

Determining Evacuation Fleet Sizes for US Noncombatant Evacuation Operations in South Korea

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Background

- Noncombatant Evacuation Operations (NEOs) are operations to evacuate US citizens from a host nation to a safe haven in an emergency
- A South Korea NEO provides a complex scenario with a more robust network and larger populations than past NEOs
- A combination of buses, trains, and helicopters are available in South Korea to transport people to a sea port evacuation point
- An existing mixed-integer linear programming (MILP) model provides specific decision and routing data based off of optimal flow through deterministic scenarios

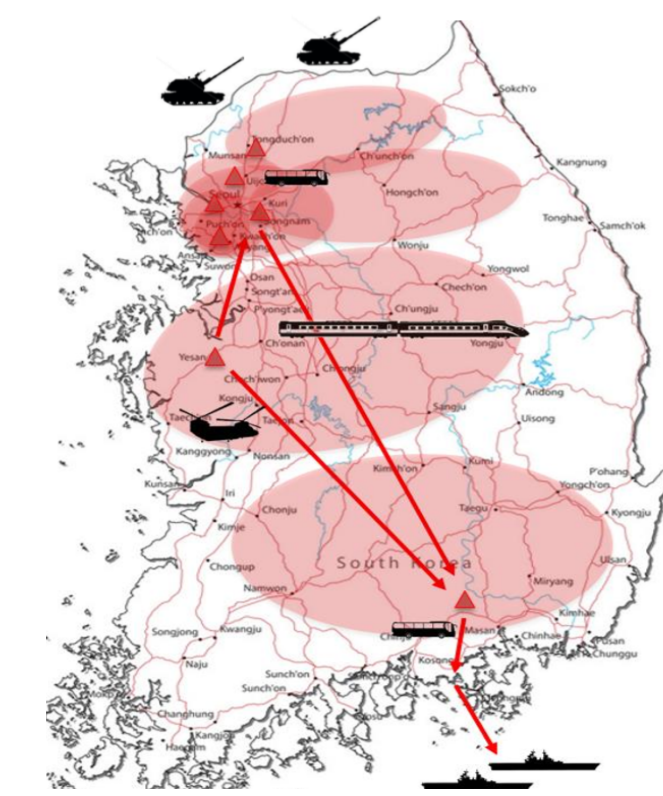


Figure 1: Characteristics of a South Korean NEO

Objective

- Design a simulation model that can answer more broad “what-if” questions and run stochastic scenarios
- Utilize outputs from the existing MILP model to decide where to allocate resources in a simulation
- Assess the effect that the amount of buses and helicopters have on the total evacuation time and other key performance indicators

Assumptions

- The US Military has little influence over the South Korean train system
- Trains have a capacity of 750, buses have a capacity of 45, and helicopters (CH-47 Chinooks) have a capacity of 35

Simulation Design

Network: 14 separate nodes span the system consisting of US Army bases, train stations, and predetermined evacuation locations

Routes: Selected from the MILP as the most common routes for optimal flow over multiple arrival patterns

Arrivals: Evacuees assemble at each assembly point following a time varying Poisson process subject to the regional population

Vehicle Allocation: Vehicles are assigned to routes based on their utilization through multiple runs of the MILP model as shown in Table 1 and 2

Experimental Design: Support military planning by evaluating different resource combinations to understand how decisions affect total evacuation times and number of evacuees at each node

Scenario: Evacuate Department of Defense families and US Government Employees living in South Korea (a total of 18679 evacuees) over an average assembly time of 24 hours

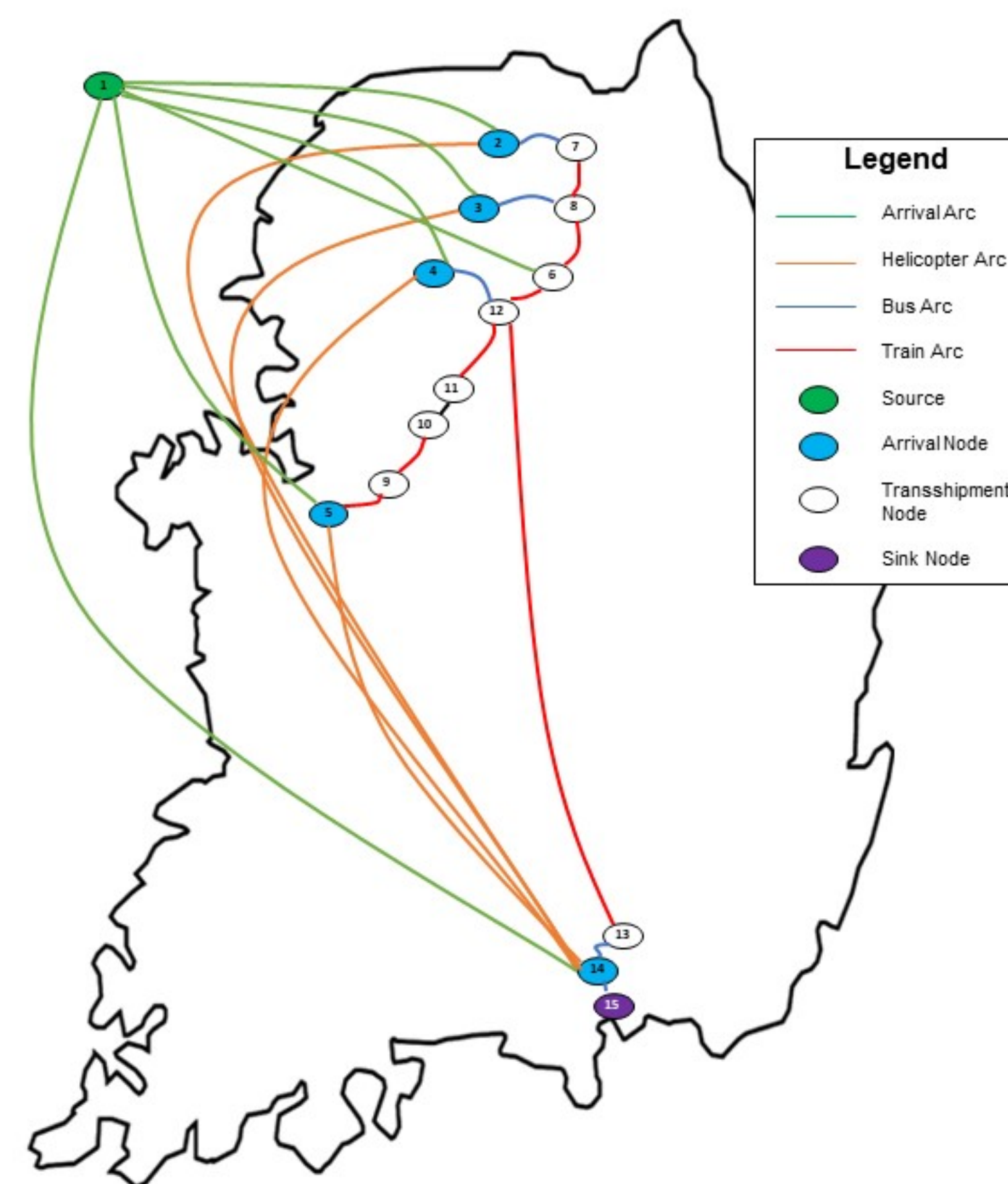


Figure 2: Diagram of the South Korea NEO network

Bus Experimental Breakdown								
Route	Allocation*	10	20	30	40	50	60	70
2 to 7	5.0%	1	1	2	2	3	3	4
3 to 8	5.9%	1	1	2	2	3	4	4
4 to 12	9.1%	1	2	3	4	5	6	7
5 to 9	6.3%	1	2	2	3	3	4	5
13 to 14	29.8%	3	6	9	12	15	18	21
14 to 15	41.7%	3	8	12	17	21	25	29

Table 1: Bus allocation among routes from assembly points to train stations and from train stations to sink

Helicopter Experimental Breakdown							
Route	Allocation*	0	4	8	12	16	20
2 to 14	5.8%	0	0	0	1	1	1
3 to 14	6.2%	0	0	0	1	1	1
4 to 14	22.4%	0	2	3	4	6	7
5 to 14	52.7%	0	2	5	6	8	11

Table 2: Helicopter allocation among routes from assembly points to Node 14

*May not add up to 100% due to rounding

Results

Average Total Evacuation Time (hours)

Buses	Helicopters					
	0	4	8	12	16	20
10	175.8	111.1	92.8	80.8	71.3	69.9
20	82.9	74.0	66.4	61.6	53.1	48.9
30	66.3	56.4	53.1	50.6	44.5	42.9
40	52.5	47.7	45.1	42.5	39.8	38.9
50	44.8	42.3	40.1	38.8	38.6	37.4
60	44.3	40.6	40.3	39.3	38.4	38.0
70	43.9	40.9	40.1	39.6	38.4	38.0

Table 3: Evacuation time decreases as more helicopters and buses are added to the simulation. After 50 buses, however, the drop-off in evacuation time is minimal, due to the restrictions on train capacity.

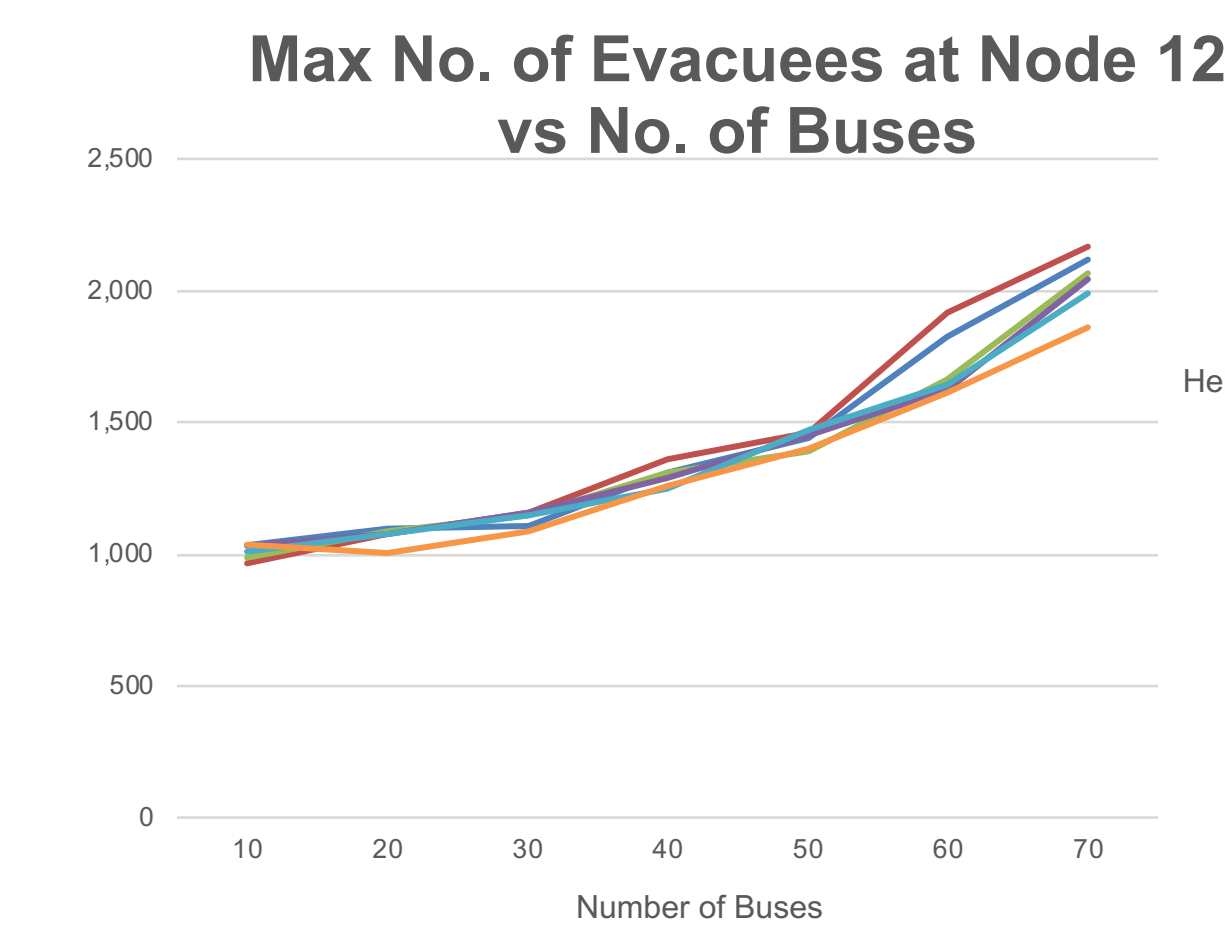


Figure 3: Increasing the number of buses results in a larger pileup of evacuees at train stations (Nodes 6-13).

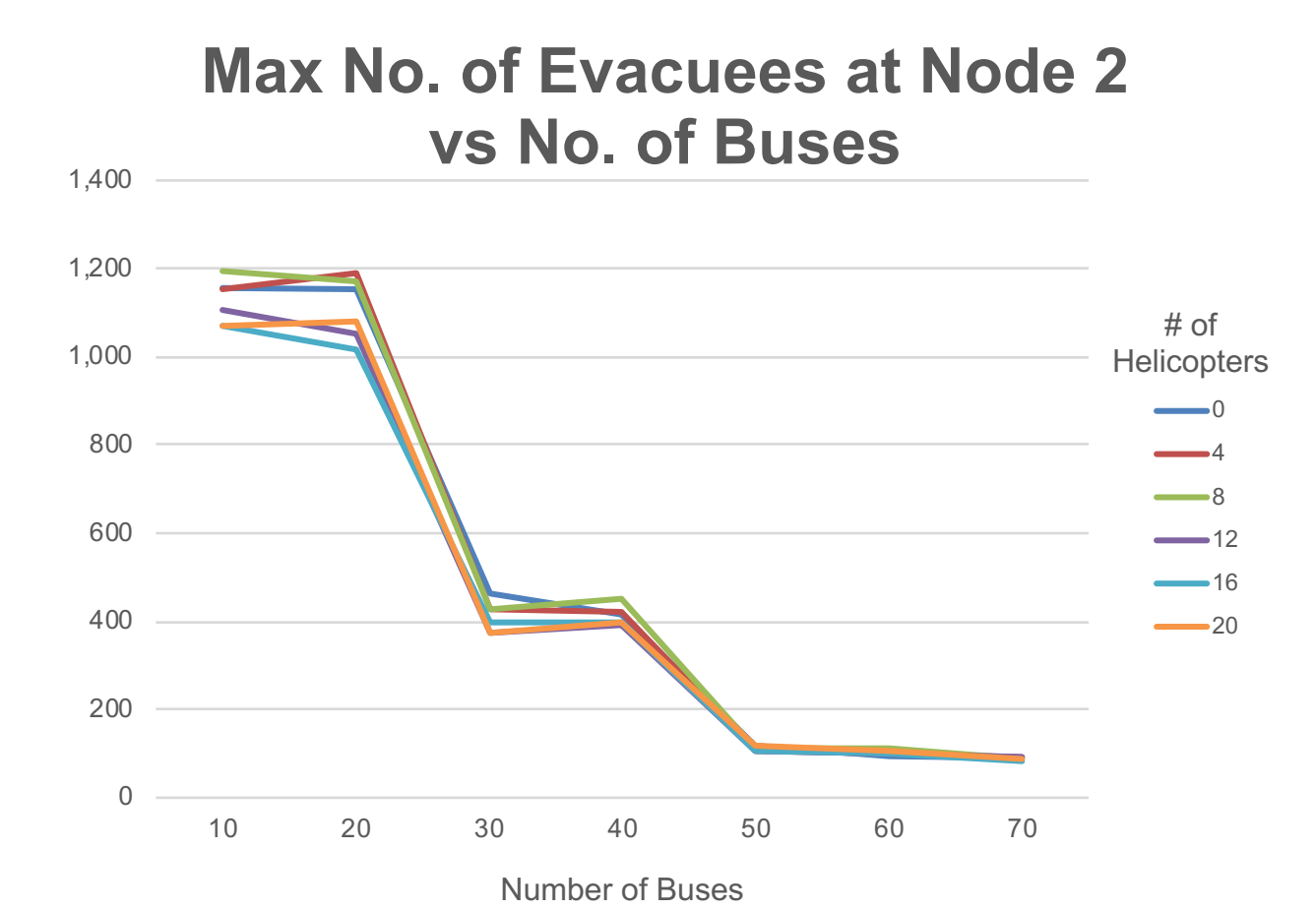


Figure 4: Increasing the number of buses results in a smaller number of evacuees waiting at the outlying assembly points (Nodes 2-5).

Conclusion

- Evacuation time plateaus at 50 buses—additional buses provide minimal performance returns
- The addition of more buses to the evacuation results in more evacuees waiting at train stations and less waiting at assembly points, which could be advantageous logistically in terms of food and water distribution
- Due to the bus saturation point, it is difficult to replace helicopters with buses and achieve the same results
- The increase of buses and helicopters in the system provides diminishing marginal returns, as expected, though helicopters prove to be the more strategic and consistently valuable of the two resources