to assist in the effort, some of which dispatched themselves, while others fed misinformation to be dispatched unintentionally to ground-zero. This destabilized network of fire protection of the City of New York was, at its most, vulnerable to another attack or catastrophe and it is the effort of this analysis to show this fact.

Problem Statement

Analyze response times for FDNY Fire Engines, Ladders, and various Special Rescue Units in a Network to see how their time changes based on attacks to that network:

- How will an optimal interdiction affect FDNY's ability to respond to disasters in a timely manner?
- How many attacks would be necessary to significantly impede FDNY's mission?

The measure of effectiveness selected for this analysis is the fire department's response time (in minutes). Mission accomplishment means all required fire fighting assets have arrived at the target destination. Failure, then, is the inability of all required fire fighters to reach the disaster site. For this study, the required fire fighting force is varied to stress the model and how it becomes more vulnerable to attack as this requirement increases.

This network was modeled as a Minimum Cost Flow network. The fire department's objective is to respond to the disaster as quickly as possible with the least costly units available, in such a force as required to successfully defeat the casualty. The objective for the attacker is to impede this fire response by eliminating borough-connecting bridges, thus degrading counter-disaster efforts and increasing loss of life.

Data Sources

Cost and delay data was calculated by collected firehouse and bridge locations from the New York City Data Mine (<http://nycopendata.socrata.com/>). Distance calculations were derived from Cartesian coordinates utilizing station and bridge latitude/longitude locations. Since distances involved in this study occur within twenty nautical miles, error associated with using Cartesian coordinates is roughly 20-30 yards, which has negligible impact on response times. Cost calculations were based on data of average response times for fire stations in their respective boroughs. Fire houses were assigned circular areas of coverage based on the total area of the borough in question. The radius of a fire house' circle of responsibility was determined by the average distance of any point from its center ($2R/3$) and the necessary time required to arrive at any bridge based on information from Google.Maps. Based on the assumption below, capacities of fire houses were set to equal one, and bridge capacities were set at a value high enough to be computationally infinite.

Assumptions

- Borough response times are homogeneous.
 - All fire houses in a borough are equal and respond equally quickly
- FDNY response is contained within NYC borders.
 - No outside assistance from New Jersey or surrounding islands
- All non-attacked bridges are currently available for transit.
 - No bridges are out-of-service or under repair.
- Responding Fire Houses utilize all resources available.
 - Regardless of emergency, all assets are utilized if the station is triggered
- Response is instantaneous
 - No lag time from dispatch or fire fighter preparation

Results

Response times calculated during this study increased as expected as the number of required fire fighter personnel and equipment increased to combat the disaster. As this requirement increased, additional resources were pulled from surrounding boroughs to meet this demand. When attacks were introduced, bridges that connected nearby boroughs with closer fire houses were attacked first. Initially this involved the separation of Manhattan from Brooklyn and Queens, which forced their assets to transverse through The Bronx, thus increasing response time. As the number of attacks increased further, isolation of Manhattan from all other boroughs was the goal of the terrorists, at which point the fire houses organic to Manhattan would have to combat the disaster. As the number of required fire fighting personnel increased further still, the terrorist strategy changed, and isolating Manhattan and The Bronx became the strategy. The number of required bridges to do this is smaller, thus requiring fewer attacks. The separation of The Bronx from Queens required the combined

resources of Manhattan and The Bronx to defeat the disaster. This change in strategy resulted in showing that the attack strategy was not nested. As the number of required fire fighters increased to almost the entire city, fewer and fewer attacks were necessary to defeat the fire department. Eventually the network was defeated by the removal of the a single bridge, which connects Brooklyn and Staten Island, thus removing that borough's available resources and making the demand not met.

Conclusion and Future Research

The result of our analysis demonstrates that to overwhelm the capability of the FDNY requires an attack of similar magnitude to the one that occurred in 9/11. To combat this sort of attack requires a massive emergency response and a substantial amount of resources and manpower from over half of the city's fire stations. Another way to overwhelm the FDNY requires the isolation of the borough where an attack is occurring, in this study, Manhattan. Executing this type of attack requires a highly sophisticated planned attack, which would probably not go unnoticed. In this instance, it would require the terrorist to attack all the bridge nodes, of which Manhattan alone has about 15 bridges connecting the boroughs to it. This extensive bridge network would have to be defeated for the attack to succeed and to overwhelm the FDNY organic to the island of Manhattan. Future research opportunities are to determine fire house dispatch procedures that would help define individual node capacities. Additionally, to obtain a list of fire houses which were officially dispatched to the World Trade Center attacks and those that self-dispatched to help in the disaster.