Back-Story

In 1975, a 40 mile section of the island of Hawaii slid 11 feet into the ocean and caused a 7.2 earthquake and 15 meter high tsunami in a matter of minutes. Currently there is still a 5,000 cubic mile section of the Big Island that is displacing 10 centimeters per year that is predicted to have the potential of creating a megatsunami of 500 meter high waves. The seismic activity since 1983 of the active volcano (Kilauea) has created this danger called the Hilina Slump.

The Hilina Slump has continuously been separating itself from the island of Hawaii and is eventually predicted to create a 500 meter tsunami with the potential to hist Waikiki within 30 minutes.

Inevitably, another partial large displacement of this slump is likely to occur in the near future. The fallout of the Hilina Slump would allow up to 30 minutes for evacuation on parts of the island of Oahu. This is different than residents are accustomed to; an earthquake caused tsunami occurring in Alaska or Washington State (the most likely tsunami source for Hawaii) has an allowance of about five to six hours of evacuation time. Overall, the most likely course of action for the damaging effects of the Hilina Slump would occur to the rural lands of the Big Island and immediate neighboring islands, but the most dangerous course of action would be for its effects to hit the heavily populated area of Waikiki, Oahu. Waikiki is within the path of a Hilina Slump tsunami and houses approximately 20,000 residents, tourists, and workers.

<u>Problem statement:</u> The objective of this analysis is to determine the impact of a slip of the Hilina Slump on the overall tsunami evacuation preparedness of the Waikiki area. Given 30 minutes of evacuation time, 20,000 evacuees, four required routing network points (choke points), and a limited capacity for final shelter locations, we analyzed the critical paths, potential government enhancements to road networks, and identified the follow-on displaced personnel shelter support pattern to understand the required follow-on logistical maintenance.

Map of tsunami path modeled on an earthquake on the Big Island. Oahu would have less than 30 minutes to evacuate.

Modeling

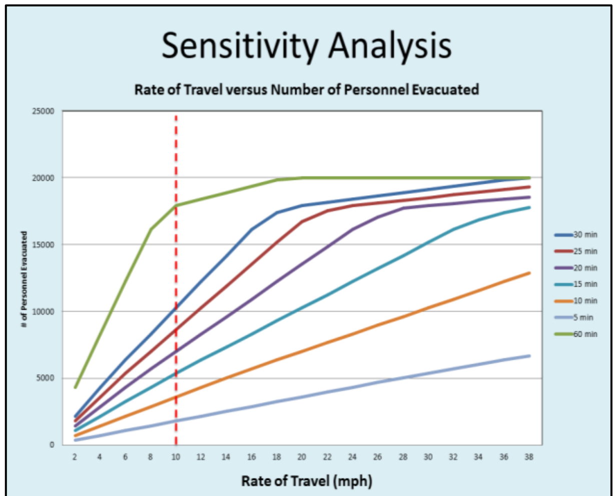
The problem is formulated as a max flow model and solved with the General Algebraic Modeling System (GAMS). The complete directed graph consists of 79 nodes and 165 arcs connecting the nodes. The nodes were population centers in Waikiki (i.e. major hotels), key road intersections, and evacuation shelters. The arcs followed the road network connecting the nodes. There were two types of nodes that were split for the purpose of attack; road network choke points and shelters.

Distance was used as the cost variable. The farther a path was, the less likely it was chosen as a path. The capacity of the arcs was estimated as a function of arc distance, the number of road lanes for that arc, an average car length constant, estimated ideal traffic travel time, and evacuation time from initial warning sirens. We used supply/demand nodes to drive the network flow. All flow was required to go through one of four choke point based on the geographic layout of the metropolis. This model assumes completely rational actors that are all traveling at the same rate and departing at the same time.

The measure of effectiveness was the number of personnel moved from start to end point.

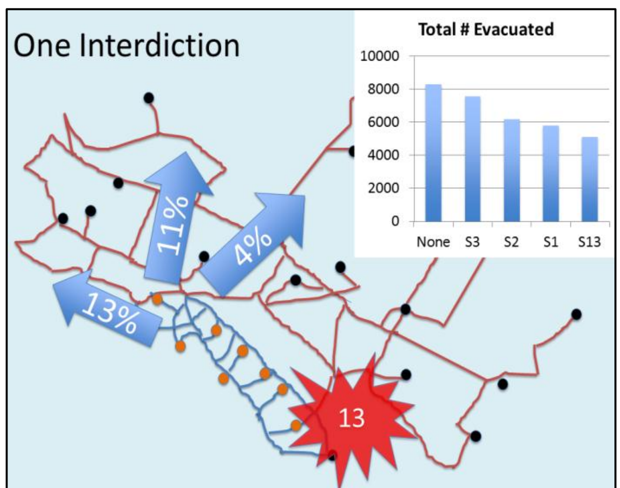
Analysis

Our analysis aimed to identify the resiliency of the confined road network and its capability of delivering all 20,000 residents to a shelter. Under reasonable traffic conditions the model supports the city's vertical evacuation policy; not all evacuees driving will evacuate in time. A baseline comparison of 60 minutes was used to validate the model; in October 2012 the city was able to evacuate Waikiki within the required timeline due to a tsunami warning that occurred at 3:00 a.m. Sensitivity analysis of the rate of travel versus the number of personnel evacuated showed diminishing results past 18 mph traffic rates for most evacuation timeframes.



Sensitivity analysis to identify how the varying evacuation reaction times will affect the number of personnel evacuated. This is specific to all personnel evacuating by automobile. Diminishing effects occur at at about 18mph for most evacuation timeframes. A rate of travel exceeding 10 mph is not expected.

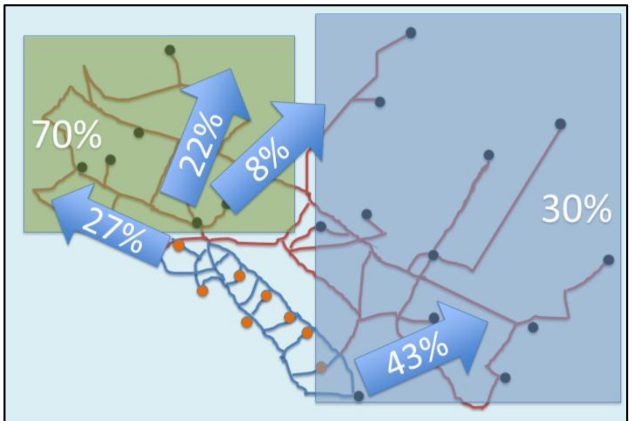
Since traffic conditions are never maintained at ideal, a series of accidents were interdicted to identify key nodes for police support. With a single accident or abandoned car occurring on just one of the four exit choke points (13), the model identified a delay for 10,000 evacuees. With a decreased capacity, due to heavy traffic conditions and a delayed reaction of evacuation, only 5,000 in the model were evacuated.



The model identified the best location for police support is at point 13; the most detrimental location for an accident on the network.

Our secondary analysis aimed to identify potential improvements in the evacuation support structure. Considering the small evacuation distance required, walking out of the evacuation zone is a plausible course of evacuation to avoid the vehicular traffic delay scenario; however this is dependent on the actual elevation tsunami water levels reach.

The model also identified the general flow of evacuees out of the area. Shelters to the northwest of Waikiki were modeled to receive the majority of evacuees (57%), compared to 43% of the flow exiting from the southeastern choke point. The problem with this flow is that 70% of the total shelter capacity is located in the northwestern region; an abundance of shelter space. In contrast, 30% of the available shelter capacity is located in the southeastern region; a shortage of shelter space for the traffic flow. In addition, six of the shelters in the northwestern area are situated at elevations comparable to the evacuated area. In the event of proportional geographic statistics to the 2011 tsunami that hit Japan, all of these shelters would go under water (tsunami waters reached 40 meter land elevation).



70% of the shelter capacity is located in the northwestern region, however only 57% of the network flow is directed to that area. In contrast, there is a shortage of shelter capacity based on the directed network flow in the southeastern exit.

Summary and Conclusion

The current evacuation zones in Waikiki covers up to 20 meters elevation and about one mile inland distance; much less than the recent 9.0 magnitude earthquake driven tsunami that hit Japan (40 meters and six miles inland) that resulted in over 15,000 deaths. In the event of a megatsunami, the city will not be capable of evacuating all of its residents within the 30 minutes of arrival to a safe location (which extends beyond the current evacuation zone); therefore the model supports the city's current policy for vertical evacuation in that situation. In a smaller scale slump, with disaster specifications similar to the 2011 tsunami that hit Japan, Oahu requires the identification of additional shelters capable of housing 13,000 in the vicinity of the University of Hawaii to support the network flow of evacuee traffic. Currently, published disaster shelter locations do not clearly distinguish between different types of natural disasters; therefore tsunami evacuating residents could potentially move to geographic locations safe for hurricanes, but not safe for tsunamis.

A future study in the logistical rebuilding of Waikiki is still required. In parallel, just to the west of Waikiki are Joint Base Pearl Harbor-Hickam and the Honolulu International Airport. In the event of a tsunami hitting this area, its major transportation nodes could potentially be inoperable at the same time resulting in a major decrease of operational effectiveness for strategic air mobility and the island's ability to recover. Hawaii is almost 100% supported by imports for food, supplies, gas, and building material. It also requires the use of export barge shipping of trash; 2,000 tons per week. The external requirement for logistical support of a recovery effort and the estimated timeframe for its arrival are essential for identifying the islands on-hand requirements.

Synonymous to a partial Hilina Slump tsunami, is a devastating hurricane hitting Waikiki. The area has exceptional tsunami warning systems, and has improved its evacuation procedures, however the second order effects of logistically supporting an evacuation is not clear. Waikiki is not the most likely path of the current natural disasters; however it is the most deadly course of action for any disaster in the Hawaiian Islands.