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2013

16th Annual High School Mathematical Contest in Modeling (HiMCM) Summary Sheet

(Please attach a copy of this page to your Solution Paper.)

Team Control Number: 4004
Problem Chosen: A

Please type a summary of your results on this page. Please remember not to include the name of your school, advisor, or team members on this page.

Based on the given information of time taken to travel from one zone to another, we created a model of the optimum configurations of three, two, and one ambulances in the county, and determined whether the ESC could cover a catastrophe. We started by setting definitions, assumptions, and variables, and then started analyzing the given data to see which ambulances could reach which zones within 8 minutes, to see which configurations could actually cover all 6 zones of the county. Following, with the 13 configurations that *could* cover the whole county, we analyzed each one based the ambulances' coverage of people within time constraints, based on data from emergency calls per day and time spent travelling to provide services to the person. With the remaining three ambulances that we determined to cover the same amount of people, we decided the optimum configuration through comparing the spare minutes of each ambulance, with the configuration being placing ambulances in zones 2, 4, and 6, with 97.7% of the people being covered and 6250 people left uncovered. However at the end, because not everyone was covered, three ambulances would not be able to cover everyone. Next, we repeated the process for two ambulances and one ambulance, and determined the configuration to be in zones 2 and 5, and in zone 2 respectively. Two ambulances covered 77.55% of the people and left 60,615 uncovered, and thus could not cover everyone. One ambulance covered 45.83% of the people and left 146,259 people uncovered and thus also could not cover everyone. We continued by trying multiple methods for three ambulances to tackle disasters, and we discovered that the best way to operate the ambulances in its stations was to use the "disaster-saver" method where an ambulance would go to a closest zone and operate there until all calls were dealt with before returning to its original zone. This method covered up to 94.1% of the people but left at least 16,045 people uncovered, so we determined that the ESC alone would not be able to cover a catastrophic event did occur. Although as a whole the county may be fine after the catastrophe, it will most likely have received much help from the state or country it is in. In addition, with the information gathered from researching case studies in places including Japan, Cuyahoga of Ohio, and San Diego, we discovered methods for the county or state to be prepared for catastrophes including floods, earthquakes, and hurricanes. Finally, we ended by writing a memo outlining our recommendations from our model and analysis finding for the ESC.

TEAM # 4004 - 2013 Math Modeling

Problem A - Emergency Medical Response

Restatement of the Problem:

Given information about the time required by an ambulance to travel between any two districts, and a table of population in each zone, we will find out which zones ambulances should be stationed in to cover as much of the population as possible within 8 minutes. We will model the locations of ambulances with one, two, and three ambulances available. We will also calculate how many people can and cannot be covered with one, two or three ambulances within 8 minutes of their call. Based on this, we will choose a final model that will cover the most people possible. We will also model a catastrophic situation involving all zones, and simulate how the Emergency Services Coordinator (ESC) should react. We will also research how real life counties respond to such catastrophic events. Lastly, we will prepare a 1-2 page memo summarizing our findings to provide to the Emergency Services Coordinator.

Summary:

Based on the given information of time taken to travel from one zone to another, we created a model of the optimum configurations of three, two, and one ambulances in the county, and determined whether the ESC could cover a catastrophe. We started by setting definitions, assumptions, and variables, and then started analyzing the given data to see which ambulances could reach which zones within 8 minutes, to see which configurations could actually cover all 6 zones of the county. Following, with the 13 configurations that *could* cover the whole county, we analyzed each one based the ambulances' coverage of people within time constraints, based on data from emergency calls per day and time spent travelling to provide services to the person. With the remaining three ambulances that we determined to cover the same amount of people, we decided the optimum configuration through comparing the spare minutes of each ambulance, with the configuration being placing ambulances in zones 2, 4, and 6, with 97.7% of the people being covered and 6250 people left uncovered. However at the end, because not everyone was covered, three ambulances would not be able to cover everyone. Next, we repeated the process for two ambulances and one ambulance, and determined the configuration to be in zones 2 and 5, and in zone 2 respectively. Two ambulances covered 77.55% of the people and left 60,615 uncovered, and thus could not cover everyone. One ambulance covered 45.83% of the people and left 146,259 people uncovered and thus also could not cover everyone. We continued by trying multiple methods for three ambulances to tackle disasters, and we discovered that the best way to operate the ambulances in its stations was to use the "disaster-saver" method where an ambulance would go to a closest zone and operate there until all calls were dealt with before returning to its original zone. This method covered up to 94.1% of the people but left at least 16,045 people uncovered, so we determined that the ESC alone would not be able to cover a catastrophic event did occur. Although as a whole the county may be fine after the catastrophe, it will most likely have received much help from the state or country it is in. In addition, with the information gathered from researching case studies in places including Japan, Cuyahoga of Ohio, and San Diego, we discovered methods for the county or state to be prepared for catastrophes including floods, earthquakes, and hurricanes. Finally, we ended by writing a memo outlining our recommendations from our model and analysis finding for the ESC.

Outline of the Paper

Part 1) Assumptions with Justification, Variables, Terms Defined, and Given Resources

Part 2) Operation under 3 ambulances

- Demonstrates which configuration best suits the positions of 3 ambulances, and how effective it is in catering citizens

Part 3) Operation under 2 ambulances

- Demonstrates which configuration best suits the positions of 2 ambulances, and how effective it is in catering citizens

Part 4) Operation under 1 ambulances

- Demonstrates which configuration best suits the positions of 1 ambulance, and how effective it is in catering citizens

Part 5) Operation under a catastrophic event

- Analyzes the action plan of other areas, declares an optimal method of operating under a rare but catastrophic event, and observes how effective it is in catering citizens

Part 6) Non-technical memo

- Provides a brief outline suggesting our model and plan.

Part 7) Bibliography

- Provides list of sources.

Part 1

Assumptions with Justification, Variables, Terms Defined, and Given Resources

Variables and Terms Defined:

Variables

- Configuration of ambulances: As we need to know the locations of the three ambulances at a given time, we put three values in a configuration, with each value showing the current zone of each ambulance.
- Number of ambulances
- Number of emergency calls (controlled)
- Population (controlled)
- Travel time between zones (controlled)

Terms

- ESC: Emergency Services Coordinator
- Catastrophe: A harmful event causing personal injury that affects all zones of the county.
- A, or Ambulance A: An ambulance
- B, or Ambulance B: An ambulance
- C, or Ambulance C: An ambulance
- x,y,z: A set of three numbers classifying a configuration of ambulances in zones x, y and z
- CBO: Community Based Organization
- NGO: Non-Governmental Organization
- Average Day: A typical day, not the average of all days
- Call: A phone call for an ambulance
- Covered: A person is covered if his call for an ambulance can be responded to within 8 minutes. Our models find the percentage of population covered, or the percentage of the population whose calls for ambulances will be responded to within 8 minutes.
- As individual numbers in data tables:
- 1: Zone 1
- 2: Zone 2
- 3: Zone 3
- 4: Zone 4
- 5: Zone 5
- 6: Zone 6

Assumptions with Justification:

1. Table 1 given in the problem reads with the right-most column indicating the starting zone, and the uppermost row indicating the finishing zone. *The conventions of reading and creating tables leads our team to conclude that to find the average travel time from one zone to another, the right-most column is the starting zone and the upper-most column indicates the finishing zone.*

2. The location of an ambulance within a zone does not matter, it only matters that the ambulance is within a zone.
There is no way to determine what the zones will be like, or what areas they will be covering, with the information provided. Since no county name was provided, it is impossible to do further research to gain more insight as to what the zones look like. There are simply too many possibilities and assumptions that are required in order to form a map of the zones in order to fully flesh out the scenario properly, factors such as streets, traffic jams etc. would need to be figured out. After making assumptions for all of this, the margin of error would be so high as to make this unrealistic. Therefore, the location of the ambulance within the zone can be assumed irrelevant.

3. This scenario occurs in a county in the United States of America.
Given that this is a primarily American contest, it is most likely that the situation addresses a county in America. This is also reasonable given how Emergency Service Coordinators primarily exist in the United States, and not other countries.

4. There is a hospital in every zone.
There are 5,724 registered hospitals in the United States and 314 million people in the United States. This gives 1 hospital per 54,856 people. For our county, this is slightly below 5 hospitals. Since there are 6 zones in our county, and because it is very likely that a zone could have one more hospital than average. Since it would be best for a hospital to have maximum distribution of services and maximum access to the people, it would make sense for the hospitals to be positioned in locations that can be quickly accessed by the general population. This means six hospitals, one in each zone.

5. Only hospitals are capable of taking care of the patients rescued by the ambulances.
We assume that doctor's clinics and the like are incapable of treating people in genuine need of an ambulance. As a result ambulances must go to hospitals, and will go to the hospital in the zone or the hospital from the ambulances' point of origin. This makes sense, as normal doctors clinics are not equipped with the resources to handle genuine ambulance calls.

6. Calls are equally distributed by population and over time.
As the only information provided is travel times, we have no way of knowing the population density or crime rates of zones. We also cannot know the crime or injury rate per day of that county, or . As a result, we assume that everyone has an equal chance of calling the ambulance regardless of what zone they are in or what time it is.

7. Ambulances take calls and attend to calls 24/7, and operate with maximum efficiency.
We assume that in this county, as in most of the US, emergency rooms and ambulances operate constantly. It would not be feasible to precisely model how quickly an ambulance would be able to shift people, refuel, restock, and do other necessary functions. We are further assuming that patients can be instantly loaded and unloaded on and off the ambulance, in order to maximize efficiency.

8. Ambulances attend all calls, even illegitimate ones.
Many calls for ambulances are not legitimate. We assume that at the time of calling it is impossible to tell the difference between a legitimate call and someone faking pain in a prank call, and that therefore the ambulance will attend every call.

9. Ambulances return to their station before going after a new call.
As assumption 6 states that calls are evenly distributed across population, it would not be possible to determine if an ambulance would receive a call while moving out or not. Therefore, it would be best to assume that an ambulance must move back to where its stationed in order to restock and reorient itself before moving out to assist another call.

10. Any catastrophe that occurs affects the whole county equally, harming the same percentage of citizens in each zone.
Problem requirements say that the catastrophe affects many people from all zones, which means it must be a countywide disaster. Again, since the exact size and shape of the zones is not and can not be known, it is safest to assume that the catastrophe affects all citizens equally, by harming the same percentage of citizens in each zone.

11. During catastrophe scenarios, the only support from other parties other than the ESC will be guaranteed government support.
As no information about the county is provided besides travel times and population, we have no information on the NGOs or traveling doctors that might be in the town. As a result, the safest assumption is that only the most basic government aid will be provided.

12. More population means larger area occupied.
While travel times between zones are provided, travel speed is not, and so it is not possible to calculate the area of the county. With the information provided, the safest assumption is that a higher population means a larger area, and that the ratio of our county's area to the average US county's area is the same as the ratio of our county's

population to the average US county's population.

13. Catastrophes occur immediately at the beginning of the day.
It is impossible to predict when a catastrophe could happen. As a result, an arbitrary time for the catastrophe must be chosen. Since problem requirements ask whether the ESC could handle the catastrophe, it makes sense to give the ESC the most time to respond to the catastrophe, which means having the catastrophe occur at the start of the day.

14. There are 24 hours in a day.
Although days are not exactly 24 hours worth of seconds, it is safest to assume that there are exactly 24 hours in a day, as the number of minutes in a day can change.

Given Resources:

Table 1. Average Travel Time (min.)

Zone	One	Two	Three	Four	Five	Six
One	1	8	12	14	10	16
Two	8	1	6	18	16	16
Three	12	18	1.5	12	6	4
Four	16	14	4	1	16	12
Five	18	16	10	4	2	2
Six	16	18	4	12	2	2

Table 2. Population by zone

Zone	Population
1	50,000
2	80,000
3	30,000
4	55,000
5	35,000
6	20,000

Part 2

Operation under 3 ambulances

We begin by determining which zones an ambulance can reach within 8 minutes. Zones that an ambulance can reach in 8 minutes from a given zone are covered if there is an ambulance in the given zone and the ambulance has enough time to reach a person there. The zones the ambulance is able to serve, based on the zone the ambulance is in, is shown below:

Table 3. Zones covered by an ambulance in a zone (travel time less than 8 minutes)

Zone with ambulance	Zones served
1	1 and 2
2	1, 2 and 3
3	3, 5 and 6
4	3 and 4
5	4, 5 and 6
6	3, 5 and 6

Given the travel times between zones and zone population, we are to find the best way of placing three ambulances to maximize the number of people that can be covered by an ambulance. Since no information about how exactly the ambulance goes about picking people up, we had to deduce a logical way for ambulances to pick people up. Ambulances can only pick people up within 8 minutes, as stated in the problem. Then, they would have to spend the average travel time within the zone to travel back to the zone's hospital (As stated in assumption 4, there is a hospital in every zone.) Lastly, the ambulance must travel back to its original location before picking up a call, as stated in assumption 9. This is demonstrated in figure 1.

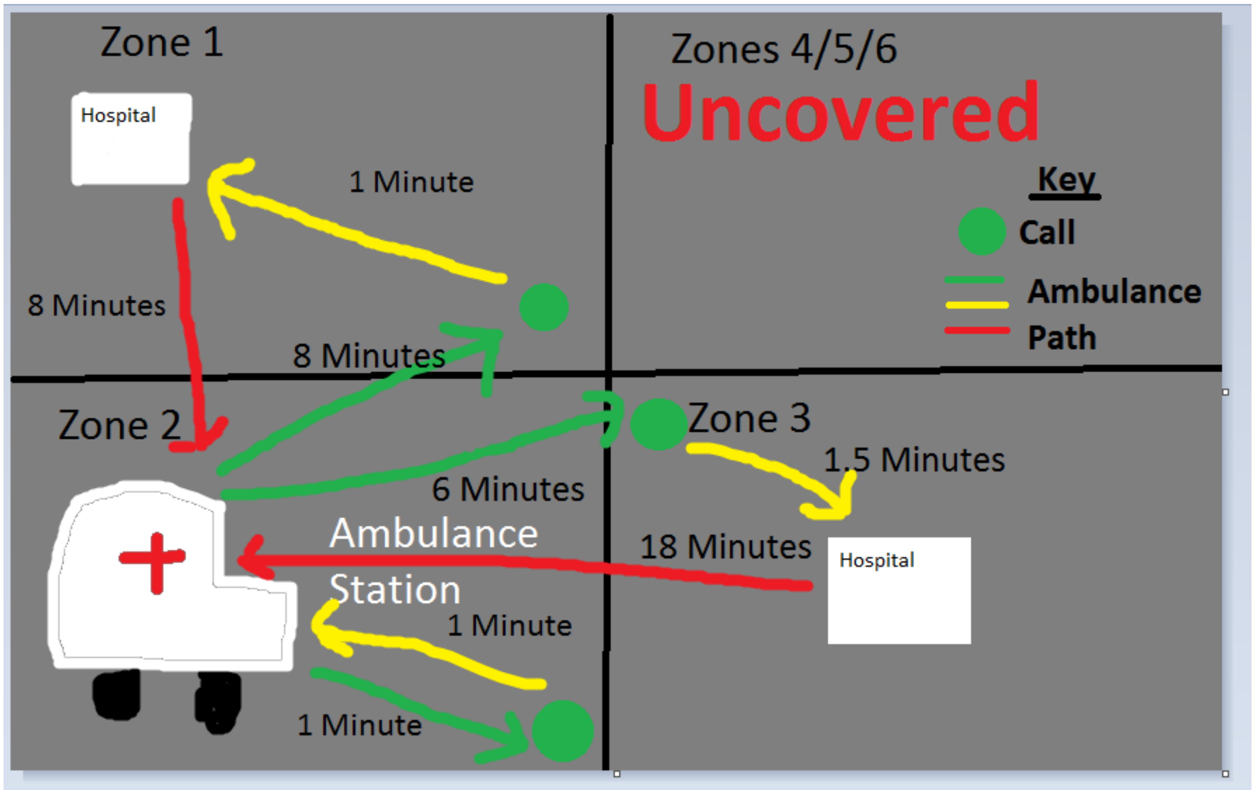

Figure 1. Ambulance paths to zones

In figure 1, the ambulance is stationed in zone 2. From zone 2, the ambulance can reach zones 1 and 3 within 8 minutes, the problem's maximum time to reach a patient. As a result, the ambulance cannot cover zones 4, 5 and 6 at all. This diagram shows how the ambulance would respond to a call from each zone. Green lines represent the ambulance going out to a call, yellow lines the ambulance taking the call's patient to the zone's hospital, and red lines the ambulance returning to its station. For a call in its own zone, an ambulance only needs to spend double the travel time within its zone. For other zones, it takes the time there, the time back, and the time in the zone per patient. Now that we have figured out how the ambulance picks up patients, we can look at optimum ambulance configurations.

As there are 6 zones, we start with 216 permutations of where ambulances can be: 6 possibilities for A, 6 possibilities for B, and 6 possibilities for C. However, A, B, and C are physically the same, so there is no distinction between having A in zone 1, B in zone 1 and C in zone 2 and having A in zone 2, B in zone 1, and C in zone 1. Therefore, we are looking for configurations, not permutations. The equation for configurations is as follows:

$$_{n}C_{r} = \frac{n!}{r!(n-r)!}$$

Figure 2. Equation for Combinations

Using the equation for combinations, we can narrow down the 216 permutations of three ambulances to just 56. We can then analyze the zones covered by three ambulances based on their configuration. The values for the second, third and fourth columns were determined by checking the ambulance's location in table 3. The total zones covered were all the zones covered by ambulances, without any repeats. The number of people covered was found by checking the population of each zone covered in table 2. Finally, rows with configurations that cover all zones, and at least theoretically cover all people, were bolded and highlighted yellow.

Table 4. Zones and People Covered by Three Ambulances' Location

Configuration (A, B, C)	Zones covered by A	Zones covered by B	Zones covered by C	Total Zones Covered	People Covered
1,1,1	1,2	1,2	1,2	1,2	130000
1,1,2	1,2	1,2	1,2,3	1,2,3	160000
1,1,3	1,2	1,2	3,5,6	1,2,3,5,6	215000
1,1,4	1,2	1,2	3,4	1,2,3,4	215000
1,1,5	1,2	1,2	4,5,6	1,2,4,5,6	240000
1,1,6	1,2	1,2	3,5,6	1,2,3,5,6	215000
1,2,2	1,2	1,2,3	1,2,3	1,2,3	160000
1,2,3	1,2	1,2,3	3,5,6	1,2,3,5,6	215000
1,2,4	1,2	1,2,3	3,4	1,2,3,4	215000
1,2,5	**1,2**	**1,2,3**	**4,5,6**	**1,2,3,4,5,6**	**270000**
1,2,6	1,2	1,2,3	3,5,6	1,2,3,5,6	215000
1,3,3	1,2	3,5,6	3,5,6	1,2,3,5,6	215000
1,3,4	**1,2**	**3,5,6**	**3,4**	**1,2,3,4,5,6**	**270000**
1,3,5	**1,2**	**3,5,6**	**4,5,6**	**1,2,3,4,5,6**	**270000**
1,3,6	1,2	3,5,6	3,5,6	1,2,3,5,6	215000
1,4,4	1,2	3,4	3,4	1,2,3,4	215000
1,4,5	**1,2**	**3,4**	**4,5,6**	**1,2,3,4,5,6**	**270000**
1,4,6	**1,2**	**3,4**	**3,5,6**	**1,2,3,4,5,6**	**270000**
1,5,5	1,2	4,5,6	4,5,6	1,2,4,5,6	240000
1,5,6	**1,2**	**4,5,6**	**3,5,6**	**1,2,3,4,5,6**	**270000**

1,6,6	1,2	3,5,6	3,5,6	1,2,3,5,6	215000
2,2,2	1,2,3	1,2,3	1,2,3	1,2,3	160000
2,2,3	1,2,3	1,2,3	3,5,6	1,2,3,5,6	215000
2,2,4	1,2,3	1,2,3	3,4	1,2,3,4	215000
2,2,5	**1,2,3**	**1,2,3**	**4,5,6**	**1,2,3,4,5,6**	**270000**
2,2,6	1,2,3	1,2,3	3,5,6	1,2,3,5,6	215000
2,3,3	1,2,3	3,5,6	3,5,6	1,2,3,5,6	215000
2,3,4	**1,2,3**	**3,5,6**	**3,4**	**1,2,3,4,5,6**	**270000**
2,3,5	**1,2,3**	**3,5,6**	**4,5,6**	**1,2,3,4,5,6**	**270000**
2,3,6	1,2,3	3,5,6	3,5,6	1,2,3,5,6	215000
2,4,4	1,2,3	3,4	3,4	1,2,3,4	215000
2,4,5	**1,2,3**	**3,4**	**4,5,6**	**1,2,3,4,5,6**	**270000**
2,4,6	**1,2,3**	**3,4**	**3,5,6**	**1,2,3,4,5,6**	**270000**
2,5,5	**1,2,3**	**4,5,6**	**4,5,6**	**1,2,3,4,5,6**	**270000**
2,5,6	**1,2,3**	**4,5,6**	**3,5,6**	**1,2,3,4,5,6**	**270000**
2,6,6	1,2,3	3,5,6	3,5,6	1,2,3,5,6	215000
3,3,3	3,5,6	3,5,6	3,5,6	3,5,6	85000
3,3,4	3,5,6	3,5,6	3,4	3,4,5,6	140000
3,3,5	3,5,6	3,5,6	4,5,6	3,4,5,6	140000
3,3,6	3,5,6	3,5,6	3,5,6	3,5,6	85000
3,4,4	3,5,6	3,4	3,4	3,4,5,6	140000
3,4,5	3,5,6	3,4	4,5,6	3,4,5,6	140000
3,4,6	3,5,6	3,4	3,5,6	3,4,5,6	85000
3,5,5	3,5,6	4,5,6	4,5,6	3,4,5,6	140000
3,5,6	3,5,6	4,5,6	3,5,6	3,4,5,6	85000
3,6,6	3,5,6	3,5,6	3,5,6	3,5,6	85000
4,4,4	3,4	3,4	3,4	3,4	85000

4,4,5	3,4	3,4	4,5,6	3,4,5,6	140000
4,4,6	3,4	3,4	3,5,6	3,4,5,6	140000
4,5,5	3,4	4,5,6	4,5,6	3,4,5,6	140000
4,5,6	3,4	4,5,6	3,5,6	3,4,5,6	140000
4,6,6	3,4	3,5,6	3,5,6	3,4,5,6	140000
5,5,5	4,5,6	4,5,6	4,5,6	4,5,6	110000
5,5,6	4,5,6	4,5,6	3,5,6	3,4,5,6	140000
5,6,6	4,5,6	3,5,6	3,5,6	3,4,5,6	140000
6,6,6	3,5,6	3,5,6	3,5,6	3,5,6	85000

In determining which configuration of ambulances would work best, we can eliminate configurations that do not cover all zones, as those do not even have a chance at covering a significant amount of the population. Configurations that cover all zones are as follows:

1,2,5	1,3,4	1,3,5	1,4,5	1,4,6
1,5,6	2,2,5	2,3,4	2,3,5	2,4,5
2,4,6	2,5,5	2,5,6		

This is a total of 13 configurations. Next, we determined that the probability of an average person calling the ambulance on a given day. In doing this we took the number of ambulance calls on a day in the United States, 500,000, and divided it by the number of counties, 3,007, yielding 166.27 calls in the county per day. This amount of calls is for the average county with a population of 104,000, however, and given how our county has a population of 270,000, this means that the number of calls per day is proportionally increased to 432.3 calls per day, which we will round to 432 calls in the county per day. In mathematical format, this is:

$$\frac{\text{500,000 calls in US}}{\text{3007 counties}} = \frac{\text{166.27 calls *270,000 ppl/county}}{\text{104,000 ppl/county average}} = \text{432.3 calls} \approx \text{432 calls per day}$$

Since assumption 6 says calls come equally from all zones by population, table 5 below shows both the percentage of population per zone and the percentage of total calls per zone.

Table 5. Percent of Total Population per Zone

Zone	% Population	Number of Calls
1	18.5185185%	80
2	29.6296296%	128
3	11.1111111%	48
4	20.3703704%	88
5	12.9629630%	56
6	7.40740741%	32

The number of calls per zone is determined by multiplying the percentage of population in a given zone by the number of calls that the entire county gets, 432. It is necessary to round these numbers as there cannot be part of a call each day. Even though these fractions are rounded, they still sum to 432 calls, which means that the rounding worked correctly and did not substantially affect the overall results of this model.

Table 6. Number of Calls per Zone

Zone	Number of Calls
1	80
2	128
3	48
4	88
5	56
6	32

We then analyzed Table 1, our provided resource on travel times, and adjusted the travel times to be more useful in our calculations. In table 7 below, the time to go from the zone on the right to the zone on the top and back is listed, while as our provided table 1 is simply the time from the zone on the left to the zone on the top, as stated in assumption 1.

Table 7. Travel Times, Combined Going and Returning (minutes)

Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	2	16	24	30	28	32
Zone 2	16	2	24	32	32	34
Zone 3	24	24	3	16	16	8
Zone 4	30	32	16	2	20	24
Zone 5	28	32	16	20	4	4
Zone 6	32	34	8	24	4	4

Table 8 below is similar to Table 7 above, except that the time taken to deliver a patient to the hospital is now incorporated. This amount of time is equivalent to the amount of time needed to travel within a zone, since as stated in assumption 4 there is a hospital within each zone, and it takes this amount of time to deliver a patient. The additional of “hospital delivery time” is not necessary when we do intra-zonal deliveries as the destination of the ambulance, the hospital, is where the patients will also end up, therefore removing the need for the patients to be dropped off at another location, and reducing the time needed to suitably address a call.

Table 8. Travel Times, Combined Going, Delivering to Hospital, and Returning (minutes)

Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	2	17	25.5	31	30	34
Zone 2	17	2	25.5	33	34	36
Zone 3	25	25	3	17	18	10
Zone 4	31	33	17.5	2	22	26
Zone 5	29	33	17.5	21	4	6
Zone 6	33	35	9.5	25	6	4

With the necessary background information laid out in tables 5 through 8, we now direct our attention back to ambulance configurations. In table 9 below the ambulance configurations that covered all zones are listed as they were in table 4. There is also the additional column of zone overlap, which will be needed to figure out how ambulances cover zones.

Table 9. Ambulance locations that cover all regions

Zones	Zones covered for 1st region	Zones covered for 2nd region	Zones covered for 3rd region	Extra Zones Covered	People Covered
1,2,5	1,2	1,2,3	4,5,6	1,2	**270000**
1,3,4	1,2	3,5,6	3,4	3	**270000**
1,3,5	1,2	3,5,6	4,5,6	5,6	**270000**
1,4,5	1,2	3,4	4,5,6	4	**270000**
1,4,6	1,2	3,4	3,5,6	3	**270000**
1,5,6	1,2	4,5,6	3,5,6	5,6	**270000**
2,2,5	1,2,3	1,2,3	4,5,6	1,2,3	**270000**
2,3,4	1,2,3	3,5,6	3,4	3,3	**270000**
2,3,5	1,2,3	3,5,6	4,5,6	3,5,6	**270000**
2,4,5	1,2,3	3,4	4,5,6	3,4	**270000**
2,4,6	1,2,3	3,4	3,5,6	3,3	**270000**
2,5,5	1,2,3	4,5,6	4,5,6	4,5,6	**270000**
2,5,6	1,2,3	4,5,6	3,5,6	3,5,6	**270000**

After finding which ambulance configurations cover all zones, the logical next step is to calculate how much time each ambulance configuration would take, and thus determine whether it would be possible to cover every single person on an average day in a given ambulance configuration. To do this, we first determined which zones each ambulance should cover in cases of overlap. We then determined the amount of time necessary to get to a zone, take a patient to a hospital, and return to the initial starting point per call, and then calculated the total amount of time spent per zone for a given ambulance in a given ambulance configuration. We then calculated the theoretical total time spent by each ambulance, and subtracted it from the number of minutes in a day to calculate how much left-over time or overtime each ambulance had. If the ambulance did not go over-time, then the time allocated per zone would be the amount of time spent, as stated before, with the actual calls taken identical to the number of calls received.

However, if the ambulance did go over-time, then the time allocated for each zone would be determined by the time it takes an ambulance to recover a patient in a given zone. This is the only logical way of handling an excess of calls, as answering the closest calls will answer the most calls and save the most lives. This inevitably resulted in situations where a zone was left completely uncovered, which is unfortunate, but there is no other way around this if we wish to maximize efficiency of time. This was done both in unique and non-unique regions to maximize efficiency of the limited number of minutes in a day. As a result of this, the ambulance would not go over-time, sticking to its 24 hour schedule, but it would not be able to handle all the calls. The number of calls that would actually be taken would then be less than the number of calls received.

Next, we took non-unique zones and distributed the amount of time through these zones to maximize the number of cases handled. To reduce the total amount of time spent on overlapping zones, we prioritized ambulances that operated in their own zone. If an ambulance is already over-time, then it is not capable of handling non-unique zones. This entire process was done with every configuration that would be able to reach all the zones, namely those listed in table 9. The results table beneath each configuration summarizes the results of each configuration.

What follows is sequence of tables for each configuration listed in table 9. In each set of configurations, there are three tables. The first table of each configuration details what occurs under circumstances where the population of unique zones that can be covered is covered by the ambulances assigned to such zones. The second table of each configuration details what occurs when the population of non-unique zones that can be covered is covered by the ambulances assigned to such zones. The third table of each configuration summarizes the results of the configuration, outlining the percentage of the population covered, the number of calls that can be responded to suitably, and the actual population that is covered. Essentially, these are a series of tables that find the percentage of population covered for each configuration listed in table 9. This information is in tables 10 through 48. As this would be ungainly to read, it is summarized in table 49, where this explanation continues.

Ambulances in Zones 1, 2, 5

Table 10. Ambulance covering zones that don't overlap in 1, 2, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	3	48	25.5	48 * 25.5 = 1224 minutes	1440-1224 = 216 minutes	1224 minutes	48
5	4,5,6	88, 56, 32	21, 4, 6	88*21+56*4 +32*6 = 2264 minutes	1440-2264 = 824 minutes overtime	1024, 224, 192,	49, 56, 32

Table 11. Ambulance covering zones that do overlap in 1, 2, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1 (until no time left)	1	80	2	80 * 2 = 160 minutes	1440-160 = 1280 minutes	160 minutes	80
2 (until no time left)	2	128	2	128*2 = 256 minutes	216-256= 40 minutes overtime	216	108
2 (after 2 ran out)	1	Remaining: 20	17	17*20=340 minutes	1280-340 minutes = 940 minutes	340 minutes	20

Table 12. Results of ambulance covering zones for 1, 2, 5 configuration

Total Calls Taken	48 + 49 + 56 + 32 + 80 +108 + 20 = 393
Calls made in the county	432
Percentage of calls taken/covered	90.97%
Population	245,625 people covered

Ambulances in Zones 1, 3, 4

Table 13. Ambulance covering zones that don't overlap in 1, 3, 4 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1	1,2	80,128	2, 17	80*2+128*17 = 2336 minutes	1440-2336 = 896 minutes overtime	554, 886	80, 75
3	5,6	56,32	18, 10	56*18+32*10 = 1328 minutes	1440-1328= 112 minutes	1008, 320	56, 32
4	4	88	2	88*2 = 176 minutes	1440-176 = 1264 minutes	176	88

Table 14. Ambulance covering zones that do overlap in 1, 3, 4 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3 (until no time left)	3	48	3	48*3 = 144 minutes	112-144 = 32 minutes overtime	112 minutes	37 calls
3 (after ambulance 3 ran out)	4	Remaining: 11	17	11*17 = 187 minutes	1264-187 = 1077 remaining	187 minutes	11

Table 15. Results for ambulance covering zones for 1, 3, 4 configuration

Total Calls Taken	80+75+56+32+88+37+11 = 379
Calls made in the county	432
Percentage of calls taken/covered	87.73%
Population covered	236871

Ambulances in Zones 1, 3, 5

Table 16. Ambulance covering zones that don't overlap in 1, 3, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1	1,2	80,128	2, 17	80*2+128*17 = 2336 minutes	1440-2336 = 896 minutes overtime	160, 1280	80, 75
3	3	48	3	48*3 = 144 minutes	1440-144= 1296 minutes	144 minutes	48
5	4	88	21	88*21 = 1848 minutes	1440-1848 = 509 minutes overtime	1440	69

Table 17. Ambulance covering zones that do overlap in 1, 3, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
6	3	32	10	32*10 = 320 minutes	1296-320 = 976 minutes	320 minutes	32
5	3	56	18	56*18 = 1008 minutes	976-1008 = 32 minutes over	187 minutes	11

Table 18: Results for ambulance covering zones for 1, 3, 5 configuration

Total Calls Taken	80+75+48+69+32+11 = 315
Calls made in the county	432
Percentage of calls taken/covered	72.9%
Population covered	196,875 people

Ambulances in Zones 1, 4, 5

Table 19. Ambulance covering zones that don't overlap in 1, 4, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1	1, 2	80, 128	2, 17	2*80 + 128*17 = 2336	1440 - 2336 = 896 minutes over	160, 1280	80, 75
4	3	48	17.5	48 * 17.5 = 840	1440 - 840 = 600	840	48
5	5, 6	56, 32	4, 6	56 * 4 + 32 * 6 = 416	1440 - 416 = 1024	224, 192	56, 32

Table 20. Ambulance covering zones that do overlap in 1, 4, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
4	4	88	2	88 * 2 = 176	600 - 176 = 424	176	88

Table 21. Results for ambulance covering zones for 1, 4, 5 configuration

Total Calls Taken	80 + 75 + 48 +56 + 32+ 88 = 379
Calls made in the county	432
Percentage of calls taken/covered	87.73%
Population covered	236,875 people

Ambulances in Zones 1, 4, 6

Table 22. Ambulance covering zones that don't overlap in 1, 4, 6 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1	1, 2	80, 128	2, 17	2*80 + 128*17 = 2336	1440 - 2336 = 896 minutes over	160, 1280	80, 75
4	4	88	2	88*2 = 176 minutes	1440-176 = 1264 minutes	176	88
6	5, 6	56, 32	6, 4	6 * 56 + 32 * 4 = 464	1440 - 464 = 976 minutes	336, 128	56, 32

Table 23. Ambulance covering zones that do overlap in 1, 4, 6 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	4, 6 (6 used)	48	9.5	9.5 * 48 = 456	976 - 456 = 520	456	48

Table 24. Results for ambulance covering zones for 1, 4, 6 configuration

Total Calls Taken	80 + 75 + 88 + 56 + 52 + 48 = 399
Calls made in the county	432
Percentage of calls taken/covered	92.36 %
Population covered	249,375 people

Ambulances in Zone 1, 5, 6

Table 25. Ambulance covering zones that don't overlap in 1, 5, 6 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
1	1, 2	80, 128	2, 17	2*80 + 128*17 = 2336	1440 - 2336 = 896 minutes over	160, 1280	80, 75
5	4	88	21	88 * 21 = 1848	1440 - 1848 = 408 minutes overtime	1440	69
6	3	48	9.5	48 * 9.5 = 456	1440 - 456 = 984	456	48

Table 26. Ambulance covering zones that do overlap in 1, 5, 6 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
6	6	32	4	4 * 32 = 128	984-128 = 856	128	32
5	6	56	6	6 * 56 = 336	856 - 336 = 520	336	56

Table 27. Results for ambulance covering zones for 1, 5, 6 configuration

Total Calls Taken	80 + 75 + 69 + 48 + 32 + 56 = 360
Calls made in the county	432
Percentage of calls taken/covered	83.3%
Population covered	225,000 people

Ambulances in Zones 2, 2, 5

Table 28. Ambulance covering zones that don't overlap in 2, 2, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
5	4, 5, 6	88, 56, 32	21, 4, 6	1848 + 224 + 192 = 2264	1440 - 2264 = 824 minutes overtime	1024, 224, 192	49, 56, 32

Table 29. Ambulance covering zones that do overlap in 2, 2, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	2_1	128	2	256	1440-256 = 1184	256	128
1 (until no time left)	2_1	80	17	1360	1184 - 1360 = 176 minutes overtime	1184	70
1 (after ambulance 2_1 ran out)	2_2	Remaining: 10	17	170	1440 - 170 = 1270	170	10
3	2_2	48	25.5	1224	1270 - 1224 = 46	1224	48

Table 30. Results for ambulance covering zones for 2, 2, 5 configuration

Total Calls Taken	49 + 56 + 32 +128 + 70 + 10 + 48 = 393
Calls made in the county	432
Percentage of calls taken/covered	90.97%
Population covered	245,625 people

Ambulances in Zones 2, 3, 4

Table 31. Ambulance covering zones that don't overlap in 2, 3, 4 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1, 2,	80, 128	17, 2	1360 + 256 = 1616	1440 - 1616 = 176 minutes overtime	1184, 256	70, 128
3	5, 6	56, 32	18, 10	1008 + 320 = 1328	1440 - 1328 = 112	1008, 320	56, 32
4	4	88	2	88*2 = 176 minutes	1440-176 = 1264 minutes	176	88

Table 32. Ambulance covering zones that do overlap in 2, 3, 4 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3 (until no time left)	3	48	3	144	112 - 144 = 32 minutes overtime	112	37
3 (after ambulance 3 ran out)	4	11	17.5	192.5	1264 - 192.5 = 1071.5	192.5	11

Table 33. Results for ambulance covering zones for 2, 3, 4 configuration

Total Calls Taken	70+128+56+32+88+37+11 = 422
Calls made in the county	432
Percentage of calls taken/covered	97.7%
Population covered	263,750 people

Ambulances in Zone 2, 3, 5

Table 34. Ambulance covering zones that don't overlap in 2, 3, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1, 2,	80, 128	17, 2	1360 + 256 = 1616	1440 - 1616 = 176 minutes overtime	1184, 256	70, 128
5	4	88	21	88*21 = 1848 minutes	1440-1848 = 509 minutes overtime	1440	69

Table 35. Ambulance covering zones that do overlap in 2, 3, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	3	48	3	144	1440 - 144 = 1296	144	48
6	3	32	10	320	1296 - 320 = 976	320	32
5	3	56	18	1008	976 - 1008 = 32 minutes overtime	976	54

Table 36. Results for ambulance covering zones for 2, 3, 5 configuration

Total Calls Taken	70+128+69+48+32+54 = 401
Calls made in the county	432
Percentage of calls taken/covered	92.8%
Population covered	256,194 people

Ambulances in Zones 2, 4, 5

Table 37. Ambulance covering zones that don't overlap in 2, 4, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1, 2	80, 128	17, 2	1360 + 256 = 1616	1440 - 1616 = 176 minutes overtime	1184, 256	70, 128
5	5, 6	56, 32	4, 6	56 * 4 + 32 * 6 = 416	1440 - 416 = 1024	224, 192	56, 32

Table 38. Ambulance covering zones that do overlap in 2, 4, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	4	48	17.5	840	1440 - 840 = 600	840	48
4	4	88	2	196	600 - 196 = 404	196	88

Table 39. Results for ambulance covering zones for 2, 4, 5 configuration

Total Calls Taken	70+128+56+32+48+88 = 422
Calls made in the county	432
Percentage of calls taken/covered	97.7%
Population covered	263,750 people

Ambulances in Zones 2, 4, 6

Table 40. Ambulance covering zones that don't overlap in 2, 4, 6 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1, 2	80, 128	17, 2	1360 + 256 = 1616	1440 - 1616 = 176 minutes overtime	1184, 256	70, 128
4	4	88	2	176	1440 - 176 = 1264 minutes	176	88
6	5, 6	56, 32	6, 4	336 + 128 = 464	1440 - 464 = 976 minutes	336, 128	56, 32

Table 41. Ambulance covering zones that do overlap in 2, 4, 6 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	48	9.5	456	976 - 456 = 520	456	48

Table 42. Results for ambulance covering zones for 2, 4, 6 configuration

Total Calls Taken	70+128+88+56+32+48 = 422
Calls made in the county	432
Percentage of calls taken/covered	97.7%
Population covered	263,750 people

Ambulances in Zones 2, 5, 5

Table 43. Ambulance covering zones that don't overlap in 2, 5, 5 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2,3	80, 128, 48	17, 2, 25.5	80*17+128*2+48*25.5= 2840 minutes	1440-2840=1400 minutes overtime	1184,256,0	70,128,0

Table 44. Ambulance covering zones that do overlap in 2, 5, 5 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
5	5_1	56	4	224	1440 - 224 = 1216	224	56
6	5_1	32	6	192	1216 - 192 = 1024	192	32
4	5_1	88	21	1848	1024 - 1848 = 824 minutes overtime	1024	49
4	5_2	Remaining = 39	21	819	1440 - 819 = 621	819	39

Table 45. Results for ambulance covering zones for 2, 5, 5 configuration

Total Calls Taken	70+128+0+56+32+49+39 = 374
Calls made in the county	432
Percentage of calls taken/covered	86.6%
Population covered	233,750 people

Ambulances in Zones 2, 5, 6

Table 46. Ambulance covering zones that don't overlap in 2, 5, 6 configuration

Ambulance #	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1, 2	80, 128	17, 2	1360 + 256 = 1616	1440 - 1616 = 176 minutes overtime	1184, 256	70, 128
5	4	88	21	1848	1440 - 1848 = 408 minutes overtime	1440	69

Table 47. Ambulance covering zones that do overlap in 2, 5, 6 configuration

Zones covered	Ambulance #	Calls from the zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
6	6	32	4	128	1440 - 128 = 1312	128	32
5	6	56	6	336	1312 - 336 = 976	336	56
3	6	48	9.5	456	976 - 456 = 520	456	48

Table 48. Results for ambulance covering zones for 2, 5, 6 configuration

Total Calls Taken	70+128+69+32+56+48 = 403
Calls made in the county	432
Percentage of calls taken/covered	93.3%
Population covered	251,875 people

Summary of Configurations

Table 49. Summary of tables 10 through 48.

Configuration	Percent Calls Answered	Population Covered
1,2,5	91.0%	245,625
1,3,4	87.7%	236,871
1,3,5	72.9%	196,875
1,4,5	87.7%	236,875
1,4,6	92.4%	249,375
1,5,6	83.3%	225,000
2,2,5	91.0%	245,625
2,3,4	**97.7%**	**263,750**
2,3,5	92.8%	256,194
2,4,5	**97.7%**	**263,750**
2,4,6	**97.7%**	**263,750**
2,5,5	86.6%	233,750
2,5,6	93.3%	251,875

Out of all of the configurations listed above, it is clear that there are three configurations that are much better than the rest, with 97.7% of all calls answered and 263,750 people out of 270,000 total. In fact, the next best configuration covers only 251,875 people out of 270,000 total, just 93.3%. Even with the best possible configuration, it is not possible to cover every single person in the city, as no configuration of ambulances could answer all the calls. There are ways to optimize the path of the ambulance further, for example, picking up multiple patients before dropping by a hospital, but this would come at the cost of the victims and the probability that they survive the ambulance trip. It would also require us to make additional assumptions on the level of care that can be provided in the ambulance, and Occam’s Razor advises that we minimize the number of unnecessary assumptions.

From the three remaining configurations that each had 97.7% population coverage, namely,

2,3,4 2,4,5 2,4,6

we need to choose one to be the optimal configuration to recommend to the ESC. While they all cover the same percentage of people, there are ways to differentiate them. One anomaly observed in calculating this data was that all of these configurations had some ambulances with excess minutes. However, these ambulances with excess minutes could not help out other ambulances that didn't have enough time, because they could not reach the necessary zone within 8 minutes. Therefore, a good criteria for determining the best configuration is which system has most excess minutes out of all the configurations, as these excess minutes allow the ambulance to reach people that do not need to be reached within 8 minutes but are still in critical condition, or allowing time for the ambulance to resupply. Table 50 shows the excess minutes for each of the three optimum configurations highlighted yellow in table 49.

Table 50. Comparing excess minutes for the 3 optimum configurations

Configuration	Excess Minutes
2, 3, 4	1071.5
2, 4, 5	1024 + 404 = 1428
2, 4, 6	1264 + 520 = 1784

From table 50, it is clear that the configuration 2,4,6 is the best in terms of extra minutes, meaning that the ambulances in 2,4,6 have the most spare time to rescue others while still maintaining the maximum possible number of people served under our 8 minute constraint. Clearly, having an ambulance in zone 2, an ambulance in zone 4, and an ambulance in zone 6 is the best way to cover the most people while still having the most free time to be able to rescue other people that can be reached in over 8 minutes.

Counting only people reachable within 8 minutes as per problem requirements, there would be 6,250 people who are left without service in the worst case scenario, as out of the 270,000 people in the county, there are 263,750 people who are accounted for. However, given the amount of time that the ambulances have under the 2,4,6 configuration, the number of people left without service would probably be even lower. Depending on the locations of these people and the frequency with which this occurs, number of people left without service could potentially be 0 on some days, although this is not very likely.

Part 3

Operation with 2 ambulances

Next, we are presented with the scenario of one ambulance being away on a call, so we must determine where to place ambulances with only two ambulances for maximum possible coverage. Although we are asked to find if we can cover every person, since we cannot cover every person with three ambulances, it is impossible to cover every person with two ambulances. However, we can still find the total number of people that can be covered. With only two ambulances, the same method of ambulance travel still applies, there are simply fewer ambulances. The same graphic as in figure 1 is provided again as a reminder, though it is interesting to note now that in fact an ambulance in zone 2 is a practical solution, as we saw in the three ambulance scenario.

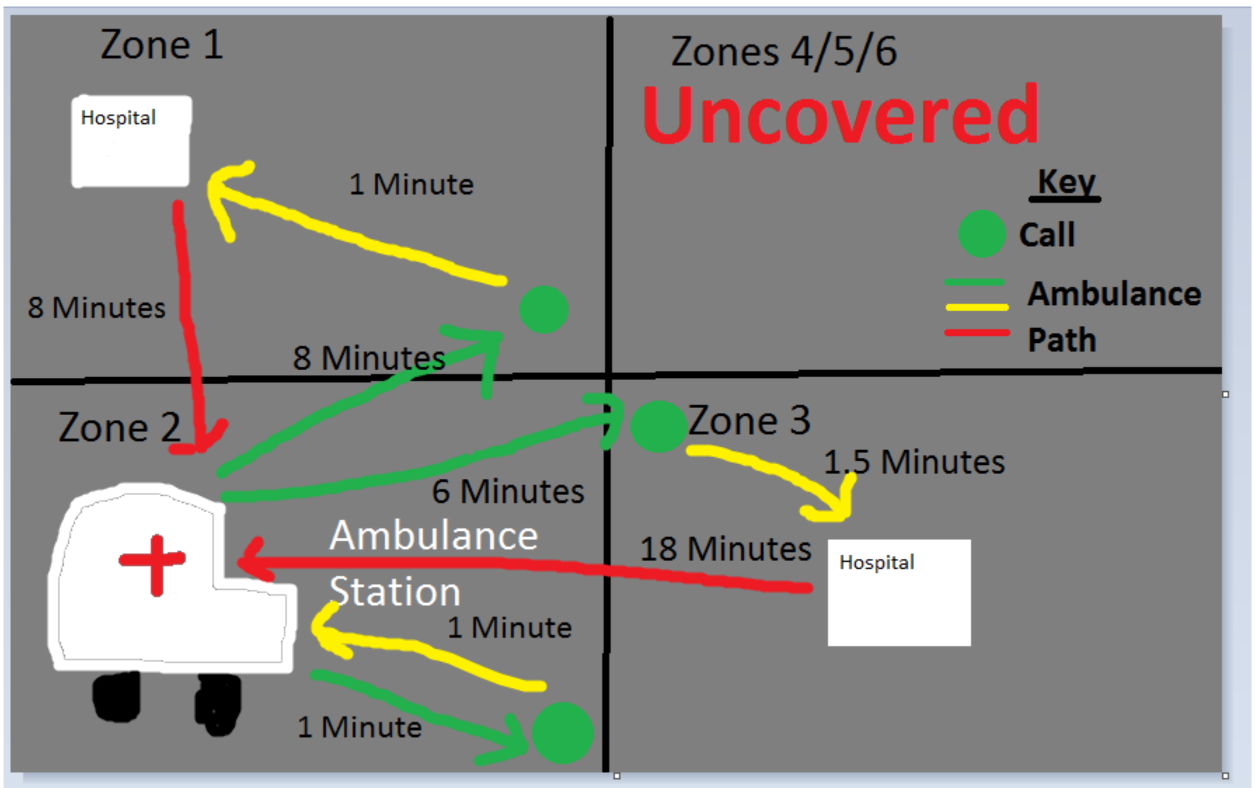

Figure 3. How an ambulance reaches calls

To determine the ideal placement of ambulances with only two ambulances, we must follow much the same process and commence with a table of all configurations of two ambulance's positions, table 51. This process again would start off by seeing how many people any two configurations of ambulances could cover within in 8 minutes. Following this, we would determine how many people those two ambulances could reach.

Table 51. Zones and people covered by two ambulances' location

Configuration (A,B)	Zone A Cover	Zone B Cover	Total Zones Covered	People Covered
1,1	1,2	1,2	1,2	130000
1,2	1,2	1,2,3	1,2,3	160000
1,3	1,2	3,5,6	1,2,3,5,6	215000
1,4	1,2	3,4	1,2,3,4	215000
1,5	1,2	4,5,6	1,2,4,5,6	240000
1,6	1,2	3,5,6	1,2,3,5,6	215000
2,2	1,2,3	1,2,3	1,2,3	160000
2,3	1,2,3	3,5,6	1,2,3,5,6	215000
2,4	1,2,3	3,4	1,2,3,4	215000
2,5	**1,2,3**	**4,5,6**	**1,2,3,4,5,6**	**270000**
2,6	1,2,3	3,5,6	1,2,3,5,6	215000
3,3	3,5,6	3,5,6	3,5,6	85000
3,4	3,5,6	3,4	3,4,5,6	140000
3,5	3,5,6	4,5,6	3,4,5,6	140000
3,6	3,5,6	3,5,6	3,5,6	85000
4,4	3,4	3,4	3,4	85000
4,5	3,4	4,5,6	3,4,5,6	140000
4,6	3,4	3,5,6	3,4,5,6	140000
5,5	4,5,6	4,5,6	4,5,6	110000
5,6	4,5,6	3,5,6	3,4,5,6	140000
6,6	3,5,6	3,5,6	3,5,6	85000

We start with 36 permutations for the ambulance locations: 6 possibilities for ambulance A, and 6 possibilities for ambulance B. However, as previously mentioned, ambulances A and B are the same, so order does not matter - Ambulance A in zone 5 and Ambulance B in zone 2 is the same as having Ambulance A in zone 2 and Ambulance B in zone 5. As a result, we are looking for configurations, not permutations, of which there are only the 21 shown above.

Of the 21 configurations shown above, there is only one configuration, an ambulance in zone 2 and an ambulance in zone 5, that will cover all regions and thus all people. As we have previously explained, it is best to cover all regions when possible, so this is by default the best configuration and the one we will use.

We use the same probability of someone calling an ambulance as we did for calculating coverage with three ambulances. By taking the national number of ambulance calls, over the number of counties, times by our county's population divided by the average county population, we found there were 432 calls in our county per day. As with the previous part of the problem, the number of calls per day per zone will stay the same, as if there are less ambulances, people will still be injured at the same rate. Similarly, the time taken to travel between zones will also be the same.

Now we must calculate how many people this specific configuration can serve, through the same method as used in the tables above, albeit simplified as there is no overlap in zone coverage so only two tables are necessary per configuration that covers all zones. This is because there are no non-unique regions, and only unique regions. To simplify this further, there is only one configuration that covers all zones, so there are only two tables in total, tables 52 and 53. Of course, there are only two ambulances in the table instead of three since this is calculating optimum coverage with two ambulances.

Table 52. Call coverage with optimum two ambulances' arrangement, 2 and 5.

Ambulance Zone	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2,3	80, 128, 48	17, 2, 25.5	80*17+128*2+48*25.5= 2840 minutes	1440-2840=1400 minutes overtime	1184,256,0	70,128,0
5	4,5,6	88, 56, 32	21, 4, 6	88*21+56*4+32*6 = 2264 minutes	1440-2264 = 824 minutes overtime	1024, 224, 192,	49, 56, 32

Table 53. Results for two ambulances in zones 2 and 5

Total Calls Taken	70+128+0+49+56+32 = 335
Calls made in the county	432
Percentage of calls taken/covered	77.55%
Population covered	209,385 people

Table 54. Percent of population covered by zone, with ambulances in zones 2 and 5.

Zone Number	Calls Made	Calls Covered	Population	Population Covered	% of population covered
1	80	70	50,000	43,750	87.5%
2	128	128	80,000	80,000	100%
3	48	0	30,000	0	0%
4	88	49	55,000	30,625	55.68%
5	56	56	35,000	35,000	100%
6	32	32	20,000	20,000	100%

Clearly, even with optimum ambulance placement, it is not possible to cover everyone in the county. Zones two, five and six received 100% coverage of their residents. This is because zones two and five had the ambulances, while as zone 6 was only 6 minutes away from the zone 5 ambulance. Zone 2's ambulance could cover almost all of Zone 1's population, with only 10 calls missed in a day. Zone 5's ambulance could cover barely over half of Zone 4's calls, missing 39 calls each day out of 88. Zone 3, however, was 25.5 minutes away for the Zone 2 ambulance, and so was completely neglected. While citizens living in Zone 3 may find it unfair that their ambulance calls are not answered, this arrangement provides the greatest possible overall coverage and thus saves the greatest number of lives.

The coverage with an ambulance in zone 2 and 5 is 77.55%, and so this is the best way to arrange two ambulances. Although this is lower than our results for part 1 of the problem, this is still a very good coverage percentage. Only 22.45% of the population is left without coverage, which equates to 60,615 people left without ambulance coverage.

Part 4

Operation under 1 ambulance

If two ambulances are unavailable, for repairs or some other reason, the ESC should be prepared for having only one ambulance. Finding the optimum position for one ambulance requires a similar method as that used above: List all possible options, and then test for population covered with each option. However, unlike the two and three ambulance calculations, with one ambulance it is not possible to cover all the regions, so no option is inherently better than another because it covers all zones. Therefore, all zones must be tested. Tables 55 through 57 show the percentage of population covered by an ambulance in a given zone, and how that number was derived.

Table 55. One ambulance 's positions and population covered

Zone of ambulance	Total zones covered	People covered
1	1 and 2	130,000
2	1,2 and 3	160,000
3	3,5 and 6	85000
4	3 and 4	85000
5	4,5 and 6	110000
6	3,5 and 6	85000

Table 56. One ambulance's zone and calls taken

Ambulance Zone	Zones covered	Calls from zone	Time spent per journey (minutes)	Total time spent (minutes)	Excess time remaining	Time Allocated	Calls Actually Taken
1	1,2	80,128	2,17	2*80+128*17=2336 minutes	1440-2336 = 896 minutes overtime	160, 1280	80,75
2	1,2,3	80,128,48	17,2,25.5	80*17+2*128+48*25.5 = 2840 minutes	1440-2840 = 1400 minutes overtime	1184,256,0	70,128,0
3	3,5,6	48,56,32	3,18,10	48*3+56*18+32*10=1472 minutes	1440-1472 = 32 minutes overtime	144,976,320	48,54,32
4	3,4	48,88	17.5,2	48*17.5+88*2=1016 minutes	1440-1016=424 minutes	840,176	48,88
5	4,5,6	88,56,32	21,4,6	21*88+4*56+6*32=2264 minutes	1440-2264 = 824 minutes overtime	1024,224,192	49,56,32
6	3,5,6	48,56,32	9.5,6,4	9.5*48+56*6+32*4=920 minutes	1440-920 minutes = 520 minutes	456,336,128	48,56,32

Table 57. Percent of population covered by one ambulance in a zone

Zone With Ambulance	Zones Covered	Calls Made	Calls Reached	Population In Zones	Population Covered	% of total population covered
1	1,2	208	155	130,000	96875	35.88%
2	1,2,3	256	198	160,000	123750	45.83%
3	3,5,6	136	134	85,000	83750	31.02%
4	3,4	136	136	85,000	85000	31.48%
5	4,5,6	176	137	110,000	85625	32.71%
6	3,5,6	136	136	85,000	85000	31.48%

Table 57 clearly shows that with only one ambulance, it is impossible to cover even half the population. Either the ambulance could not reach all the calls it was supposed to cover because it ran out of time, or it reached all the calls it was able to but there weren't enough people within 8 minutes to cover over half the population. The highest population coverage was obtained by an ambulance in zone 2, which could cover 45.83% of the population, and had the former problem holding it back from more people. An ambulance in zone 2 performed as shown in table 58 and 59.

Table 58. Results for an ambulance in zone 2

Total Calls Taken	70+128+0=198
Calls made in the county	432
Percentage of calls taken/covered	45.83%
Population covered	123,750

Table 59. Coverage distribution of a single ambulance in zone 2

Zone	Calls made	Calls covered	Population	Population % covered
1	80	70	50,000	87.5%
2	128	128	80,000	100%
3	48	0	30,000	0%

Clearly, we cannot come close to covering all areas with one ambulance. In fact, the best overall coverage only actually covers the two zones with highest population, and does not even touch the other zones. Although this may be unpopular among zones not covered, this saves the highest number of people, and so this is what the ESC should choose when forced to station only one ambulance.

45.83% of the total population is covered by an ambulance in zone 2, leaving 54.17% of the population without coverage under such circumstances. This means that 146,259 people do not get coverage, while 123,741 people do. This is maximum number of people that can be covered under such circumstances.

Part 5

Operation under a catastrophic event

To determine how the ESC (Emergency Service Coordinator) would cover catastrophic events, we approached the problem in two ways. First of all, we looked at how real counties and cities prepare for events of environmental, social, economic, or structural collapse, and how they dealt with them if such a case occurred. Using this information, we applied it to the county that we were given and explained how the ESC should cover the situation, and determined whether the ESC would be able to cover the situation in such an event.

How Counties and Cities Prepared for and Reacted to Catastrophic Scenarios

We took a case study approach to this section, taking counties and cities that have established or dealt with catastrophic or disaster scenarios, and analyzing them, with their relationship to how they relate to our county factored in. With each case study, the situation is read, understood and analyzed, and then reflected upon.

Case Study A: San Diego

San Diego has a five objective approach to dealing with catastrophes: To provide a system for the effective management of emergency situations, to identify lines of authority and relationships, to assign tasks and responsibilities, to ensure adequate maintenance of facilities, services and resources, and to provide a framework for adequate resources for recovery operations.

Under the Unified San Diego County Emergency Services Organization Operational Area Emergency Plan, it is stated that emergency incidents are best planned for when they are coordinated at the lowest level of government involved in the emergency. It is also stated that mutual aid is often requested, and given under most circumstances, since the responsibility of the government is to mitigate the harms of catastrophes.

Local parties that deal with medical situations in Los Angeles include the Sheriff, the Medical Examiner, the HHSA (health and human services agency), the Public Health Services department, and the Emergency Medical Services department. Clearly, city and governmental personnel working for the San Diego will also help out in such situations.

The private sector also plays a pivotal role, with CBOs (Community Based Organizations), NGOs (Non-Governmental Organizations), and the ReadySanDiego Business Alliance playing a crucial role before, during and after disasters.

San Diego has planned for earthquakes, tsunamis, flooding, wild land fires, droughts, urban fires, dam failures, transportation accidents, nuclear-related incidents, hazardous material incidents, water, gas or energy shortage, landslides and acts of terrorism. However, not all of these are related to the topics that we will be covering, as will be justified in the second part of this problem.

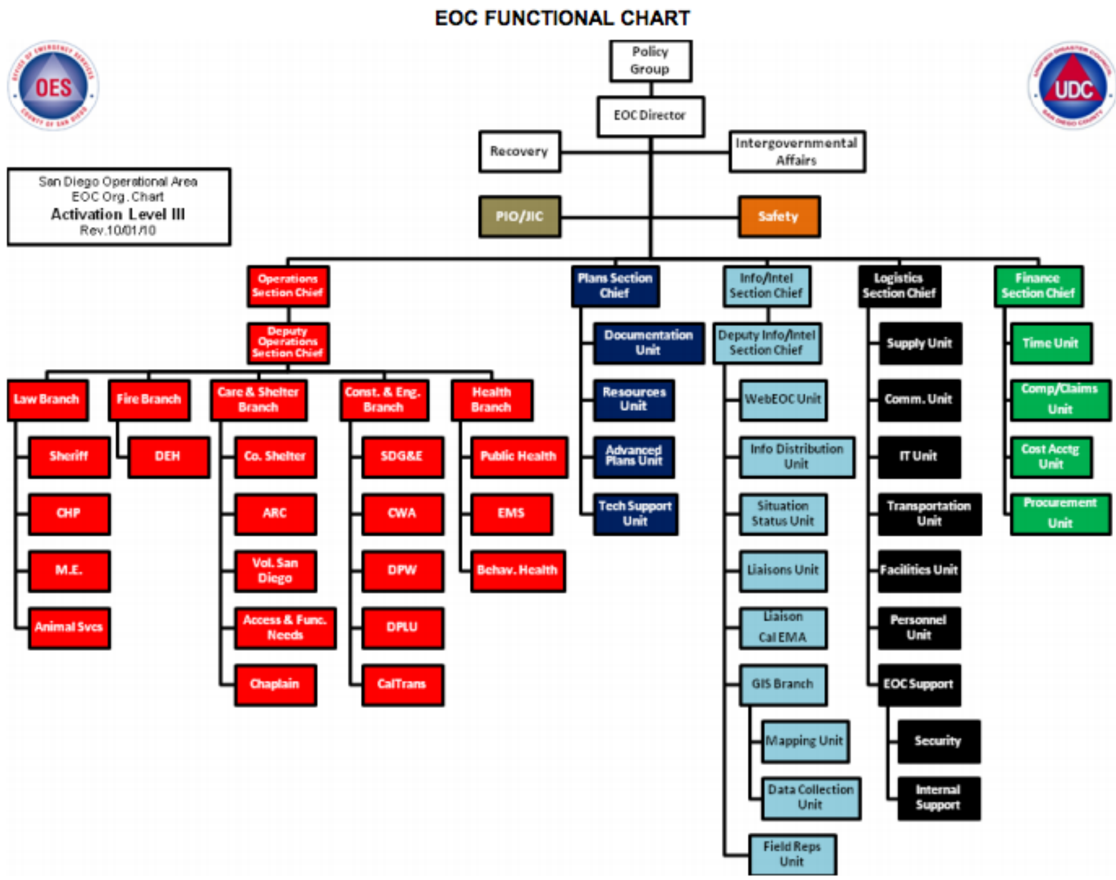

Figure 4. Emergency Plan Structure for San Diego

The priorities of San Diego under such circumstances include ensuring that the immediate needs of the people are met (food, clothing, water, shelter, medical attention, information etc.), restoration of facilities and properties (regardless of public or private), meeting the long-term needs of the people, and in general, returning the city to its former state prior to the catastrophe or disaster.

Management must be done on all levels to keep track of resources, people, and other information in order to ensure that things are being done as efficiently and accurately as possible.

Specifically, the purpose of the medical team is to coordinate medical operations and allocation of medical resources, the creation of field treatment sites, working with non-governmental medical organizations, and the transportation of medical equipment and injured people.

Fire and rescue operations need to search and rescue people who are in positions that are physically dangerous to them, put out and mitigate the damage from fires, and to facilitate prioritization of resources. Law enforcement also needs to respond in these scenarios, by preventing people from acting against the law and to coordinate any plans that are being carried out by the government at times.

Care and shelter operations are also critical to ensure that the people are supplied with the resources and materials that they need to survive, and eventually, to rebuild where necessary. Care and shelter operations also provide assistance to those who need it as required and act as a liaison to other non-governmental organizations. Communications and warning systems are crucial to spreading vital information to citizens, as well as to aid communications between various governmental and non-governmental parties. Construction and engineering teams are mostly useful after catastrophes, where reconstruction is necessary to rebuild and restore damaged property, but the teams are also useful in clearing out debris, creating shelters, and other engineering operations in general.

Governmental agencies that assist with disaster situations include the SBA (Small Business Administration), the DHU (Department of Housing and Urban Development), the USDA (United States Department of Agriculture), the IRS (Internal Revenue Service), the FEMA (Federal Emergency Management Agency), the Social Security Administration, the Health and Human Service, as well as the Food and Drug Administration. Clearly, San Diego is well prepared for catastrophes, and its catastrophe management plan provides good advice that will help us in this problem.

Case Study 2: Cuyahoga

Firstly, the Cuyahoga Emergency Base Plan declares the EOC (Cuyahoga County Emergency Operation Center) as the base of operations from which emergency response activities can be directed, coordinated and/or supported.

The Emergency Base Plan permits decisions and actions from many parties. A declaration of a countywide state of emergency permits the Cuyahoga County Office of Emergency Management to make decisions necessary for public health and life safety. Under an emergency declaration, the County may ask the State of Ohio for additional resources in the form of equipment or personnel. If the scope of the disaster is beyond the financial and response capabilities of the State and County combined, then the governor may make a state-level emergency declaration. Following a governor’s declaration, a request to the federal government for assistance may be activated. Only the Executive or his designee may request assistance from other agencies.

Cuyahoga County, in cooperation with state and federal agencies, establishes five emergency action levels, with level 5 having the lowest emergency status, and level 1 reserved for the greatest emergency situations.

Level 5 (Local Resources), being the lowest level of emergency, can be handled by up to six personnel with one or two single resources. The incident is typically contained within two hours after resources arrive on scene.

Level 4 (Local & County Resources) is typically contained within one operational period in the control phase, usually several hours after resources arrive on scene. Command Staff and General Staff functions are activated as needed, and several resources are required to mitigate the incident, including a Task Force or Strike Team.

Level 3 (Local, County & Regional Resources) usually extends into multiple operational periods. Some or all of the Command and General Staff positions may be activated, as well as Division/Group Supervisor and/or Unit Leader positions. A written IAP (Incident Action Plan) is typically required for each operational period.

Level 2 (Local, County, Regional & State Resources) is considered when resources are requested from outside of Cuyahoga County and Region 2 of Ohio, and the incident spans multiple operational periods. Most or all of the Command and General Staff positions are filled. A written IAP is required for each operational period.

Level 1 (Local, County, Regional, State & Federal Resources) is the most complex, requiring national resources to safely and effectively manage. All Command and General Staff positions are activated, and branches may need to be established. There is a high impact on the local jurisdiction, requiring additional staff for office administrative and support functions.

At any time before, during, or after an event, the Incident Commander may request either an activation of the EOC, or an EOC liaison to serve as an on-scene representative. The administrators will then determine if the EOC should be partially or fully activated. If the EOC is partially activated, the administrator will determine the appropriate level of staffing and issue the corresponding notification. During a full activation, all pre-identified personnel will be requested to staff the EOC either in their County role or as a representative from an Emergency Support Function (ESF).

Upon activation, the EOC can assist in coordinating resources (obtaining, deploying, and tracking resources requested by responding personnel), public warning (communicating to the general public regarding the nature of the hazard), and being a command post.

Cuyahoga County declares primary and support EOC facilities with different roles in activation, set-up, and operation. Primary agencies are responsible for performing and coordinating action plans. Support agencies have the responsibility to support the primary agency in accomplishing the ESF mission and tasks.

Case Study 3: Japan

After the massive earthquake that hit Japan on September 1st in 1923, Japan realized that its old infrastructure, buildings, and approach to emergency was outdated and would no longer survive the deadly natural catastrophes that would often plague its nation. Flimsy and fire-prone wooden and brick structures that used to litter Tokyo were replaced with buildings of much sturdier concrete and steel, the buildings kept from rising too high to prevent potentially fatal collapses. Transportation infrastructure was developed and flourished, allowing for Tokyo and the rest Japan to regrow.

There are numerous public awareness events that take place throughout the year to inform the public of how to deal with natural disasters, and also boasts among the world's best early warning systems for multiple types of natural disasters, such as earthquakes and tsunamis. All of these help to ensure that everything goes as smoothly as possible during a catastrophic scenario, so that the people have as much time to prepare for such scenarios as they can, and so that the people know what to do in order to put themselves out of harms way and ensure that order and restoration can begin as soon as possible.

To protect against tsunamis and floods, numerous shelters capable of withstanding earthquakes, floods and tsunamis have been built, allowing for the people to have a place to go to in the event that their homes are destroyed or need somewhere to rest. Tsunami walls and floodgates also help prevent flooding and minimize the amount of unwanted water in the territory. These preventative measures can be applied elsewhere to also counter threats of floods.

Building codes in Japan are constantly revised to ensure that buildings and other structures will be able to withstand the numerous different catastrophes that occur in Japan. Mandatory checks are carried out to ensure that these codes are enforced and put into place, and while this is costly (upwards of four billion dollars in the Shizuoka prefecture in thirty years just for improving structural integrity), it is necessary to ensure that the rebuilding process is as efficient and optimal as possible. Safety of not just public buildings of the government, but also private buildings is upheld in Japan.

Various private sector and non-governmental organizations also step in to contribute, such as the Red Cross. These organizations assist with providing supplies, reconstruction, caring for the injured, ill or otherwise disabled, among other things. The idea of mutual assistance between all parties is one that is highly valued, and one that is carried out for mutual benefit.

Japan’s legal system has also adopted to ensure that it does not fall apart in the event of a disaster, and can cope with such disasters. Legislation such as the Disaster Countermeasures Basics Act in 1961, the Erosion Control Act in 1897, the Disaster Relief Act in 1947, the Building Standard Law in 1950, the River Act in 1964 and the Act on Special Measures for Large-scale Earthquakes in 1978 all contribute to disaster management and provide a framework for how people, government workers, and the government should act under these circumstances.

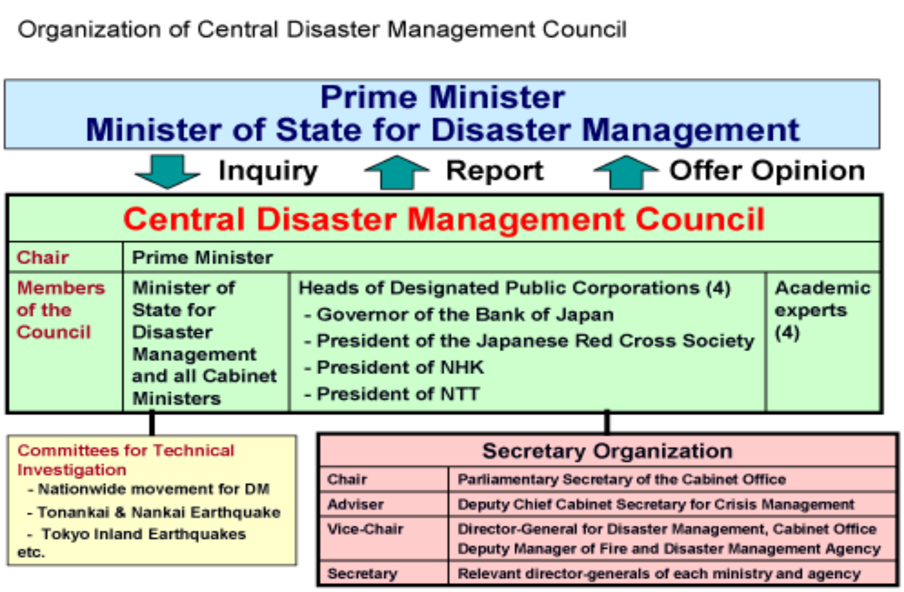

Figure 5. Emergency Plan for Organization of Central Disaster Management Council

As can be seen from Figure 5, the organizational structure in the event of a disaster at the governmental level is highly structured and organized. Responsibilities are clearly outlined, with the distribution of roles also given. The fact that this is open for the common people also indicates some level of transparency to ensure legitimacy, and means that people know what is going on, which is important so that they do not panic or act inappropriately under catastrophic scenarios.

The distribution of roles and planning goes beyond the most upper-echelons of government. The Basic Disaster Management Plan is the basis for all other plans created in Japan, and can also be said to be the master plan. From this plan stems the Disaster Management Operation Plan, with each created by government organizations and public corporations, and the Local Disaster Management Plan is similar, but only applies at the prefectural and municipal level. The purpose of this plan is to broadly state the organizational responsibilities of parties involved, implementing measures to prevent disasters from occurring, as well as planning counter-measures to prepare and respond to disasters, with long-term goals such as economic stability and rebuilding in mind.

How the ESC Should Tackle Catastrophic Scenarios, and Whether it Would be Feasible for the ESC to Handle Such Scenarios

At first glance, it appears difficult to do a risk assessment of possible catastrophic scenarios and how to deal with them, since so little information about the county itself is given. Nothing is known about the location, circumstances and details of the county, save for the population and travel time between zones. As a result, the potential types of catastrophic events cannot be narrowed down to anything specific. However, it is still possible to make broad generalizations and general plans in order to address the most common types of catastrophes, and what to do in order to mitigate the harms of such catastrophes.

It is also worth noting that the ESC will not be the only agency and party operating during such catastrophe scenarios, and that other parties will probably be assisting with the situation as much as possible. However, given that it is not possible to determine what these parties are, and how they react to given situations, it is only possible to assume that only the most basic government support that is guaranteed will be given during such circumstances, as seen in assumption 11.

Given our assumptions, and the limited information we possess, the most logical start is to find information on catastrophes. Assumption 10 restricts us to catastrophes that could affect the whole country. Catastrophes that could affect the entire country include both natural and manmade disasters. Some types of natural catastrophes that meet assumption 10 include forest fires, storms, tsunamis, floods and earthquakes. The types of manmade disasters that could affect an entire county are limited, yet there are some. For example, an oil spill, a sewage plant failure, or a large chemical production complex toxic waste handling system failure could all contaminate the water supply. If the alarm was not raised soon enough, a large number of citizens could consume the tainted water and become ill enough to need an ambulance. A war could also qualify as a manmade disaster, and would certainly devastate a county.

However, there are many assumptions that have to be made about manmade disasters. Starting with contaminated water, it is highly improbable that a significant number of people would not notice that they had drunk contaminated water. Furthermore, it is unlikely that all hospitals come equipped to deal with people who have consumed contaminated water. Not all hospitals being able to handle this would force us to assume that a hospital was in a specific district. By this point, there are an excessive number of assumptions, and Occam's razor eliminates mass water contamination as a potential catastrophe. Similarly, many other types of disasters can then by removed because of Occam's razor.

Another possible catastrophe is war. War would almost certainly occur on a scale able to devastate a county, however, there are several flaws with war as a catastrophe for the county to prepare for. First, this violates assumption 11, as in a war there would certainly be more than just county medical services to provide aid. While it is fine to go against assumptions and remove them, the reasons for having assumption 11 stand. We cannot predict the scale of the war, what the civilian casualty rate will be, what types of weapons will be used, what aid will be sent to the county etcetera. There are simply too many unknown quantities that we would have to make assumptions about. Occam's razor therefore similarly eliminates war as a catastrophe the ESC should prepare for. Clearly, natural disasters are the most applicable catastrophes for the ESC to prepare for.

However, there is one type of natural disaster we should not take measures to prepare for. If there were a global pandemic, or nationwide epidemic, or indeed any major infectious disease, it would certainly be deadly. However, the ESC would not be facing this catastrophe alone. In times of pandemic, the US government has always stepped in with aid. For example, during the swine flu / H1N1 pandemic in 2009, the US government worked to create a vaccine, and quarantines the United States so that as little excess. As a result, the ESC would not be facing the disaster alone. By assumption 11, we should not consider contagious disease as a catastrophe the ESC should prepare for, since they would have aid in coping with the disaster.

Now that it has been decided that the ESC should focus on natural disasters, there are several options. As the location of the county was not specified, it could be anywhere, so any type of natural disaster could apply. Some types of natural disasters include tropical storms, which would be called hurricanes as our county is in the US, and earthquakes. Tropical storms could also cause tsunamis and flooding. If the county was in a dry area forest fires could be a catastrophe for the county.

In preparing for natural disasters, common protocol is to prepare for the worst. However, it should be noted that as this county only possesses three ambulances for 270,000 people, it is highly unlikely that the county will be able to cope with a true catastrophe. Nevertheless, we looked at the primary types of natural disasters and their frequency rates to determine the risk of our particular county having a certain natural disaster. Then we can advise the ESC on how best to prepare for the top three most likely disasters.

Table 60. Frequency of natural disasters by county (unadjusted for un-localized disasters)

Type of disaster	US Occurrences since 1900	Historical average for one county in 1 year	Chance for our county by population***	Years Per Occurrence
Major flood	91	0.02678%	0.06953%	1438
Major hurricane	193	0.05680%	0.14746%	678
Major forest fire*	9	0.00265%	0.00688%	14535
Major earthquake**	35	0.01030%	0.02674%	3740
Total (excluding forest fire) ****	319	0.09389%	0.24375%	410

*Forest fires counted in the data table were only huge forest fires, but these huge forest can now be discounted because fires are not a modern occurrence and major ones only occurred long before fire suppression began.

**As earthquakes come in all varieties of intensities, we are only counting earthquakes that caused deaths, as if there were deaths there were almost certainly injuries the ESC would need to help out in.

***While a county having more people does not necessarily directly mean that there is a higher chance of a disaster, it very likely that a county with more people has a bigger geographical area and thus a higher chance of having a disaster. This is based on assumption 12, which states that a greater population generally leads to a greater amount of area occupied. Thus, to calculate the chance for our county by population is calculated by dividing the historical chance of occurrence in 1 year by the number of total counties in the US multiplied by the ratio of 270,000 over the average population of a county.

****Forest fires are excluded from the total, given how they are events that only occur in very specific regions of the United States. These regions generally are not susceptible to flooding-type disasters. Therefore, it makes sense to say that counties with the potential to have forest fires and counties with the potential to have floods would be mutually exclusive. Given that floods are much more likely to occur than forest fires, and also given how forest fires are relatively easy to deal with, and also cause relatively minimal human casualty, it makes sense to exclude forest fires.

Table 61 differs from Table 60 in that it adjusts for un-localized disasters or catastrophes that usually spread over one region. This is due to the fact that such disasters usually do spread beyond just one county, often encompassing entire states. As a result, it would be inaccurate to assume that one disaster would only affect one county. This inaccuracy in our data is why the years per occurrence in Table 60 seems extraordinarily high. Therefore, the figures in table 61 assume that a disaster would, on average, affect one state, or approximately 60 counties (3007 counties divided by 50 states). As an average, this makes sense, given how some disasters, such as floods, often only affect areas within a state, while hurricanes affect multiple states at a time.

Table 61. Frequency of natural disasters by county (adjusted for un-localized disasters)

Type of disaster	US Occurrences since 1900	Historical average for one county in 1 year	Chance for our county by population***	Years Per Occurrence
Major flood	91	1.61%	4.1718%	23.97
Major hurricane	193	3.4%	8.8476%	11.30
Major forest fire*	9	0.159%	0.414%	242.25
Major earthquake**	35	0.619%	1.61%	62.33
Total (excluding forest fire)	319	5.65%	14.66%	6.83

Table 61 gives us a much more reasonable catastrophe occurrence, every 6.83 years.

Now that we have determined the frequency of disasters, we must provide the ESC with specific advice as to cope with these disasters. Specifically, we must make sure that the ESC can save as many people as possible, and recover within 6.83 years and be prepared for the next disaster.

First, we will look at how to save as many people as possible during a catastrophe. We first found the worst number of injuries from each of these events when they occur, as it makes sense for the ESC to prepare for the worst.

Table 62. Largest amount of casualties from natural disasters in the US

Type of Disaster	Name of worst disaster (since 1990)	Injuries	Deaths	Casualties (Total)	Casualties (county)
Flood:	Black Hills	3057	328	3385	56
Hurricane:	Hurricane Katrina	5698	1833	7531	126

Earthquake:	Northridge	8700	57	8757	146
Total:	All of the above	17455	2216	19673	328

Of course, these are not the worst disasters in history. The China Floods in 1931 killed four million people. However, not only are we only dealing with the US, but we are also no longer in 1931. Therefore, we will only be looking at catastrophes during recent times, which we will define as since 1990, as that best reflects the state, conditions, and infrastructure of a typical county today.

We will be doing 2 methods for each type of disaster with the optimal method because we need to test which method works better. The two methods are the “Disaster-Saving Method” and the “Disaster Hour Method”. The optimal configuration with three ambulances, as stated previously in the three ambulances case, would be to use the 2, 4, 6 configuration. Both methods assume that the disaster begins the moment the day begins, according to assumption 13, and they both use the same data in terms of how many more extra deaths occur. Finally, both methods also use the same method to deal with emergency situations. This method consists of going to a zone, delivering patients to the hospital in the zone and not returning to the original zone until all the patients in the zone have been dealt with appropriately. Then, the ambulance would move on to a new zone.

The “Disaster-Saving Method” is one where the ambulances go to the closest zone (since they are all affected by the catastrophe), and help all the people in the zone, before moving on to the next zone, where they help all the people there, and then move on to the next zone. This occurs no matter how much time it takes to save all of the people. What is not calculated is the amount of people who are not affected by the disaster but need to be attended to because their issues come up during the disaster. Therefore, these people are dropped from the calculation, and time is not taken to deal with them. Moving on from there, the ambulances continue with their daily patrol routines, moving to deal with an issue as they get calls.

The “Disaster Hour Method” is one where the ambulances go to the closest zone (since they are all affected by the catastrophe), and help as many people as they can in the zone, before moving on to the next zone, where they help as many people as they can, and so on so forth. However, the ambulance only has one hour to do this, and whenever the hour runs out, no matter at what point this occurs, this model assumes that the injured all die and cannot be treated, so the ambulance continues with its daily patrol routine from that point on. However, the people who do get injured during this one-hour period is calculated when compared to the “Disaster-Saving Method”, meaning these people are accounted for.

When trying to calculate the number of calls an ambulance can service in an emergency, travel times are slightly altered. When we calculated the ambulance coverage on a normal day, we had the ambulance go out to the zone with the call, put the person in the hospital, and then return to its station position before going after new calls. This setup is illustrated in figure 6 below.

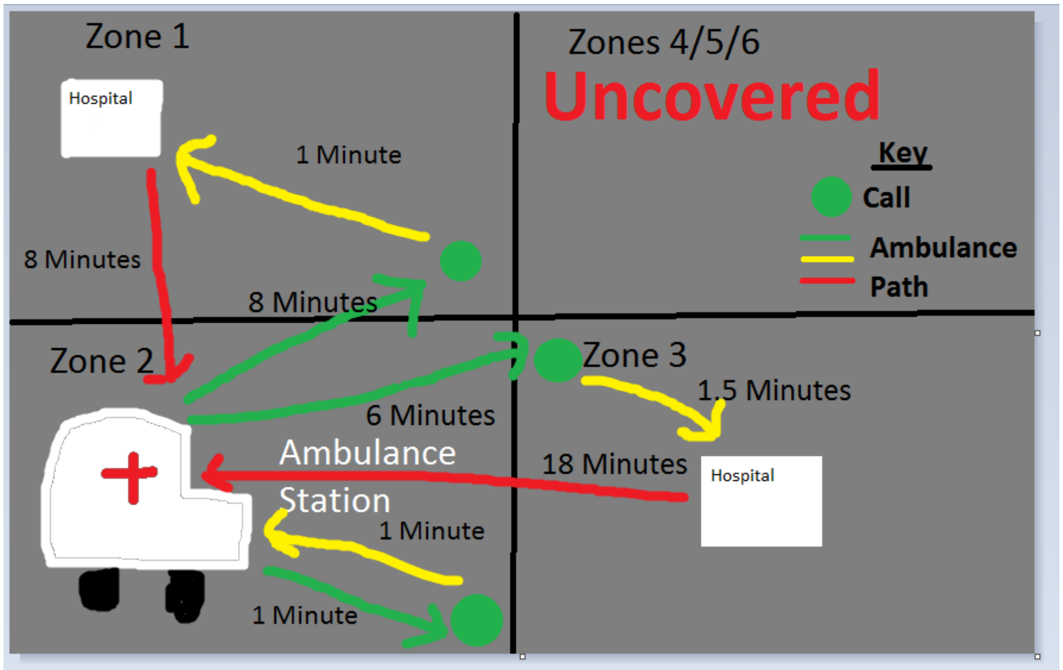

Figure 6. Ambulance path in covering calls

However, in a catastrophe situation, it is pointless for the ambulance to return to its original station after each person. Instead, the ambulance can pick up everyone in a zone and drop them off at that zone's hospital, then only when the zone is finished return to base. This allows ambulances to operate far more efficiently, as shown in figure 7 below.

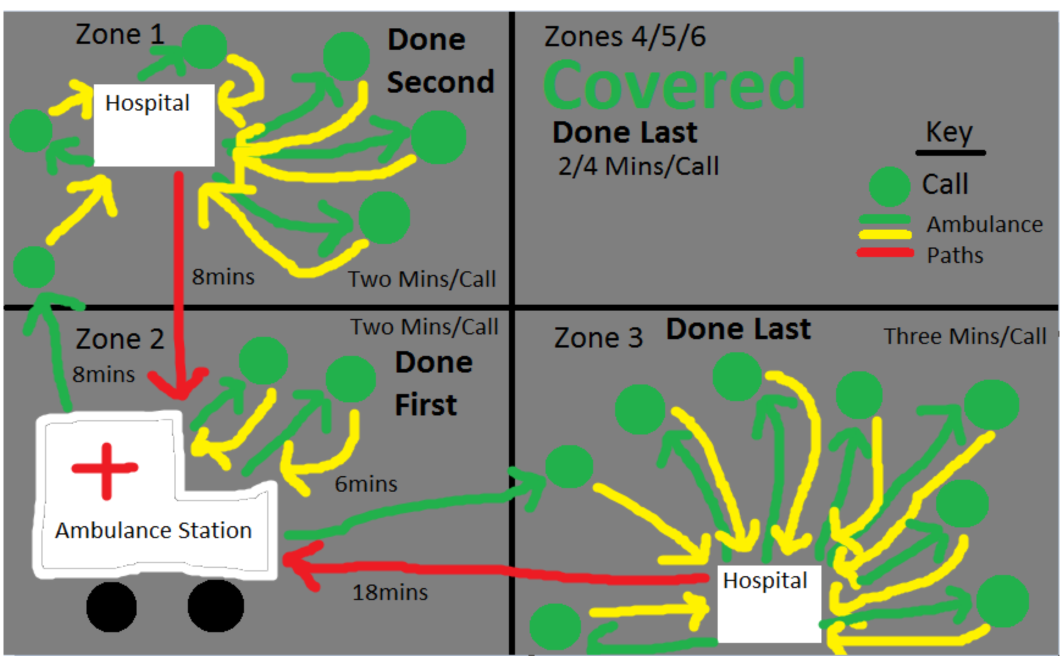

Figure 7. Ambulance path in a catastrophe situation

In a catastrophe situation, when ambulances receive a large number of calls from the same location, they first clear the calls in their own zone, as this saves the most people fastest. They then go to the next closest zone, in this scenario, zone 1, and save all the people there. However, instead of stopping back at the ambulance's station in between, they only run between the call and the zone's hospital. When zone 1 is done, however, they do stop back at the ambulance station. This is because such constant running between calls depletes the ambulance's supplies, and so it makes sense that it will need to resupply. The ambulance then goes to zone 3, as that has the next greatest travel time. Finally, it travels to zones 4, 5 and 6, and uses the same method to save people there if another ambulance has not gotten there first.

Since ambulances can operate faster, they may be able to cover the catastrophe, however, we should analyze how best to cover the catastrophe. First, we must find the number of extra calls received. Table 63 calculates the time required to handle a zone by an ambulance when it is operating under an emergency path, where x is the number of calls received.

Table 63. Times under emergency situation

Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	2*x	17+x*2	25.5+x*3	31+x*2	30+x*4	34+x*4
Zone 2	17+x*2	2*x	25.5+x*3	33+x*2	34+x*4	36+x*4
Zone 3	25+x*2	25+x*2	3*x	17+x*2	18+x*4	10+x*4
Zone 4	31+x*2	33+x*2	17.5+x*3	2*x	22+x*4	26+x*4
Zone 5	29+x*2	33+x*2	17.5+x*3	21+x*2	4*x	6+x*4
Zone 6	33+x*2	35+x*2	9.5+x*3	25+x*2	6+x*4	4*x

Table 64 is the number of new calls received during a flooding catastrophe. Of course, this includes the number of normal injuries, as those will still occur even in a flood.

Case in Flood

Table 64. Amount of calls per Flood Day

Zone:	Normal Calls:	Extra Calls:	Total Calls:
Total	414	56+18 = 74	488
1	77	10 + 3 = 13	90
2	123	18 + 5 = 23	146
3	46	6 + 2 = 8	54
4	84	11 + 4 = 15	99
5	54	7 + 2 = 9	63
6	31	4 + 1 = 5	36

Configuration Save Disasters

Table 65. Ambulance covering disasters in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	People Dropped
2	1,2	10, 18	37 + 36 = 73	4 + 6 = 10
6	3,5,6	6,7, 4	27.5 + 34 + 16 = 77.5	3 + 3 + 2 = 8
4	4	11	22	1

Table 66. Ambulance covering zones that don’t overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	76, 122	17, 2	1292 + 244 = 1536	1367 - 1536 = 169 minutes overtime	1123, 244	66, 122

6	5,6	53, 30	6, 4	318 + 120 = 438	1362.5 - 438 = 924.5	318, 120	53, 30
4	4	87	2	174	1418 - 174 = 1244	174	87

Table 67. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	45	9.5	427.5	924.5 - 427.5 = 497	427.5	45

Table 68. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	10+18+6+7+4+11+66+122+53+30+87+45 = 459
Calls made in the county	488
Percentage of calls taken/covered	94.1%
Population covered	253,955 people

Configuration One-Hour

Table 69. Ambulance covering disaster hour in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	13, 23	221 + 46 = 267	60 - 267 = 207 minutes overtime	14, 46	1, 23
6	3,5,6	8, 9, 5	33.5 + 42 + 20 = 95.5	60 - 95.5 = 35.5 minutes overtime	0, 40 ,20	0, 9, 5
4	4	15	30	60-30 = 30	30	15

Table 70. Ambulance covering zones that don't overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	77, 123	17, 2	1309 + 246 = 1555	1380-1555 =175 minutes overtime	1134, 246	67,123
6	5,6	54, 31	6, 4	324 + 124 = 448	1380 - 448 = 932	324, 124	54, 31
4	4	84	2	168	1380 - 168 = 1212	168	84

Table 71. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	46	9.5	437	932-437 = 495	437	46

Table 72. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	1+23+9+5+15+67+123+54+31+84+46 = 458
Calls made in the county	488
Percentage of calls taken/covered	93.9%
Population covered	253,402 people

Case for Hurricane

Table 73. Amount of Calls for Hurricane

Zone:	Normal Calls:	Extra Calls:	Total Calls:
Total	414	126+23 = 149	558
1	77	23+3=26	103
2	123	37 + 5 = 42	165
3	46	14 + 2 = 16	62
4	84	26 + 4 = 30	114
5	54	16 + 2 = 18	72
6	31	9 + 1 = 10	41

Configuration Save Disasters

Table 74. Ambulance covering disasters in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	People Dropped
2	1,2	23, 37	63 + 74 = 137	8, 12
6	3,5,6	14, 16, 9	51.5+70+36 = 157.5	5, 6, 4
4	4	26	52	3

Table 75. Ambulance covering zones that don't overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	72, 116	17, 2	1224 + 232 = 1456	1303 - 1456 = 153 minutes overtime	1071, 232	63, 116
6	5,6	50, 28	6, 4	300 + 112 = 412	1282.5 - 412 = 870.5	300, 112	50, 28

4	4	85	2	170	1388 - 170 = 1218	170	85

Table 76. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	43	9.5	408.5	870.5-408.5 = 462	408.5	43

Table 77. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	23+37+14+16+9+26+63+116+50+28+85+43 = 510
Calls made in the county	558
Percentage of calls taken/covered	91.4%
Population covered	246,774 people

Configuration One-Hour

Table 78. Ambulance covering disaster hour in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	26, 42	69 + 84 = 153	60 - 153 = 93 minutes overtime	0, 60	0, 30
6	3,5,6	16, 18, 10	57.5 + 78 + 40 = 175.5	60 - 175.5 = 115.5 overtime	0, 20, 40	0, 4,10
4	4	30	60	60-60 = 0	60	30

Table 79. Ambulance covering zones that don't overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	77, 123	17, 2	1309 + 246 = 1555	1380 - 1555 = 175 minutes overtime	1134, 246	67, 123
6	5,6	54, 31	6, 4	324 + 124 = 448	1380 - 448 = 932	324, 124	54, 31
4	4	84	2	168	1380 - 168 = 1212	168	84

Table 80. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	46	9.5	437	932-437 = 495	437	46

Table 81. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	479
Calls made in the county	558
Percentage of calls taken/covered	85.8%
Population covered	231,774 people

Case for Earthquake

Table 82. Amount of Calls for Earthquake

Zone:	Normal Calls:	Extra Calls:	Total Calls:
Total	414	146 + 18 = 164	578
1	77	27 + 3 = 30	107
2	123	43 + 5 = 48	171
3	46	16 + 2 =18	64
4	84	30 + 4 =34	118
5	54	19 + 2 = 21	75
6	31	11 + 1 = 12	43

Configuration Save Disasters

Table 83. Ambulance covering disasters in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	People Dropped
2	1,2	27, 43	71 + 86 = 157	9, 14
6	3,5,6	16, 19, 11	57.5 + 82 + 44 = 183.5	6, 7, 4
4	4	30	60	4

Table 84. Ambulance covering zones that don’t overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	71, 114	17, 2	1207 + 228 = 1435	1283 - 1435 = 152 minutes overtime	1055, 228	62, 114
6	5,6	49, 28	6, 4	294 + 112 = 406	1256.5 - 406 = 850.5	294, 112	49, 28

4	4	84	2	168	1380 - 168 = 1312	168	84

Table 85. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	42	9.5	399	850.5 - 399 = 451.5	399	42

Table 86. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	27+43+16+19+11+30+62+114+49+28+84+42 = 525
Calls made in the county	578
Percentage of calls taken/covered	90.8%
Population covered	245,242 people

Configuration One-Hour

Table 87. Ambulance covering disaster hour in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	30, 48	77 + 96 = 173	60 - 173 = 113 minutes overtime	0, 60	0, 30
6	3,5,6	18, 21, 12	63.5 + 90 + 48 = 201.5	60 - 201.5 = 141.5 minutes overtime	0, 12, 48	0, 2, 12
4	4	34	68	60 - 68 = 8 minutes overtime	60	30

Table 88. Ambulance covering zones that don't overlap in 2, 4, 6

Ambulance #	Zones covered	Calls from zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
2	1,2	77, 123	17, 2	1309 + 246 = 1555	1380 - 1555 = 175 minutes overtime	1134, 246	67, 123
6	5,6	54, 31	6, 4	324 + 124 = 448	1380 - 448 = 932	324, 124	54, 31
4	4	84	2	168	1380 - 168 = 1212	168	84

Table 89. Ambulance covering zones that do overlap in 2, 4, 6

Zones covered	Ambulance #	Calls from the zone	Time Spent per Call	Total time spent (minutes)	Excess time remaining (minutes)	Time Allocated	Calls Actually Taken
3	6	46	9.5	437	932-437 = 495	437	46

Table 90. Results for ambulance covering zones for 2, 4, 6

Total Calls Taken	479
Calls made in the county	578
Percentage of calls taken/covered	82.9%
Population covered	223,754 people covered

From the data tables above, it is clear that the "Disaster-Saving Method" is much more efficient at saving people than the "Disaster Hour Method", given how it has a much greater percentage of calls taken and covered, and also covers a larger population as a result. From the data table below, we can see that this is the case, and that the "Disaster-Saving Method" ought to be used, as opposed to the "Disaster Hour Method".

Table 91. Results from the “Disaster-Saving” and “Disaster Hour” Models with Configuration 2, 4,6 for Ambulances

Disaster Type	Method Used	Percentage Taken	Population Covered
Flood	“Disaster-Saving”	94.1%	253,955 people
Flood	“Disaster Hour”	93.9%	253,402 people
Hurricane	“Disaster-Saving”	91.4 %	246,774 people
Hurricane	“Disaster Hour”	85.8%	231,774 people
Earthquake	“Disaster-Saving”	90.8%	245,242 people
Earthquake	“Disaster Hour”	82.9%	223,754 people

Therefore, under most disaster situations, it would be far better to use the “Disaster-Saving” method than the “Disaster Hour” method. This is due to the fact that the “Disaster Hour” method eventually reaches a saturation with regards to how many people can be handled. Even if one increases the amount of time allocated for the Disaster Hour, it is still less efficient than the Disaster-Saving method. As a result, when there is a disaster, the ambulances will, as usual, run a 2,4,6 configuration and use the Disaster-Saving method.

This will not be completely accurate, because, as stated above, there are some people who are left uncovered that would be covered by the ambulances under the Disaster-Saving method, when compared to the ideal Disaster-Saving method. This means that the actual efficiency would be slightly higher, given how the emergency ambulance route is more efficient.

This means that not everybody was covered. Under the Disaster-Saving method, all people in the disaster will be covered and safe. However, the problem with the Disaster-Saving method is that it takes too much out of the regular, meaning that regular people with injuries from there on out may not receive treatment. This is supported by the fact that the highest percentage of people covered under the Disaster-Saving method is 94.1%. Under the Disaster Hour method, the disaster is not able to be handled properly, given the time constraints on the ambulances, meaning that the disaster is not covered. The rest of the day is also not completely covered. This means that it is worse than the Disaster-Saving method, given its best coverage is 93.9% of the population. Therefore, the ESC will not be able to completely cover the medical situation with the limited number of ambulances available.

Moving on from allocation of ambulance resources, we also need to deal with how the city on the whole will deal with each kind of disaster. We will be going through each individual type of disaster, and the appropriate response from the ESC and the government.

Designing for Catastrophic Events

Regarding All Catastrophic Scenarios

The ESC, in conjunction with local and state governments, should create plans to deal with each catastrophic scenario, detailing responsibilities of parties involved, and organizing resources to ensure that if and when such a disaster occurs, the county will be safe. Since not much information about the county is given, we assume that the ESC will not be able to provide many resources or much manpower if necessary. This can be seen by the fact that the ESC is only able to afford three ambulances for a population of 270,000 people, when each ambulance usually costs somewhere in the region of $20,000. From this, we know that the local, state, and NGOs will have to bear most of the burdens in this scenario. However, given that there is no guarantee that there are any NGOs that will help, this is a factor that cannot be relied upon. Therefore, only the local and state governments will be able to contribute meaningful resources and manpower, although the ESC will probably be able to assist in coordination.

Depending on the structure of the local and state government, this means that parties will need to be responsible for medical teams (which the ESC helps with), fire and rescue operations, law enforcement, care and shelter operations, communications and warning systems, construction and engineering teams. In general, existing law enforcement should not have to be bolstered in disaster scenarios, medical teams have been covered by the ESC, fire and rescue operations should mostly be covered by existing fire departments and law enforcement people. However, care and shelter operations, communications and warning systems, and construction and engineering teams would need to be created.

Management on all levels is required in order to keep track of resources, people and other information involved. This is to ensure that things are being done as efficiently and accurately as possible. The goal of disaster recovery should always be to mitigate damage done by the catastrophic event, and to help the county recover to its former state. Planning must be done for all probable scenarios, and not just floods, earthquakes, and hurricanes, so that the county is prepared for all eventualities. However, ones that will probably not or never occur, such as nuclear fallout if there are no sources of nuclear energy, waste, material or synthesis in the region, should not be considered, due to the extremely low probability of such an event occurring. However, since no information is provided on the county, we cannot disregard any of these possibilities in this section.

In general, plans should provide a system to effectively manage emergency situations, identify sources of authority and clearly define relationships, to delegate tasks and responsibilities, to ensure that there are sufficient resources, facilities and services, and to provide a framework for long-term recovery and growth. Mutual aid should be requested where necessary, although not relied upon, given how it may not always be received.

To prepare for such scenarios, infrastructure should be improved. This goes beyond just improving the state of public services, such as hospitals and shelters, although it is helpful, and requires the improvement of transportation systems and nearly all facilities and buildings. Facilities and buildings should be made to have a greater structural integrity, and should be more resistant to damage from all sources, including waves, fire, and even pressure. This can be achieved by creating new building codes and making sure that they are enforced. Early-warning systems to detect incoming disasters should also be implemented, to allow more time for preparation, evacuation, and other responses to such a disaster. Necessary legislation to enact this should also be passed.

Government agencies that will generally help after the fact include the SBA (Small Business Administration), the DHU (Department of Housing and Urban Development), the USDA (United States Department of Agriculture), the IRS (Internal Revenue Service), the FEMA (Federal Emergency Management Agency), the Social Security Administration, the Health and Human Service, as well as the Food and Drug Administration, although they may not apply to every disaster scenario.

Not much clear information on what physical action to take is given in this section, given how the nature of every catastrophic scenario is different, leading to different solutions. What may work in one scenario may be detrimental in another, and so information on how to deal with specific scenarios will be provided in later sections.

Finally, when we talk about the ESC covering a natural disaster or some catastrophic scenario, this is the ESC in conjunction with the state government and the local government. To cover would mean to adequately protect the common people, and be able to salvage situations so that rebuilding is possible, and so that minimal damage is to done to resources, property, and people.

Regarding Floods

Floods are situations where there is too much incoming water, either because local bodies of water, such as rivers or lakes, have overflowed, or because there is an excess intake of water, from sources such as the ocean or rain. Usually, the results of floods are devastating, pushing territory and houses underwater, leaving people to evacuate the scene or move to high ground to stay safe. This results in large amounts of property damage and sometimes injuries and deaths when people do not evacuate from the region quickly enough.

First of all, preparations must be made so that floods cause minimal damage even if nothing is done during and after the flood occurs. As per the section regarding all catastrophic scenarios, detectors should be put in place to find out when flooding will occur ahead of time, so that the people will have an adequate warning when such an event does occur. This will give more time for people to get out of the way or get to high ground, so that they are safer, and will give more time for emergency services to respond to an impending natural disaster.

Another part of these preparations would be to construct various anti-flooding structures. These structures include tsunami walls and flood gates, which when implemented by the ESC and other affiliated organizations, would block incoming water and prevent it from overflowing into the county region. These would also help to redirect the water to other regions which would not suffer from the threat of flooding. In this way, the height of the flooding would be less than expected.

Obviously, other preventative measures such as organization of such measures and counter-measures, as well as most things detailed in this section, should be coordinated by the ESC and other affiliated organizations. Other measures include informing the public of what to do in the event of a flood, through various public service announcements or other forms of communication from government to the people. This is to ensure that the people can react as best as they can in the event of a flood. Various locations should be designated as safe areas to retreat to in the event of a flood.

When a flood actually occurs, it is first necessary to send out search and rescue parties to make sure that all people are safe. Depending on the severity of the flooding, this can be done through people wading through water, or with boats capable of traveling quickly through narrow areas. They would go door to door, checking for people who are still inside, and bringing them out to safety. Helicopters could also assist here by providing aerial vision and quick transport. Government workers will also need to set up shelters at safe areas in a flood, and see that there is no trouble or conflict. Law enforcement can assist if there is trouble or conflict in such regions.

Figure 8. A Flood Shelter

There is no feasible way to make a flood disappear, and so it is necessary to just wait for the flood to gradually disappear. However, depending on how long it takes for the flood to recede, shelters may need to be stocked with large amounts of water, food, medical supplies, and places to rest. People will be at least temporarily living in this region, so these shelters need to be equipped for this eventuality. Care must be given to those who need it, which the section on the ambulance distribution and configuration covers.

Meanwhile, search and rescue operations must continue to go on, in case there are people who are still missing, and need to be rescued. On top of that, management of resources and record-keeping must continue. Inevitably, there will be some property damage and loss of resources when such floods occur. However, it would be best to ensure that as little property and resources is destroyed as possible. This can be done by creating more structurally sound and waterproof structures, which would then be able to withstand floods.

Once the floodwaters recede, people should be ordered to return to their homes and properties as fit. However, if people have lost their homes or are unable to return to them for other reasons, they should be given leeway, and should be allowed to stay in shelters until suitable housing can be found. The injured should be allowed to stay in hospitals until they have recovered. Funding from local and state governments, as well as from governmental agencies, should be funding all of the shelters, resources and emergency medical services in general.

Damage assessment should be carried out as soon as possible to determine the severity of the flood, as well as to determine the people who perished in the flood. This will allow the ESC and government to better prepare for future floods. Damage assessment will also let the government know where to focus reconstruction crews, which should be led by the engineering teams. They will rebuild broken houses and other facilities, so that they can be operational and of use. Reconstruction should not only be limited to physical buildings, but also to anything damaged in general that is government owned.

If all of these suggestions are carried out, then the county should be fairly safe from most floods. More can be added or adapted if necessary, but the ESC and other affiliated organizations should be able to deal with a flooding scenario. However, the ESC on its own would not have the resources necessary to deal with a flooding scenario.

Regarding Hurricanes

Hurricanes (also tropical cyclones, or typhoon) are natural disasters with characteristics of strong wind, rain, and thunderstorms, forming on large bodies of water. Usually, the most severe winds occur in the ocean (due to it being created at said location) and therefore is less severe when reaching land. However, it can nonetheless create devastation, not only causing strong wind and rain, but also creating high waves, storm surge, and tornadoes as a byproduct, thus causing floods (refer to the last section on floods), damage in infrastructure, and injury (from flying debris, floods, etc.)

Like with any other natural disaster, preparations must be made to prevent damage from hurricanes. Daily weather forecasts must be made, in order to be able to track, and detect incoming hurricanes, in order to prepare in advance for the upcoming disaster. Long-term prevention is not really possible.

Another part of these preparations would be to construct various anti-flooding structures. These structures include tsunami walls and flood gates, which when implemented by the ESC and other affiliated organizations, would block incoming water and prevent it from overflowing into the county region. These would also help to redirect the water to other regions which would not suffer from the threat of flooding. In this way, the height of the flooding from hurricanes would be less than expected.

Obviously, other preventative measures such as organization of such measures and counter-measures, as well as most things detailed in this section, should be coordinated by the ESC and other affiliated organizations. Other measures include informing the public of what to do in the event of a hurricane, through various public service announcements or other forms of communication from government to the people. Various locations should be designated as safe areas to retreat to in the event of a hurricane.

Government workers will also need to set up shelters at safe areas in a hurricane, and see that there is no trouble or conflict. Law enforcement can assist if there is trouble or conflict in such regions. There is no feasible way to make a hurricane disappear, and so it is necessary to just wait for the hurricane to gradually disappear. However, depending on how long it takes for the flood to recede, shelters may need to be stocked with large amounts of water, food, medical supplies, and places to rest. People will be at least temporarily living in this region, so these shelters need to be equipped for this eventuality. Care must be given to those who need it, which the section on the ambulance distribution and configuration covers.

Meanwhile, search and rescue operations must continue to go on, in case there are people who are still missing, and need to be rescued. On top of that, management of resources and record-keeping must continue. Inevitably, there will be some property damage and loss of resources when such floods occur. However, it would be best to ensure that as little property and resources is destroyed as possible. This can be done by creating more structurally sound and waterproof structures, which would then be able to withstand hurricanes.

If there is a flooding during the hurricane, the ESC should follow the procedure for flooding as well.

Regarding Earthquakes

Earthquakes are the result of a sudden release of energy in the Earth's crust, and they occur in specific places where chances of earthquakes are higher, because they are nearer to the plates of the Earth.

To prepare for an earthquake, the ESC must first determine the chances of it happening. If the chances of an earthquake is high, you must make sure that buildings are built with strong structures and are built low so that the earthquake does not cause too much damage to the area. These chances can be determined from seismic graphs, which can be formed from detectors that should be put in place so that people some time in advance to know the Earthquake is coming. This will definitely give emergency services more time to respond as well, as they can get ready.

Another important part to prepare for earthquakes is to use public service announcements to make sure the citizens of the county or country to know what to do. Citizens should be prepared to be self-sufficient for at least three days, avoid storing heavy objects in the house, securing bookcases, and having an emergency kit at home, office, and car. Also, citizens should know what to do during an earthquake. The procedure is to drop, cover, and hold so if a citizen is in a building, they should drop to the ground, take cover by getting under a sturdy desk or table, and holding on until the earthquake commences. Also, citizens should be prepared for an aftershock.

The ESC should also have ambulances and shelters prepared for when the earthquake takes place depending the magnitude of earthquakes around their location, because it may be possible that the earthquake destroys or deconstructs buildings that people live in. Having the shelters prepared would eliminate or lower the number of people who will have no shelter after the earthquake. The shelter should be long-term and equipped with food, water, shelter, and all the other basic necessities of life. The shelters should be sturdy and should not be affected by the earthquakes.

If all of these suggestions are carried out, then the county should be fairly safe from most earthquakes. More can be added or adapted if necessary, but the ESC and other affiliated organizations should be able to deal with a flooding scenario. However, the ESC on its own would not have the resources necessary to deal with a flooding scenario.

Conclusion

It is not possible for the ESC to handle any disaster catastrophic scenario on its own. However, with the assistance of the local government, state government, and possibly federal government, the county will have the resources necessary to deal with the disasters outlined above. However, the ESC cannot cover the situation without this assistance, as it probably lacks the resources to carry this out.

Through the various suggestions offered, a clear plan is detailed. This plan will allow the ESC and other affiliated groups to be able to deal with such disasters.

Part 6

Non-technical Memo

To: Emergency Service Coordinator
From: Team 4004
Date: November 3, 2013
Subject: Emergency Medical Response

Dear Emergency Service Coordinator,

The purpose of this memo is to inform you of our work. We have modeled how to cover the most people in the county with three ambulances, two ambulances, and just one ambulance. We have also determined what to do in the event of a natural disaster, with regards to ambulance distribution and general plans, as well as whether you will be able to handle the situation.

When modeling how three ambulances should be distributed; we determined where placement of ambulances would maximize the number of regions covered, and then determined the number of people each configuration of ambulances that would be covered. In the end, we had several configurations that had an equal coverage of people, so we decided to pick the configuration with most ambulance free time as the best. This configuration had an ambulance in zone 2, zone 4, and zone 6. This configuration covered 97.7% of the population, and left 6,250 people uncovered. We determined that you would not be able to cover the whole county on your own.

When modeling how two ambulances should be distributed, we determined the only configuration that would be able to handle all regions to be the one that had an ambulance in zone 2 and zone 5. This configuration covered 77.5% of the population and left 60,615 people uncovered. We determined that you would not be able to cover the whole county on your own.

Finally, when modeling how one ambulance should be distributed, all possible configurations of ambulances were tested. The best configuration was determined to be having an ambulance in zone 2, which allowed for 45.83% of the population to be covered, and left 146,259 people uncovered. We determined that you would not be able to cover the whole county on your own.

Moving on to modeling disaster scenarios, we first looked at several counties and countries, Japan, Cuyahoga of Ohio, and San Diego to determine how they dealt with disasters. We then modeled how the ambulances would best be used in a disaster scenario, through the previous described best configuration for three ambulances of 2,4,6, through two different ways of dealing with a disaster. The “Disaster-Saver” method involves an ambulance going through its assigned zones and working in these zones until all people from the disaster are treated, before going through the usual routine. The “Disaster Hour” method involves an ambulance going through its assigned zones and working in these zones for an hour, regardless of how many people are treated, before going through the usual routine. It was determined that the “Disaster-Saver” method would be more efficient in covering people, covering up to 94.1% of the population and leaving a minimum 16,045 people without coverage during a disaster. We then determined what to do in the event of a hurricane, flood and earthquake. We figured out that you alone will not be able to handle the entire scenario, but with assistance from local and state governments, you would be able to do so.

We strongly urge you to take our recommendations and start using the ambulance configurations that we have offered, given that they will be able to save the most people, and also urge you to implement our disaster plans, to minimize the damage done as a result of disasters.

Best,
Team 4004

Part 7

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