US Oil Import

The ability for the United States of America (US) to have enough oil to operate at capacity has been a source of heated political debate and a threat to national security. Recently the US has embarked on several projects to harness alternative sources of energy, but none have matured enough to replace oil. Presently the US requires 19 million barrels of oil per day (MBD) to operate. Domestic supply does not meet this demand so the US is forced to import 11.4 MBD (45%) of the oil it needs. This heavy requirement for imported oil is not expected to change in the near future and presents a large vulnerability to the US.[i]

52% of the oil the US imports comes from the western hemisphere.[ii] Although two major suppliers of oil in the western hemisphere, Mexico and Venezuela, have had recent turmoil, these sources are considered secure. This still means that the US requires 2.5 MBD from sources outside the western hemisphere. Africa and the Middle East are those other major sources of oil and are often in precarious situations where events capable of causing major disruptions to oil exportation are realistic. The ultimate goal of this project is to ensure an uninterrupted and adequate flow of oil into the US. This is accomplished by analyzing the resilience of the oil importation network in order to identify the critical and vulnerable portions so that decision makers can then fortify them or prepare alternate routes.

The resilience curves are calculated by modeling the transportation infrastructure with a minimum-cost-flow network and simulating attacks against various edges. The analysis explores the impact of interdiction on shipping cost and possible inability of the US to meet demand. The objective function of the model seeks the lowest cost to meet demand using all potential sources and routes. The output of the analysis of the resilience curves and the locations of attacks will help inform decision makers which links in the network, when attacked, cause the largest costs increases.

Some assumptions are made to reduce the model to a feasible scale. The first assumption is that US demand with not change. There are long term efforts to reduce demand but none are expected to take effect for decades. The second assumption is that foreign sources of oil will be able to compensate to changes in demand by increasing production up to 10%. A related assumption is that crude and shipping prices will not change as the network is disrupted. This assumption does stretch the bounds of reality but makes the calculations simpler and does not alter the locations of attacks and the relative magnitude of the results. Because we were interested only in the external oil transportation network we only have oil arriving to the US through the Gulf Coast. It is also assumed that when ships depart a foreign port with oil they proceed along the shortest path to a port in US and offload immediately. This ignores storage facilities en route and does not take into account any delays or account for ships that anchor offshore awaiting higher oil prices before unloading. The cost assumption we make is that moving a unit of oil for a given distance is one constant price for all pipeline and another constant price for all ships. The final assumption we use is that all attacks are equally likely to occur and equally likely to succeed.

The network used in this project is based on the production and shipment of oil into the US from the top 13 suppliers. The flow begins at an artificial “Start” node with edges that connect to countries that produce oil. It ends at the terminal node titled “US”. In between the two is the transportation network. The nodes of the network include the beginning and end of each pipeline, shipping route, canal, and chokepoint. The physical paths between the nodes are the edges and they each have an associated cost, lower bound, and upper bound which represent the transportation costs and limitations of moving oil along that route. The transportation costs are calculated by distance and a ship or pipeline cost factor. The only lower bound is on the back arc where it represents the demand of the US. Where they can be determined, upper bounds are placed. Figure 1 illustrates this network.

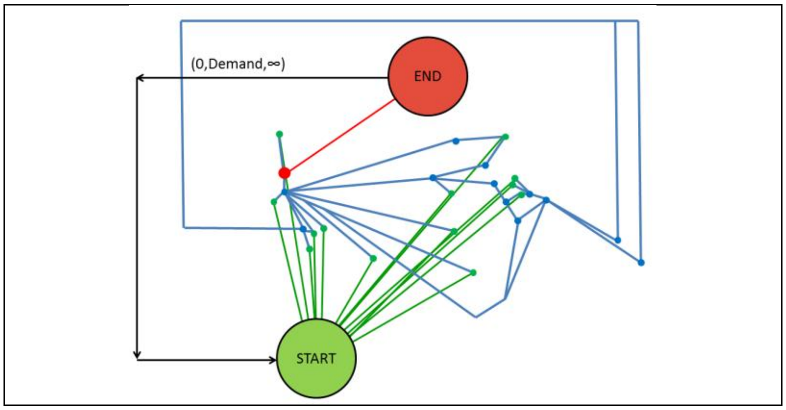


Figure 1: Oil Transportation Network

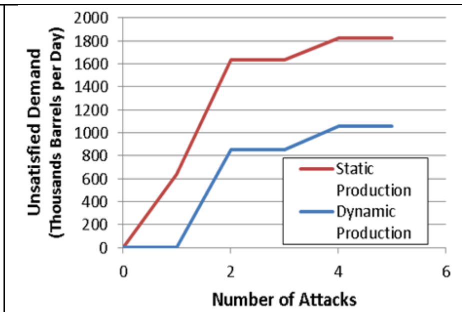
Attacks to the network take place only on the edges. The nodes that are considered vulnerable to attack are split into two nodes. For example, the Suez Canal has a north node and a south node. When the edge between the two is attacked the Suez Canal is attacked. When an edge is attacked that route is impassible and the oil must travel another route or come from a different source. Some edges cannot be attacked because they do not fall within the purview of this project. For example, a large naval force could drastically disrupt tankers crossing the Atlantic Ocean, but we are focused on smaller forces attacking pipelines and areas of constricted ship movement only. Therefore we do not include edges crossing the Atlantic Ocean in the attack possibilities. The model assumes that the attackers will always operate in the most efficient manner and attack the edge that creates the maximum increases in shipping price to the US.

The results immediately indicated that the Strait of Hormuz was the most vital chokepoint and always the first attack location. To gain further insight to the vulnerability of the other edges in the network the model was run with the ability to attack the Strait of Hormuz (scenario 1) and without that ability (scenario 2). Additionally, the results of each attack was calculated using the increased production and without that increased production.

The results of scenario 1 with up to five attacks are summarized in Figure 2 and indicate that the first edges to be attacked are the Strait of Hormuz and the Saudi Arabian East-West Pipeline. Following that the Panama Canal and the parallel pipeline are cut. The results on the oil supply are that the three suppliers in the Middle East are cut off after only two attacks. One based in South America, is cut off after the fourth. The associated resilience curves, also located in Figure 2, show that when there is no increase in supply, the US cannot meet demand after only one attack. With the increase in supply the ability to meet demand is only extended to two attacks. With some plateaus the shortfall in demand continues to increase. The total shipping cost decreases with both supply options but this is because less oil is being shipped.

The results of scenario 2 with one through four, and nine attacks are in Figure 3. With one attack, the interdiction can only increase the total shipping coast by closing Suez Canal. However, this does not decerase the amount of oil US gets. Since the unsatisfied demand is still zero, the program is not forced increase production. The following attacks prove a nuisance because shipping costs undergo a slight increase. Even with nine attacks the US is able to meet demand with only a 4% increase in production from the countries still supplying oil. In fact, the there is little addition damage to the network after 3 attacks and no additional damage after 4 attacks. The resilience curve for total shipping cost has some fluctuations as the number of attacks increases, but this is mainly because with two attacks the path from Ecuador to US is cut off and Panama Canal and Trans-Panama Pipeline are closed. Two or more attacks decreases the amount US gets by 185 TBD, and the program responds this by increasing the upper limits by 4%.

Country	Oil Imports (Thousand of BPD) No Attacks	1 Attack		2 Attacks		3 Attacks		4 Attacks		5 Attacks	
Canada	2479	2479	2720	2479	2727	2479	2727	2479	2727	2479	2727
Mexico	1210	1210	1331	1210	1331	1210	1331	1210	1331	1210	1331
SaudiArabia	1004	1000	851								
Nigeria	809	809	890	809	890	809	890	809	890	809	890
Venezuela	1063	1063	1169	1063	1169	1063	1169	1063	1169	1063	1169
Iraq	450										
Angola	460	460	506	460	506	460	506	460	506	460	506
Colombia	276	276	304	276	304	276	304	276	304	276	304
Algeria	493	493	542	493	542	493	542	493	542	493	542
Russia	563	563	619	563	619	563	619	563	619	563	619
Brazil	309	309	340	309	340	309	340	309	340	309	340
Ecuador	185	185	204	185	204	185	204				
Kuwait	182										
Total Shipping Cost	5622	4579	4805	3290	3619	3290	3619	3232	3555	3232	3555
Demand	9483	9483	9483	9483	9483	9483	9483	9483	9483	9483	9483
Unsatisfied Demand	0	636	0	1636	851	1636	851	1821	1055	1821	1055
Capacity Increase			9.7%		10%		10%		10%		10%
Locations of Attacks		Straits of Hormuz		Straits of Hormuz East West Pipeline		Straits of Hormuz East West Pipeline Suez Canal		Straits of Hormuz East West Pipeline Panama Canal Trans-Panama Pipeline		Straits of Hormuz East West Pipeline Panama Canal Trans-Panama Pipeline Suez Canal	



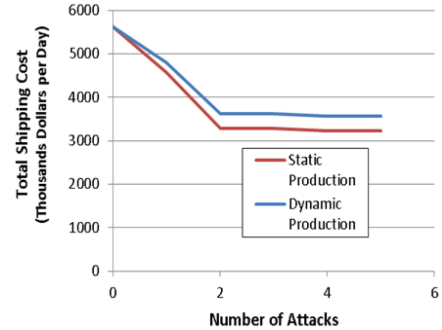
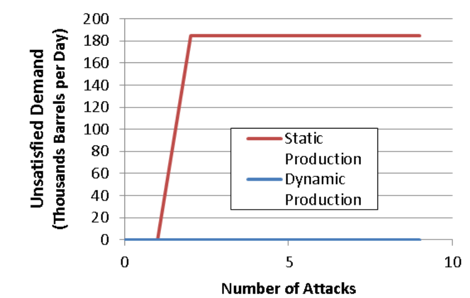


Figure 2: Results of Scenario One

Country	Oil Imports (Thousand of BPD) No Attacks	1 Attack		2 Attacks		3 Attacks		4 Attacks		9 Attacks	
Canada	2479	2479		2479	2577	2479	2577	2479	2577	2479	2577
Mexico	1210	1210		1210	1258	1210	1258	1210	1258	1210	1258
SaudiArabia	1004	1004		1004	1044	1004	1044	1004	1044	1004	1044
Nigeria	809	809		809	841	809	841	809	841	809	841
Venezuela	1063	1063		1063	1105	1063	1105	1063	1105	1063	1105
Iraq	450	450		450	285	450	285	450	285	450	285
Angola	460	460		460	478	460	478	460	478	460	478
Colombia	276	276		276	287	276	287	276	287	276	287
Algeria	493	493		493	512	493	512	493	512	493	512
Russia	563	563		563	585	563	585	563	585	563	585
Brazil	309	309		309	321	309	321	309	321	309	321
Ecuador	185	185									
Kuwait	182	182		182	189	182	189	182	189	182	189
Total Shipping Cost	5622	6421		5563	5483	6363	6246	6500	6389	6500	6389
Demand	9483	9483		9483	9483	9483	9483	9483	9483	9483	9483
Unsatisfied Demand	0	0		185	0	185	0	185	0	185	0
Capacity Increase					4%		4%		4%		4%
Locations of Attacks		Suez Canal		Panama Canal Trans-Panama Pipeline		Panama Canal Trans-Panama Pipeline Suez Canal		Panama Canal Trans-Panama Pipeline Suez Canal Su-Med Pipeline		Everywhere	



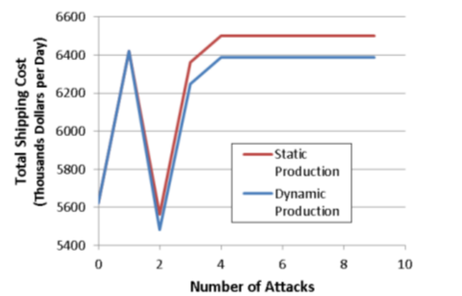


Figure 3: Results of Scenario Two

The conclusion is that the US can still satisfy demand with an attack on the Strait of Hormuz but not with any further attacks. The most dangerous course of action would be to close the Strait of Hormuz and the East-West Pipeline. This would effectively cut off the oil fields of the Persian Gulf. If the Strait of Hormuz is secure all further attacks will increase shipping costs, but demand will always be satisfied. The real world implications are that terrorist organizations which damage pipelines and portions of oil fields may get headlines, but they do not greatly affect US oil importation. However, if a nation were to close the Strait of Hormuz, it would be in the interest of the US to ensure the East-West Pipeline remains secure and open the strait as soon as possible.

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i US Energy Information Administration, (2012), Energy in Brief, retrieved from http://www.eia.gov/energy_in_brief/foreign_oil_dependence.cfm

ii Ibid