The goal of the mid-term project is for you to apply what you have learned about linear programming to a case study, and produce a professional document discussing your findings. I prefer you work in groups of two, but it is okay if you need to work alone. No groups larger than two. Each team will submit two documents, 1) a professionally formatted memo (i.e. follows guidelines established in BUAN 5210) written to a lay audience addressing the questions posed below, and 2) the R Markdown file used to complete the analysis and render the memo (all code should be clearly documented). You should code the analysis and memo to be easily reproducible (i.e. no cutting and pasting) and is easy to update if there are changes in the data (i.e. the code reads all data and names from the provided csv file). This will require you to reshape the data after reading it into R, code a network/map diagram using a package in R, and format results in tables, in addition to specifying and solving the linear programming problems

Aiding Africa: Disaster/disease relief plan

Gail McGovern, CEO of the American Red Cross, and the International Federation of Red Cross (IFRC) have decided to proactively develop aid disbursement plans for Africa, which is often considered the most disease and disaster-prone continent. African communities suffer from lack of infrastructure, unstable government and inadequate resources to cope with natural and health related disasters. Gail McGovern has recently been briefed about the difficulties of assisting communities in Africa and has decided to assemble several plans of action. The memo documenting the action plans will be shared with potential donners to help raise funds for the IFRC.

Gail McGovern works with Tadateru Konoe, the President of the Board of Governors for the IFRC, to determine the necessary workers and supplies for assisting Africa. Tadateru Konoe has indicated that along with workers, equipment, food, fuel, and other supplies, aircraft, ships, and vehicles will be needed for transport. This can all be assembled and sent from two American cities with airfields and shipping ports: New York and Jacksonville, Florida. The aircraft and ships will transfer all workers and cargo across the Atlantic Ocean to the African continent. The list of aircraft, ships, and vehicles being assembled and their characteristics are shown below (Table 1) and in the data file. All aircraft, ships, and vehicles can carry both workers and cargo. Once an aircraft or ship arrives in Africa, it stays there to support the workers.

Tadateru Konoe has been negotiating with the African countries for the last several weeks to use their ports and airfields as stops to refuel and resupply before heading deeper into Africa. The ports and airfields listed in Table 2 in the African countries will be made available to the IFRC. The team has determined that there are three strategic cities in the Africa: Niamey, Niger; Kosongo, D.R. of the Congo; and Ndjamena, Chad. Workers and cargo will be used both to support the cities and to disperse supplies across Africa.

All airplanes and ships will leave New York or Jacksonville, Florida. All ships that have traveled across the Atlantic must dock at one of the IFRC ports to unload. Trucks brought over in the ships will then carry workers and materials unloaded from the ships at the IFRC ports to the three strategic IFRC cities. All airplanes that have traveled across the Atlantic must land at one of the IFRC airfields for refueling. The planes will then carry some workers and cargo from the IFRC airfields to the three IFRC cities. Supplies and workers will be delivered to each IFRC port city, airfield city and strategic disbursement city according to the requirements listed in Table 4.

1. Code a "network map" showing the different routes workers and supplies may take to reach the African cities from the United States.

2. The IFRC and Gail McGovern do not know when the next disaster will occur so several plans will need to be designed. The first plan should be designed to enable workers and supplies to arrive at all the IFRC cities as quickly as possible. Gail McGovern refers to this as the "cost is no object" plan—as many airplanes, ships, and trucks as are necessary would be used to transfer workers and cargo from the United States to all nine cities. Therefore, no limitations exist on the number of workers and amount of cargo that can be transferred between any cities. Gail McGovern has been given the following information about the length of the available routes between cities (Table 3).

   Given the distance (Table 3) and the speed of the transportation used (Table 1) between each pair of cities, how can Gail McGovern and the IFRC most quickly move workers from the United States to each of the nine IFRC cities? How long will it take workers and supplies to reach each city using the quickest route? Which routes appear to have significant time bottlenecks that the IFRC should work to reduce? Provide a table and/or network map indicating the quickest route and travel time between the United States and African cities on the network.

3. Gail McGovern and the IFRC want to develop a second plan, one that recognizes the cost of sending workers and supplies. They therefore decide that they need to find a way to get the needed workers and supplies to the nine cities at "minimum cost". Tadateru Konoe has worked with representatives from each IFRC city to determine the number of workers and supplies the city needs at a minimum. After analyzing the requests, Tadateru Konoe has converted the requests from numbers of workers, gallons of gasoline, etc., to tons of cargo for easier planning (Table 4). Both in New York and Jacksonville, Florida there are 500,000 tons of the necessary cargo available. When the United States decides to send a plane, ship, or truck between two cities, several costs occur—fuel costs, labor costs, maintenance costs, and appropriate port or airfield taxes and tariffs (Table 3). Note, the costs of delivery are not uniform on a per mile basis due to differences of tax, tariff, and other costs (such as bribery) that vary by region.

   The IFRC faces a number of restrictions when trying to satisfy the requirements. Supplies to Niamey, Niger can only arrive via air. The truck routes into Ndjamena, Chad are restricted so at most 840 trucks can be sent to Ndjamena, Chad from each port. Some African governments are sensitive about IFRC airplanes flying through their air space. The IFRC is restricted to at most 200 flights from Lusaka, Zambia to Ndjamena, Chad and to at most 200 flights from Khartoum, Sudan to Ndjamena, Chad.

   How should the IFRC satisfy each African city's need requirements at minimum cost? Again, where are the significant bottlenecks in the system that the IFRC should work to reduce? Provide a table and/or network map highlighting the least cost route between the U.S. and African cities.

4. The IFRC has a rough estimate of the number of planes, ships, and trucks that will travel between the United States and Africa. Tadateru Konoe has contacted each of the American cities and IFRC countries to indicate the number of planes to expect at the airfields, the number of ships to expect at the docks, and the number of trucks to expect traveling across the roads. Unfortunately, Tadateru has learned that several additional restrictions exist which cannot be immediately eliminated. Because of airfield congestion and unalterable flight schedules, only a limited number of planes may be sent between any two cities (Table 5). In addition, because some countries fear that citizens will become alarmed if too many trucks travel the public highways, they object to having many trucks traveling through their countries. These objections mean that a limited number of trucks can travel between certain ports and African cities (Table 6). However, all shipping lanes have no capacity limits.

   Gail and Tadateru realize that the additional restrictions will prevent the IRFC from satisfying all the supply requirements of the IFRC cities. They decide on a third plan to disregard cost and instead maximize the total amount of cargo to the IFRC cities.

   How can the IFRC maximize the total amount of cargo that reaches Africa? Again, where are the significant bottlenecks in the system that the IFRC should work to reduce? Provide a table and/or network map highlighting the maximum cargo and routes between the U.S. and African cities.

Make sure to provide a brief introduction and summary of your findings in addition to discussing each of the three cases.

Table 1: Transport characteristics

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

Table 2: African destinations

Ports	Airfields
Dakar, Senegal	Khartoum, Sudan
Libreville, Gabon	Lusaka, Zambia
Luanda, Angola	Nairobi, Kenya

Table 3: City transport pairs, transport modes, distances and costs

From	To	Transport Mode	Distance (miles)	Cost ($000)
New York, NY	Lusaka, Zambia	Airplane	8098	50
New York, NY	Libreville, Gabon	Ship	6024	30
New York, NY	Nairobi, Kenya	Airplane	8050	55
New York, NY	Khartoum, Sudan	Airplane	7041	45
New York, NY	Luanda, Angola	Ship	6526	30
New York, NY	Dakar, Senegal	Ship	4172	32
Jacksonville, FL	Lusaka, Zambia	Airplane	7944	57
Jacksonville, FL	Libreville, Gabon	Ship	6329	48
Jacksonville, FL	Nairobi, Kenya	Airplane	7961	61
Jacksonville, FL	Khartoum, Sudan	Airplane	7084	49
Jacksonville, FL	Luanda, Angola	Ship	6828	44
Jacksonville, FL	Dakar, Senegal	Ship	3924	56
Lusaka, Zambia	Niamey, Niger	Airplane	4070	24
Libreville, Gabon	Niamey, Niger	Truck	1032	3
Nairobi, Kenya	Niamey, Niger	Airplane	2524	28
Khartoum, Sudan	Niamey, Niger	Airplane	2065	22
Luanda, Angola	Niamey, Niger	Truck	2916	3
Dakar, Senegal	Niamey, Niger	Truck	1656	5
Lusaka, Zambia	Kosongo, D.R. Congo	Airplane	746	22
Libreville, Gabon	Kosongo, D.R. Congo	Truck	1842	4
Nairobi, Kenya	Kosongo, D.R. Congo	Airplane	1090	25
Khartoum, Sudan	Kosongo, D.R. Congo	Airplane	1377	19
Luanda, Angola	Kosongo, D.R. Congo	Truck	1389	5
Dakar, Senegal	Kosongo, D.R. Congo	Truck	4623	5
Lusaka, Zambia	Ndjamena, Chad	Airplane	2110	23
Libreville, Gabon	Ndjamena, Chad	Truck	1415	7
Nairobi, Kenya	Ndjamena, Chad	Airplane	1768	2
Khartoum, Sudan	Ndjamena, Chad	Airplane	1200	4
Luanda, Angola	Ndjamena, Chad	Truck	2652	8
Dakar, Senegal	Ndjamena, Chad	Truck	2725	9

Table 4: Aid requirements	
City	Requirements (tons)
Dakar, Senegal	50000
Libreville, Gabon	100000
Luanda, Angola	130000
Khartoum, Sudan	90000
Lusaka, Zambia	150000
Nairobi, Kenya	120000
Niamey, Niger	100000
Kosongo, D.R. Congo	180000
Ndjamena, Chad	80000

Table 5: Air restrictions (question 4 only)		
From	To	Max Airplanes
New York, NY	Lusaka, Zambia	300
New York, NY	Nairobi, Kenya	500
New York, NY	Khartoum, Sudan	500
Jacksonville, FL	Lusaka, Zambia	500
Jacksonville, FL	Nairobi, Kenya	700
Jacksonville, FL	Khartoum, Sudan	600
Lusaka, Zambia	Niamey, Niger	200
Nairobi, Kenya	Niamey, Niger	0
Khartoum, Sudan	Niamey, Niger	300
Lusaka, Zambia	Kosongo, D.R. Congo	140
Nairobi, Kenya	Kosongo, D.R. Congo	40
Khartoum, Sudan	Kosongo, D.R. Congo	80
Lusaka, Zambia	Ndjamena, Chad	0
Nairobi, Kenya	Ndjamena, Chad	300
Khartoum, Sudan	Ndjamena, Chad	40

Table 6: Truck restrictions
(question 4 only)

From	To	Max Trucks
Luanda, Angola	Kosongo, D.R. Congo	250
Luanda, Angola	Ndjamena, Chad	240
Libreville, Gabon	Kosongo, D.R. Congo	300
Libreville, Gabon	Ndjamena, Chad	160
Dakar, Senegal	Kosongo, D.R. Congo	700
Dakar, Senegal	Ndjamena, Chad	450