To: Professor Green

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RE: Aiding Africa Project

Network graph

For the Aiding Africa problem, it consists 11 cities, 2 origins from the US and 9 destinations in the Africa. 6 of the Africa cities are used as connections to the other 3. The 11 cities are linked by 30 routes, every route is conducted by 1 of the 3 transportation modes(airplane, ship, truck). For each route, it has unique cost and vehicle capacities. The graph below shows the relationship between the cities and the routes.

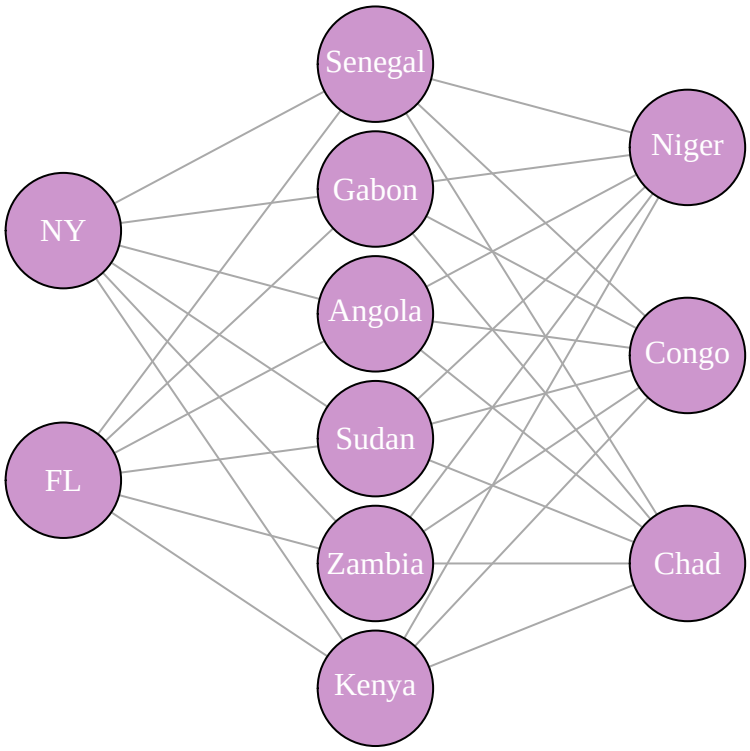

Table 1: Shortest travel time(For Case 1)

Departure City	**Arrival City**	**Travel Time (hr)**
New York, NY	Libreville, Gabon	172.11
New York, NY	Khartoum, Sudan	17.6
New York, NY	Luanda, Angola	186.46
Jacksonville, Florida	Lusaka, Zambia	19.86
Jacksonville, Florida	Nairobi, Kenya	19.9
Jacksonville, Florida	Khartoum, Sudan	112.11
New York, NY(Through Khartoum, Sudan)	Niamey, Niger	22.76
New York, NY(Through Khartoum, Sudan)	Kosongo, D.R. Congo	21.04
New York, NY(Through Khartoum, Sudan)	Ndjamena, Chad	20.60
Total		592.44

Case 1 - Shortest Paths

The minimine travel time among the 11 cities takes 592.44 hours to complete. For the shortest paths, Table 1 shows the quickest travel routes and time needed from the 2 cities in the US to the 9 destinations in Africa.

The route that indicate significant time bottlenecks is from “Jacksonville, Florida” to “Lusaka, Zambia”, this route needs to reduce 0.68 hours (approximately 41 minutes) to affect vehicle allocation across the netwoek and decrease the minumum total travel time.

Table 2: Recommended Routes for Minimum Cost Allocation(For case 2)

Departure City	**Arrival City**	**No. of Vehicles**	**Total Cargo Delivered(Tons)**
New York, NY	Lusaka, Zambia	266.7	40,005
New York, NY	Libreville, Gabon	1,166.7	280,008
New York, NY	Luanda, Angola	541.7	130,008
New York, NY	Dakar, Senegal	208.3	49,992
Jacksonville, Florida	Lusaka, Zambia	733.3	109,995
Jacksonville, Florida	Nairobi, Kenya	1,133.3	169,995
Jacksonville, Florida	Khartoum, Sudan	1,466.7	220,005
Khartoum, Sudan	Niamey, Niger	666.7	100,005
Libreville, Gabon	Kosongo, D.R. Congo	10,169.5	180,000
Nairobi, Kenya	Ndjamena, Chad	333.3	49,995
Khartoum, Sudan	Ndjamena, Chad	200.0	30,000
Total			1,360,008

Case 2 - Minimum cost flow

Network path that minimize total cost incurs a total expense of $310,861,299 USD. This value is an underestimate as it allocates number of vehicles to its decimals, which might not be realistic. So to achieve the minimum cargo requirement of each city, should round-up the number of vehicles to nearest integer.

In this case, some restictions were applied: Niamey, Niger, can only recieve cargo via air; Ndjamena, Chad, cannot receive more than 840 trucks from each port; routes between Lusaka, Zambia to Ndjamena, Chad, and Khartoum, Sudan to Ndjamena, Chad can only allow 200 flights from each airfield. Despite these restrictions, the cargo needs of all 9 destinations are still fully satisfied. Table 2 lists the routes used to achieve the minimum cost path, and the vehicle allocations for each of these routes.

There are three routes tied for tighest bottleneck: Jacksonville, FL to Lusaka, Zambia; New York, NY to Nairobi, Kenya; and Luanda, Angola, to Kosongo, D.R. Congo. The route from Jacksonville, FL to Lusaka, Zambia needs to reduce costs by at most $1,000 USD to decrease the minimum total transit cost.

Table 3: Recommended Allocation (Maximum Cargo Shipped)(For case 3)

Departure City	Arrival City	No. of Vehicles	Total Cargo Delivered(Tons)
New York, NY	Lusaka, Zambia	300.0	45,000
New York, NY	Libreville, Gabon	679.8	163,152
New York, NY	Nairobi, Kenya	500.0	75,000
New York, NY	Khartoum, Sudan	500.0	75,000
New York, NY	Luanda, Angola	577.8	138,672
New York, NY	Dakar, Senegal	293.1	70,344
Jacksonville, Florida	Lusaka, Zambia	500.0	75,000
Jacksonville, Florida	Nairobi, Kenya	640.0	96,000
Jacksonville, Florida	Khartoum, Sudan	520.0	78,000
Libreville, Gabon	Niamey, Niger	3107.3	54,999.21
Khartoum, Sudan	Niamey, Niger	300.0	45,000
Libreville, Gabon	Kosongo, D.R. Congo	300.0	5,310
Nairobi, Kenya	Kosongo, D.R. Congo	40.0	6,000
Khartoum, Sudan	Kosongo, D.R. Congo	80.0	12,000
Luanda, Angola	Kosongo, D.R. Congo	250.0	4,425
Dakar, Senegal	Kosongo, D.R. Congo	700.0	12,390
Libreville, Gabon	Ndjamena, Chad	160.0	2,832
Nairobi, Kenya	Ndjamena, Chad	300.0	45,000
Khartoum, Sudan	Ndjamena, Chad	40.0	6,000
Luanda, Angola	Ndjamena, Chad	240.0	4,248
Dakar, Senegal	Ndjamena, Chad	456.0	8,071.2
Total			816,170

Case 3 - Maximum cargo flow

Given tighter shipment restrictions on more routes, the network paths that maximizes total cargo dispatches only 816,170 tons cargo. Table 3 shows the the routes used to achieve the maximum cargo,and the vehicle allocations for each of these routes. Unfortunately, in this case, only 6 destinations recieve its full cargo requirements. The 3 cities with lacking cargo are: Lusaka, Zambia; Kosongo, D.R. Congo; and Ndjamena, Chad.

To increase the total cargo allocation, we can increase number of flights flown from Nairobi, Kenya and Khartoum, Sudan to Jacksonville, FL. We can increase number of flights by 60 and 80, respectively. These extra flights will cause bottlenecks for routes from Nairobi, Kenya and Khartoum, Sudan to Kosongo, D.R. Congo. The restriction on routes from Nairobi, Kenya and Khartoum, Sudan to Kosongo, D.R. Congo, should be increased by 60 and 80 respectively. These bottlenecks are largely driven by the cargo shortage in Kosongo, D.R. Congo, which is the largest.