Executive Summary

Attempting Escape:
A Network Based Analysis of North Korean Refugees

Background

North Korea is the most isolated country on Earth. Its people lack access to technology, transportation, television, and especially the internet. For over sixty years, three successive leaders have brutally punished their people by interning them in concentration camps, subjecting them to slave labor, and murdering them. Because of the fall of the Soviet Union and the country's lack of natural resources, development of human capital, and insane focus on military and warfare technologies, North Korea has fallen into ruin unlike any other in recent history.

As a result of this excruciating pain and suffering, those North Koreans, who somehow find out that the rest of the world does not live such as they do, often desire to escape. Those who make the decision to flee the country, do so under extremely perilous conditions. Potential escapees must not only make their way through a country that essentially prevents any form of travel, but then they must cross a treacherous and guarded border into China. Unfortunately, China, still having strong ties to Pyongyang, actively seeks North Korean refugees and deports the ones they catch back to North Korea. Escapees must also attempt to avoid kidnappers and sex traffickers throughout their journey in China.

Luckily, a few brave souls have developed a "new underground railroad" to assist those fleeing from North Korea. Throughout China, Mongolia, and Southeast Asia individuals help transport, guide, feed, and shelter North Koreans trying to seek asylum in South Korea, the United States, and the European Union.

Problem Statement

What are the best routes for North Korean escapees to take when fleeing from North Korea?

Assumptions

- All refugees start in Haeju, Kyo-Hwa-So 4, or Pungsan, which represents the southern, central, and northern regions of North Korea, respectively.
- All edge probabilities within North Korea are the same
    - Similar for border crossings and within China
- All refugees escape from North Korea into China then into either Mongolia or Southeast Asia
- Once refugees escape China they can no longer be intercepted and deported back to China
- Only considered straight line distances
- Only considering the escape of a single refugee
- Refugees travel at an average pace of 10km/hour and for an average of 14 hours/day

Research Questions

- What is the shortest escape path out of North Korea?
- What is the optimal path out of North Korea based on probability of evading authorities as edge costs?
- Where are the most likely points of interdiction both inside of North Korea and in China?
- How do attacks on the network affect a refugee's chance of escaping and their path?
- How do additional resources in the form of monetary funding, better guides, etc. enhance a refugee's chance of escaping and his/her path?

Model Description

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The network consists of three starting points within North Korea and several other nodes throughout North Korea that connect these starting points to areas along the North Korean-Chinese border. Next, the network consists of nodes along the Chinese border that act as entrance points into China. Other nodes in China include Christian Churches and additional cities that mark possible paths to Beijing, Mongolia, or Southeast Asia. Once in Mongolia or Southeast Asia, there are nodes at major airports where refugees typically escape to freedom. There are also nodes representing Bangkok, Thailand and Manila, Philippines which the refugees can flee to in order to reach safety. We then created a node called Escape that acts as a super-sink to which refugees exit the system.

The edges linking the nodes in the network are the paths the refugees take throughout their journey to freedom and the costs are straight-line distances in kilometers. Initially, the edge costs will simply be the distance between the nodes. These distances are straight-line distances between points calculated in kilometers. We solve this network based solely on shortest path, and then we introduce probabilities of evading authorities along the paths as well as border crossing interdiction points to make the model more realistic. The probabilities of evasion are based on the time spent on an edge and vary depending on location and the person's proximity to a border crossing and location within North Korea or China.

Entities interested in interdicting this network include North Korean authorities, Chinese authorities, kidnappers and sex traffickers. All forms of attack on this model we call "checkpoints." Checkpoints are never considered to be 100% effective because in the real world this would not be realistic as authorities can be paid off and escapee paths can be adjusted in order to avoid detection. Instead, a checkpoint is designed to slow the escapee by 6 hours which is still significant based on a 14 hour day of travel

Analysis of Results

First, we solved the shortest path from the three starting points within North Korea. All paths lead to Chinggis-Khaan International Airport in Ulanbaatar, Mongolia and refugees must travel over 2200 km on this path. Based on our model assumptions, the total travel time with no delays considered is approximately 17 days for all starting points. Crossing the Tumen River to get from North Korea into China results in the longest of the shortest paths.

Next, we solved for the path that provides for the maximum likelihood of escape using the more realistic model that utilized probabilities for the edge costs. Comparing these results to the shortest path results allowed us to gain the following insights. First, based on the operator resilience curve in Figure 1 below, the safest overall path begins in Kyo-Hwa-So 4 with a maximum likelihood of escape of approximately 16% with no "checkpoints" considered. However, the likelihood of escape drastically decreases as "checkpoints" are added such that escapees have less than a 2 percent chance of successfully reaching freedom when 7 checkpoints are considered. Second, the most dangerous overall path begins in Pungsan. Even without interdiction, the chance of an escapee successfully reach freedom is less than 6%. Then as "checkpoints" are added the probability of escape decreases rapidly such that at 3 roadblocks the chance of escape is less than 2 percent. Third, the safest path from all three starting points leads to Beijing. This makes sense because once on a flight out of Beijing, the refugees are considered to have reached safety.

When considering that the route that utilizes the Tumen River crossing is not only the longest but also the most dangerous, resources must first be directed to this area to assist refugees leaving Pungsan. Additional resources can be in the form of more and/or better trained guides, additional funding to be used for providing safe havens and bribing authorities, etc. The probabilities of escape drastically increase when resources are added as can be seen in Figure 2 below. Similar to the limited resources case discussed in the previous paragraph, the likelihood of escape still rapidly diminishes as "checkpoints" are added. However, the likelihood of escape does not drop below 2 percent until 6 "checkpoints" are added. With additional resources, the operator becomes much more resilient to attack. This proves that additional world involvement in assisting people escape from North Korea will improve each escapee's chances of reaching freedom.

Another option for additional resources is to add funding that increases the likelihood of an escapee not only reaching Beijing but ensuring one can get on a flight out of China once there. Even though the route that utilizes Beijing is not the shortest overall path, it is the safest because it is the quickest way out of China. Thus, future research could consider a max-flow problem that attempts to push as many escapees to safety as possible with additional resources increasing the capacity of flow into Beijing.

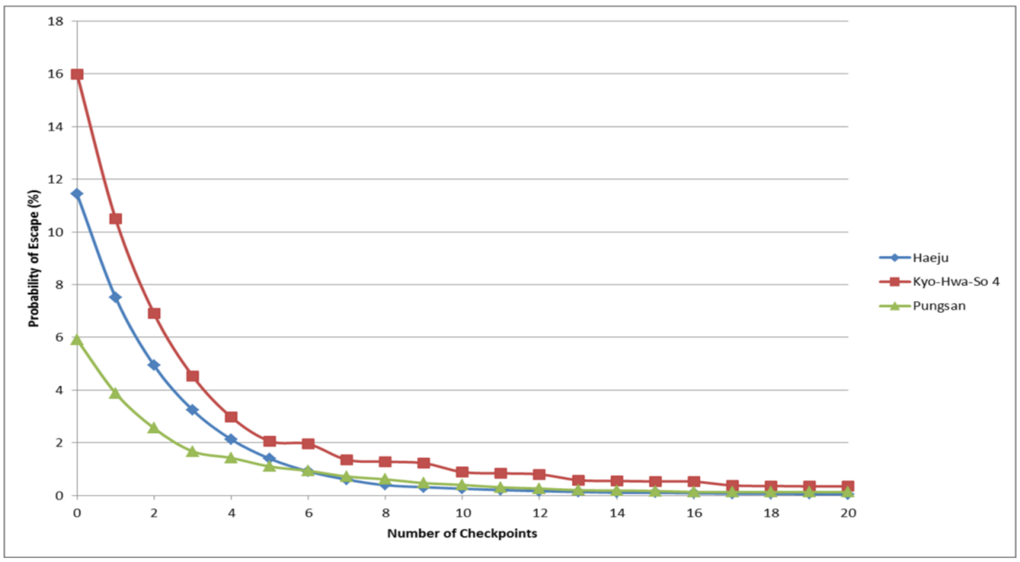

Figure 1: Operator Resilience Curve for Probability Based Model

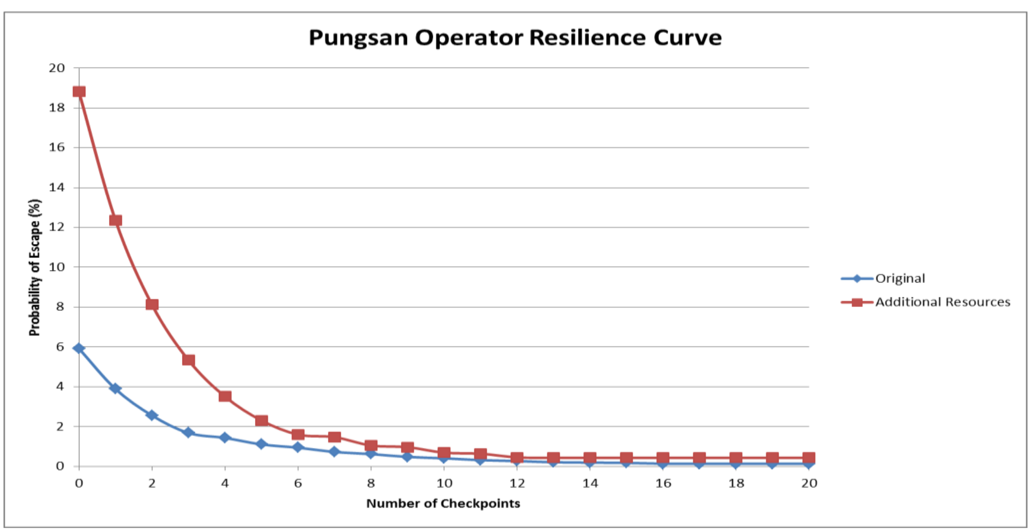

Figure 2: Operator Resilience Curve with Additional Resources Considered