Modeling Attacks to Chesapeake Bay Shipping

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According to the United States Army Corps of Engineers, 90-percent of all cargo entering the United States is from ships. The Chesapeake Bay is one of the busiest commercial shipping lanes in the United States, whereby approximately 94,908,150.01-million tons of cargo will traverse annually. This flow of cargo provides millions of Americans with the vital supplies they need and desire from overseas suppliers. Traffic to ports on the Chesapeake includes ships going to the Port of Virginia and the Port of Baltimore; the third and seventh largest ports on the Eastern United States respectively.

The Center for National Policy asserts that less than one-percent of incoming sea-based cargo is scanned for terrorist threats prior to departing our international trade partners for US waters. This presents numerous opportunities for a potential terrorist attack on shipping lanes and a possible shut down of this flow of cargo. Past events have demonstrated that this is a real threat. In 2002, al-Qaeda bombers in a small boat filled with explosives rammed a French tanker as it was approaching an oil terminal off the Yemeni coast. The attack killed one crewman and spilled 90,000 barrels of oil. The attack immediately caused insurance premiums for Yemeni ports to triple and container traffic fell by 90-percent. Further economic impacts to the region included in the loss of 3,000 port related jobs and a loss of $15-million per month in shipping revenue to Yemen. From this it is easy to see that such an attack in the Chesapeake, were the volume and value of goods is much greater, could cause inconceivable damage to the already weakened US economy.

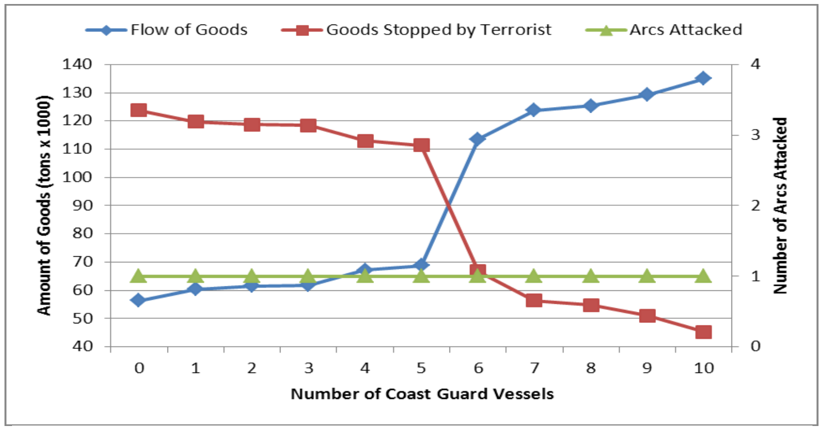

Figure 1: One Attacker

The objective of this project is to analyze how such an event could shut down commercial shipping in the Chesapeake Bay and develop a plan of defense against such an attack. For our analysis we took the viewpoint of Coast Guard vessels trying to protect these shipping lanes from a suspected attack. Developing the shipping network throughout the bay was done using

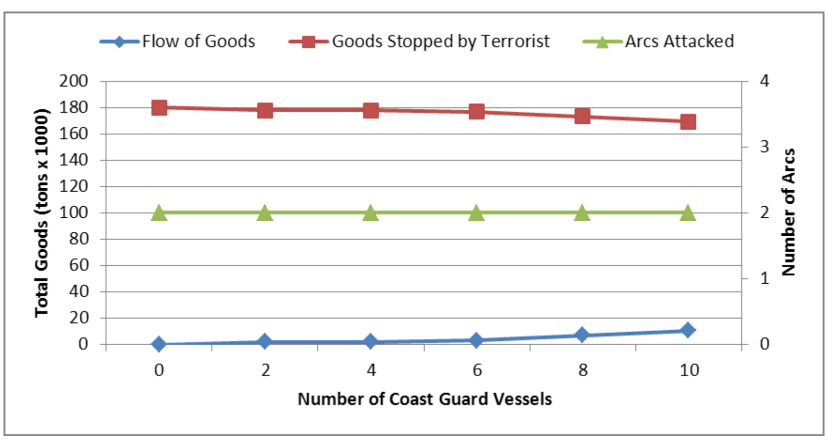

Figure 2: Two Attackers

existing navigational landmarks and lanes of travel. Nodes were initially located at key points along the shipping lanes, consisting of buoys and other aids to navigation. Nodes were also located at three of the ports in the bay: Hampton Roads, Baltimore and the Potomac. Finally, edges were created between each of these nodes along known shipping routes and other potential paths of travel. They were given weighted values based on the amount of cargo that traverses the edge on a daily basis, as provided by the Port of Virginia Annual Report and the United States Coast Guard, District of Baltimore. The mathematical model was developed using a simple max-flow model. The objective function for the model was to maximize the total flow of goods from the three port nodes, to the singular end node at Chesapeake Lighthouse.

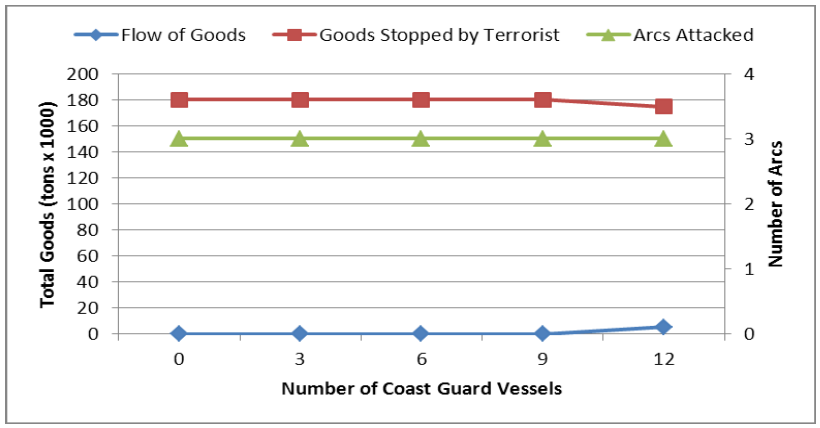

Figure 3: Three Attackers

The model showed a total of 180,235.3-tons of cargo could traverse from the network in a single day when no terrorist interdiction is present. When one edge is attacked with no Coast Guard assets to defend the area, the terrorist may successfully limit flow to only 56,455.9 tons of cargo- a 69-percent reduction in total network flow. By placing an increasing number of defenders on the terrorists "optimal" attack arcs, the amount of total cargo flow is increased from 60,480.1-tons to 68,833.8-tons, for a maximum of five defended arcs. Increasing the number of defenders from five to six however, results in a noticeable leap to 113,554.2-tons of flow. This translates to only a 37-percent reduction in total flow as opposed to when there were no defenders. These results are summarized in Figure 1.

An increase in the number of potential terrorist attackers is represented by allowing the model to attack two arcs simultaneously. Initially, when there are no defenders, they are able to shut down all shipping in the Chesapeake. By repeating the same process as before, we add defenders to the attacked arcs by removing these arcs from the list of attackable arcs in order to see how the terrorists attack plan changes. While this allows for some flow out of the network, overall the terrorists are able to maintain a relatively low flow of goods out of the network, even with ten defending units protecting arcs. Only 10,763.4-tons of cargo is able to pass through the Chesapeake with these ten units in place. The results of two attackers can be seen in Figure 2.

In Figure 3, the results of three simultaneous attackers can be seen. Once there are three attackers, regardless of the number of defenders between zero and nine, the attackers easily shut down all shipping in the Chesapeake. In this scenario 12 defenders are required to ensure any flow on the network and the resulting amount is only 5,381.7-tons of cargo. These results are not necessarily surprising, but what is interesting is the order of attack. As the number of terrorist attackers increases, the order in which arcs are attacked varies significantly. Each new attacker allows for a completely new strategy on the part of the terrorist.

By increasing to yet a fourth attacker the results become even more interesting, as can be seen in Figure 4. The same pattern of network shutdown is seen, but in fact the attack pattern between three and four attackers is the exact same up to the point where there are 12 defenders. Only when there are 12 defenders does the terrorist choose to employ the fourth attack. Again, from a strategic point of view this is a significant point because it allows the terrorist to remain flexible in his decision to attack, which makes it much more difficult for the defenders to guard against.

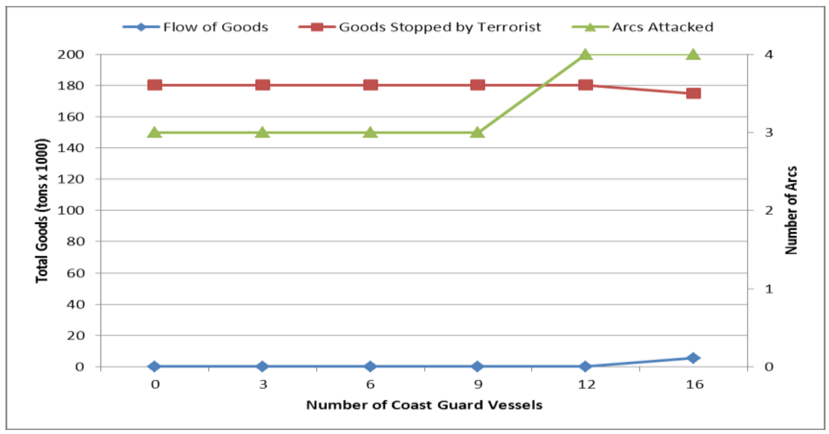

Figure 4: Four Attackers

Overall there were some surprising conclusions drawn from this analysis. With no defenders in place, an attacker can effectively shut down the network by attacking only two edges simultaneously. Determining that the attacker/defender ratio was not 1:1 was also interesting. The terrorist's ability to increase from two to three units required the defenders to increase their forces six times and from three to four attackers required the defenders to increase their forces eight times. It was also noticed that the entrance to the Chesapeake Bay causes a bottleneck of flow and this region is the only area in the network that really matters when it comes to attacking arcs. This is a result of the aggregation of all goods in the network to this one are. The model does not consider defending arcs further up in the network until this area is almost completely defended because overall the highest volume of goods transits this area. In a real world scenario, this may be slightly unrealistic, so further analysis would need to be done to determine a better measure of the network. Perhaps introducing probabilities of attack or stochasticity in the model would generate a more realistic approach. Despite these drawbacks, the final results proved interesting and should be considered as a viable means to identify potential threats to this vital supply network.