Chapter 2 Answer Key

**1. Given the analysis presented in this chapter, where would you put the capital of Logistica and why? What factors went into your decision?**

This is a bit of an open-ended question and could be good for class discussion. But it is not that difficult**—**the students should use the statistics from the Logistica spreadsheet (see <http://networkdesignbook.com/academic-use/chapter-2-material/>). Better answers will pick a city that has a low average distance and a high percentage of citizens within 100, 200, and 300 miles of the capital. Students will have different ways of weighting these factors, so you may see different answers and subtle trade-offs:

* City 11 minimizes Weighted Average Distance at 371.
* Cities 4 and 10 maximize the percent within 100 miles at 24%. City 7 is not far behind at 23%.
* City 10 maximizes the percent within 200 miles at 49%. City 4 is not far behind at 48%.
* Cities 7, 10, and 11 maximize the percent within 300 miles at 58%. Cities 3 and 4 are not far behind at 56%, while City 1 is at 54%.

A good answer or a good class discussion should talk about these quantitative factors as well as touch on the quality of the infrastructure of the cities, maybe future growth rates, and other factors (see the question below).

**2. Besides the weighted-average distance and the percentage of customers within a certain distance of the capital, what other factors might the citizens of Logistica want to consider? Of these factors, which are quantifiable and which are qualitative?**

This question relates to the preceding question. You would certainly want to consider the infrastructure, future growth rates, maybe the weather (if certain cities are cut off from others because of storms or snow), cost to build in different locations, maybe the type of workforce available, security of the site, and other factors.

**3. If the planners of Logistica had been lucky enough for their first calculation to have picked an existing city, why should they still analyze other cities?**

You may need to clarify this question. The first calculation is the physics center of gravity that ended up putting their capital in the shark-infested waters off a deserted coast.

But, what if the populations were such that the capital ended up in an existing city? They should still look at other sites for the following reasons:

* The physics center of gravity minimized the sum of the demand multiplied by the distance squared—not exactly what they wanted.
* The more detailed analysis showed subtle trade-offs—is average distance more important than a lot of citizens very close to the capital?

**4. Name a reason why minimizing weighted-average distance is more important than maximizing the percentage of customers within a certain distance. Now, name a reason why maximizing the percentage of customers within a certain distance is more important than why minimizing weighted-average distance.**

This question could also be a nice class discussion. This gets students thinking about objectives and how to compare one solution to another (you can refer back to the optimization discussion in Chapter 1).

You may get some creative answers here.

Some reasons for minimizing weighted average distance:

* It can be viewed as a more fair measure since all citizens are factored in.
* If all citizens have to drive to the capital, this would minimize the average drive time and cost.
* This measure helps the citizens who are far away.

Some reasons for maximizing the percent within a given radius:

* Sometimes, once you pass a certain distance, everything that is far away has a similar cost**—**maybe in this case, after 300 miles, the citizens will fly, and so the distance is no longer that important.
* It can be beneficial to have a large concentration of citizens very close—maybe there is more feedback, participation, and demand relative to the distance. This is the opposite of the previous point—if a citizen is close to the capital, he gets even more benefit. In a business setting, if the facility is close to customers, maybe there is extra demand.

**5. If instead of weighting the problem by the population of each city, assume that the analysis was done with each city having equal weight. That is, what matters is how close a city is to the capital, not how many people live there.**

1. **Which capital location is now the best from an average-distance point of view?**
2. **Which capital is now the best in terms of the number of cities within 100, 200, and 300 miles?**
3. **Does this make the analysis easier or harder? Why?**

To answer this question, you want to use the Logistica spreadsheet and change the population to 1 for all cities. Now, each city has an equal weight (you could use any number as long as it was the same).

a). City 15 is the best with an average of 401. It is interesting that City 16 is only 5 miles different at 406 despite being far away from 15. It is also interesting that City 19 is at 414 despite being close to 16. You could discuss these findings. 15 is good because it balances the far western cities. 16 is also good because it is close to all the cities in the North East. The average for 19 seems to jump up because it is quickly moving away from the North East cities and is far from the Western cities.

b). Cities 10 and 4 have the most cities within 100 miles at 20%. Cities 4, 10, and 11 are the best at 200 miles with 36%. And, Cities 7, 10, and 11 are the best at 48%.

c). Sometimes students will think that this makes the problem easier. However, there are still trade-offs to make. The cities that showed up in Part (a) are very different from those in Part (b).

Here is what the new input for the spreadsheet looks like:



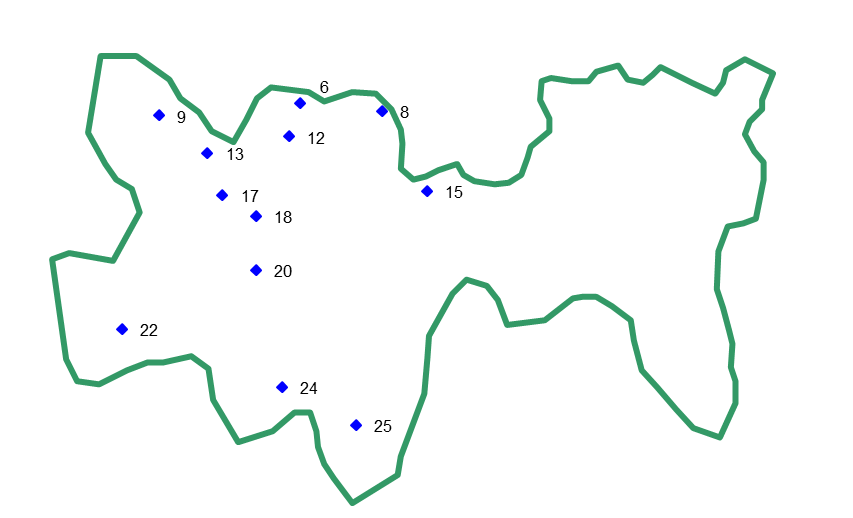
And, here is the output (the table at the bottom is the percent within 100, 200, and 300 miles):



**6. What if the western part of Logistica decided it needed a capital city as well? Assume that City 15 was the easternmost city in this region. What is the best location for the capital of the western half of Logistica? Why?**

This question allows the students to practice the analysis without knowing the answer. Of course, this is made easier because they have the spreadsheet. (You can make up a similar problem by creating your own data sets with more or fewer points and have the students re-create the analysis—you may find better ways to lay out the spreadsheet and map the points.)

The key here is to turn off the cities in the eastern part of the country. We did this by moving the cities to (0,0) and setting the population to zero. The cities you need to get rid of are 1-5, 7, 10-11, 14, 16, 19, 21, and 23. The new map looks like this:



Then, you can use the spreadsheet showing all possibilities to get the statistics:



(We’ve hidden the columns representing the eastern cities.)

City 18 does best on the average distance, but others do better within 100 and 200 miles.

**7. Often, when logistics practitioners think about having some automatic way of picking a latitude and longitude, they think about a problem such as where the four cities form a square on a map. In this case, let’s assume that each city has a population of one million, and the latitude and longitude of the four points are (15,155), (15,158), (18,155), and (18,158).**

**a. What is the latitude and longitude of the physics center of gravity?**

**b. What is the average distance to each of the cities from this point?**

**c. Is there a better point that would minimize the weighted-average distance?**

**d. If the population of City 1 were five million, what would be the physics center of gravity latitude and longitude?**

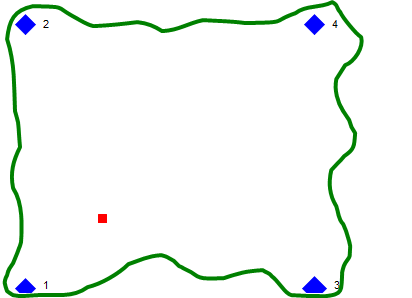
**Part (a) and (b)**. The physics center of gravity point is 16.5, 156.5. See the following chart:



**Part (c).** In this case, with a perfect square and an equal population, the physics center of gravity is also the point that minimizes the average distance. For example, if you place the site at any of the four points, the average goes up to 177. (It is a fun question to ask how frequently this situation happens—almost never!)



**Part (d).** If the population of City 1 was 5 million, then the physics center gravity moves much closer to City 1, but not all the way there. It goes to 15.8, 155.8. You can see below that locating the site at City 1 significantly lowers the average distance.



The square represents the physics of gravity when the population of City 1 is 5 million.