COVID-19 RELIEF PROPOSAL

5260 Math Modeling

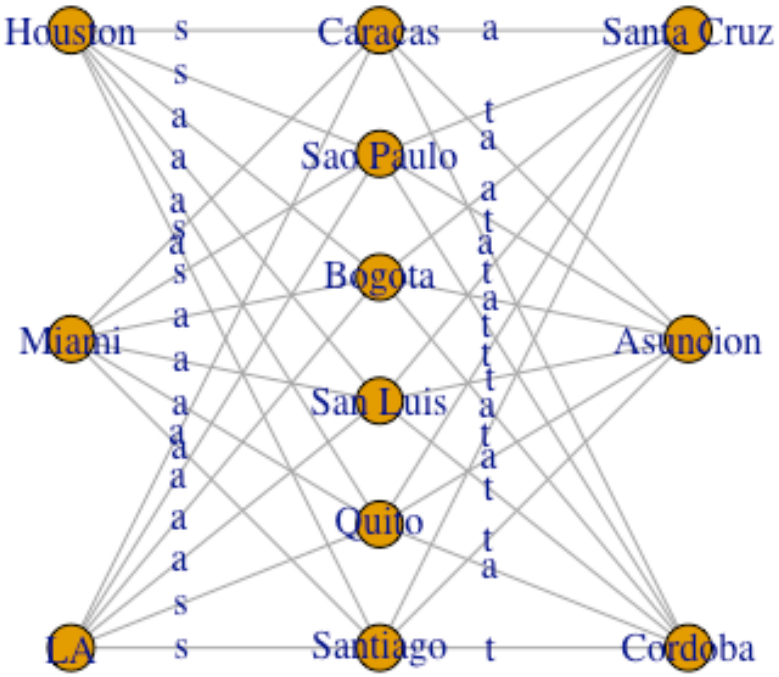
Created by

Gabe Boucaud | Kimberly Le

TABLE OF CONTENTS

To: South American Task Force, Director
From: Gabe Boucaud, Kimberly Le (on behalf of the United States Government)
Date: 13 May 2021
Subject: Three scenario plans for supplying international communities with COVID-19 Relief

The COVID-19 pandemic has been a detrimental impact on the world. Representing on the behalf of the United States' Government and working alongside with the South American Task Force (SATF), we have considered the necessary supplies and appropriate travels required by the SATF director. Below is a network map showing the routes and mode of transportation (a == airport, s == ship, t == truck), with respect to the distribution sites, staging cities and severely impacted cities:



We have curated **three** different scenario plans for your approval:

- Scenario 1: Transporting inventory to the three severely impacted cities in the least amount of total time possible.

- Scenario 2: Transporting inventory while considering the minimum cost of cargo weight and flight schedule restrictions.

- Scenario 3: Maximizing the inventory transported, while taking into account the weight and flight restrictions (from scenario 2), as well as additional flight and highway constraints.

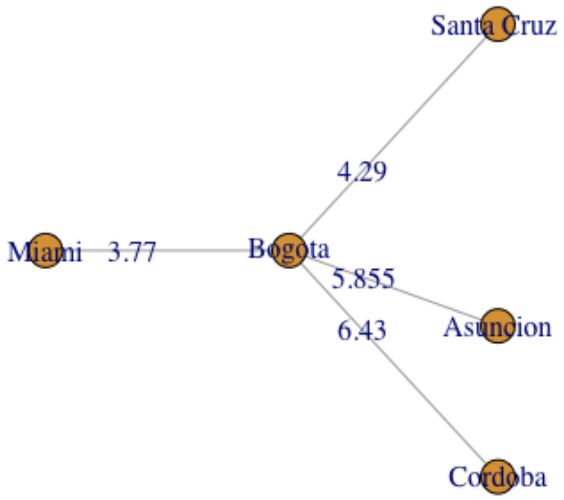
Scenario 1: Rapid Response Plan

Our first scenario calls for the fastest transportation of inventory, from the U.S. cities (Houston, Miami, LA) to the 3 severely impacted cities (Santa Cruz, Asuncion, Cordoba), and passing through at least one staging city (seen above). Given the transportation characteristics:

Table 3: Transport Characteristics

Type	Capacity (tons)	Speed (mph)
Airplane	150	400
Ship	240	35
Truck	17.7	50

We created a model to find the shortest path, as seen below:



Breaking down the diagram above, the fastest route to supply each highly impacted city is:

- 3 planes traveling for 3.77 hours from Miami to Bogota, Colombia.
- 1 plane traveling for 4.29 hours from Bogota, Colombia to Santa Cruz, Bolivia.
- 1 plane traveling for 5.855 hours from Bogota, Colombia to Asuncion, Paraguay.
- 1 plane traveling for 6.43 hours from Bogota, Colombia to Cordoba, Argentina

Which totals to 20.345 hours if the 3 planes from Miami leave at the same time.

Bottlenecks to be considered:

- The route in our solution with the most significant impact on time to supply all 3 cities is from Bogota to Cordoba.

Scenario 2: Minimum Cost Plan

The second scenario calls for a minimum cost strategy in response to several transportation constraints. (See Appendix for Details). The minimum cost to satisfy demand for all 9 South American cities are $397,313,250. The following table displays how supplies are allocated to and from each city.

	Caracas	Sao Paulo	Bogota	San Luis	Quito	Santiago
Houston	0	240,000	275,000	180,000	270,000	0
Miami	525,000	0	0	0	0	0
Los Angeles	0	0	0	0	120,000	380,000
Santa Cruz	30,000	0	0	0	120,000	0
Asuncion	120,000	0	0	0	0	0
Cordoba	75,000	0	75,000	0	30,000	0

- Use 1000 ships to transport 240000 tons of supplies from Houston to Sau Paulo at a cost of $137.50 per ton.
- Use 1834 planes to transport 275000 tons of supplies from Houston to Bogota at a cost of $240 per ton
- Use 1200 planes to transport 180000 tons of supplies from Houston to San Luis at a cost of $440 per ton
- Use 1800 planes to transport 270000 tons of supplies from Houston to Quito at a cost of $160 per ton. None of these supplies will be able to be shipped to a high-impact city via truck
- Use 2188 ships to transport 525,000 tons of supplies from Miami to Caracas at a cost of $54.17 per ton
- Use 500 ships to transport 120,000 tons of supplies from LA to Quito at a cost of $70.83 per ton
- Use 1584 ships to transport 384,000 tons of supplies from LA to Santiago at a cost of $145.83 per ton
- Use 200 planes to transport 30000 tons of supplies from Caracas to Santa Cruz at a cost of $226.67 per ton
- Use 6780 trucks to transport 120000 tons of supplies from Quito to Santa Cruz at a cost of $112.99 per ton
- Use 800 planes to transport 120000 tons of supplies from Caracas to Asuncion at a cost of $240 per ton
- Use 500 planes to transport 75000 tons of supplies from Caracas to Cordoba at a cost of $220 per ton
- Use 500 planes to transport 75000 tons of supplies from Bogota to Cordoba at a cost of $140 per ton
- Use 200 planes to transport 30000 tons of supplies from Quito to Cordoba at a cost of $246.67 per ton

Bottlenecks (limitations) to consider:

- Houston and Miami have 35,000 and 225,000 tons unused respectively. Los Angeles uses its entire supply and presents the least expensive routes to both Quito and Santiago. Because the Los Angeles to Santiago route is $127.50 less expensive than the next most cost-

effective alternative all 380,000 tons of demand are used. This causes Los Angeles to only have 120,000 additional tons to supply Quito at $70.83 per which has a demand of 240,000, the additional 120,000 plus 150,000 for high impact cities must come from Houston at $160 per ton. If we can increase the supply of Los Angeles by 120,000 tons of the 225,000 unused, we will realize cost savings of $10.7 million. If we increase the supply of Los Angeles to accommodate the full amount sent to Quito (390,000 tons) we will realize cost savings of over $24 million for the route. The route from Los Angeles to Quito is also via ship, so all units are available to be trucked to other destinations.

- If all 390,000 tons are available to be shipped from Los Angeles to Quito it will have additional cost savings in satisfying the demand requirements of Santa Cruz. Currently we fly 30,000 tons from Caracas to Santa Cruz at $226.67 per ton and drive 120,000 from Quito at $112.99. If we utilize the Quito to Santa Cruz truck route, we will see savings of $3.4 million.

Scenario 3: Maximizing total amount of cargo, disregarding cost

After receiving further details from South America governments, there are additional restrictions that we must address (See Appendix: Table 6, Table 7). The third scenario is designed to disregard cost and maximize the total amount of cargo supplied to the South American cities.

After developing a model to reflect these restrictions we see that the US can supply 2,121,860 tons of supplies using the following routes:

- Use 2282 ships to transport 547500 tons of supplies from Houston to Caracas
- Use 1192 ships to transport 285930 tons of supplies from Houston to Sao Paulo
- Use 800 planes to transport 120000 tons of supplies from Houston to San Luis
- Use 310 planes to transport 46570 tons of supplies from Houston to Santiago
- Use 700 planes to transport 105000 tons of supplies from Miami to Bogota
- Use 800 planes to transport 120000 tons of supplies from Miami to Quito
- Use 290 planes to transport 43430 tons of supplies from Miami to Santiago
- Use 875 ships to transport 210000 tons of supplies from LA to Quito
- Use 1209 ships to transport 290000 tons of supplies from LA to Santiago
- Use 450 planes to transport 67500 tons of supplies from Caracas to Santa Cruz
- Use 900 trucks to transport 15930 tons of supplies from Sao Paulo to Santa Cruz
- Use 700 planes to transport 105000 tons of supplies from Caracas to Asuncion
- Use 848 trucks to transport 15000 tons of supplies from Sau Paulo to Asuncion
- Use 500 planes to transport 75000 tons of supplies from Caracas to Cordoba
- Use 848 trucks to transport 15000 tons of supplies from Sau Paulo to Cordoba
- Use 600 planes to transport 90000 tons of supplies from Quito to Cordoba
- This totals to 2,121,860 tons of supplies
- Demand requirements would be satisfied for the following staging cities:
    - Caracas Sao Paulo, Quito, Santiago
- Demand requirements would be satisfied for the following high-impact cities:
    - Asuncion, Cordoba.

Some bottlenecks (limitations) that should be considered:

- Although we are looking to maximize the total tons of supplies provided to the 9 South American cities, we see that Miami does not use 481,870 tons of supplies even though there are 3 cities where demand requirements are not met. This occurs because Miami and Houston can only transport supplies via boat to the same 2 cities (Caracas and Sao Paulo). Due to the air restrictions and Houston being able to cover the supply for 2 full routes and 2 partial routes, Miami can only distribute 36% of their total supply. Therefore, the demand requirements are not met for both Bogota and San Luis because they are landlocked with no ocean routes.
    - These bottlenecks could be addressed if we are able to find a port city that the Columbian and Venezuelan governments are willing to pick up supplies.

- If the truck route from Sao Paulo to Santa Cruz or air route from Caracas to Santa Cruz was larger, we would be able to satisfy demand requirements of all three high-impact cities.

Appendix

Scenario 2 Constraints:

- Because of its elevation, only airplanes will be sent out of Quito unless the inventory arrived in Quito via ship.
- Only inventory that has arrived in Quito via ship can be trucked to another destination.
- Due to heavy rains, the roads around Asuncion, Paraguay are impassable. Supplies must arrive by air.
- Also, some South American airports cannot handle a heavy flight volume. Therefore, at most 500 flights are allowed from Caracas, Venezuela to Cordoba, Argentina and 500 flights from Bogota, Colombia to Cordoba, Argentina.
- In addition, 200 total flights are permitted into Santa Cruz de la Sierra, Bolivia.

Scenario 3 Constraints:

Table 6: Air Restrictions

(question 4 only)

Flights Into	Max Airplanes
Caracas, Venezuela	300
Sao Paulo, Brazil	250
Bogota, Colombia	700
San Luis, Argentina	800
Quito, Ecuador	900
Santiago, Chile	600
Santa Cruz de la Sierra, Bolivia	450
Asuncion, Paraguay	700
Cordoba, Argentina	1,100

Table 7: Truck Restrictions

(question 4 only)

From	Max Trucks
Santa Cruz de la Sierra, Bolivia	900
Asuncion, Paraguay	1,000
Cordoba, Argentina	1,200