Responding to an Anthrax Attack

Designing a Robust Plan

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The speed at which anthrax kills makes responding to a large-scale anthrax event an extremely challenging "systems problem."

Designing a mass program to rapidly dispense antibiotics requires meticulous advance planning and the careful integration of clinic processes with staffing plans, client logistics, and supply chain operations. The best clinic process in the world is not useful if gridlocked parking lots and access roads prevent clients and supplies from reaching the dispensing site.

Since it is impossible to anticipate every detail of an attack, the response plan must be ***robust***—that is, effective under a range of likely scenarios.

The Center for Emergency Response Analytics (CERA) recently worked with state planners to design a 24-hour dispensing program for 80,000 people at a popular vacation destination that we will call "Bay Island."

CERA used dynamic computer simulation to:

- Evaluate alternative dispensing strategies, using key measures of process performance.
- Determine if Bay Island's primary point of dispensing (POD) would suffice or if a secondary POD would be necessary.
- Develop POD staffing plans.
- Plan traffic and parking lot operations.
- Identify and avoid "tipping points" beyond which the plan would cease to work.
- Assess and improve the robustness of the plan.

Scenario

In his excellent paper, *Catastrophic Bioterrorism: What Is To Be Done?*, Richard Danzig recommends defining scenarios that "can serve as an anvil against which to hammer hypotheses, enabling us to establish requirements and to test the validity of different strategies for dealing with catastrophic bioterrorism." [1]

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[1] Richard Danzig, "Catastrophic Bioterrorism—What Is To Be Done?," Center for Technology and National Security Policy, National Defense University, Washington, D.C., August, 2003, http://www.ndu.edu/ctnsp/catastrophic%20bioterror.htm.

The Bay Island scenario involved an aerosolized anthrax release during the height of the tourist season. Experts would not have time to determine the extent of the attack, so officials would have to undertake an Island-wide response.

State planners asked us to assume that the Bay Island attack was the only attack. This enabled us to focus on a dispensing operation in a single location and postpone consideration of the supply chain issues and other complications that would accompany a broader bioterror campaign. [2]

Response Window

The CDC recommends that first-wave dispensing operations be completed within 48 hours of the decision to dispense. (Ten-day regimens are dispensed in the first wave—to be followed up by an extended program to dispense 50-day regimens.)

State and local planners estimated that it would take 24 of the 48 hours to muster staff and volunteers, receive the first pharmaceuticals from federal stores, and prepare the dispensing sites for first-wave operations.

The 24-hour set-up period would also give the police an opportunity to close the island's only bridge to the mainland to unauthorized island-bound traffic.

[2] We recognize that a single attack is likely to be part of a campaign designed to break the supply chain. We also recognize that public pressure may force a wider response even if an attack is isolated.

We assumed that dispensing operations would begin at 8 AM and continue for 24 hours.

Population

The most fundamental issue to POD operations planning is population.

How many regimens will the POD dispense, how many people will come to the POD, and how will they get there?

Planners can make some reasonable assumptions, prepare for them, and then take steps to make those assumptions hold true.

Bay Island has only 10,000 year-round residents. In tourist season the population swells with seasonal residents, tourists, campers, and seasonal workers.

State and local planners wanted a plan to dispense medications to the 80,000 people that would be on Bay Island at the height of the tourist season.

Planners thought that vacationing families would be reluctant to split up in order to send just one family member to the POD. For this reason, we designed the plan for a worst-case scenario in which entire families would come to the POD.

Bay Island, one of the largest islands on the east coast, has no mass transportation system. Since the primary POD is in an isolated location, most families would drive to the POD in their own cars. This could present a challenge, because the roads are congested even when the island is not under anthrax attack.

The Dispensing Process

State officials have opted for a high standard of care and have modeled their dispensing process on CDC's smallpox vaccination process.[3]

We tested a number of process designs and arrived at the process shown in Figure 1.

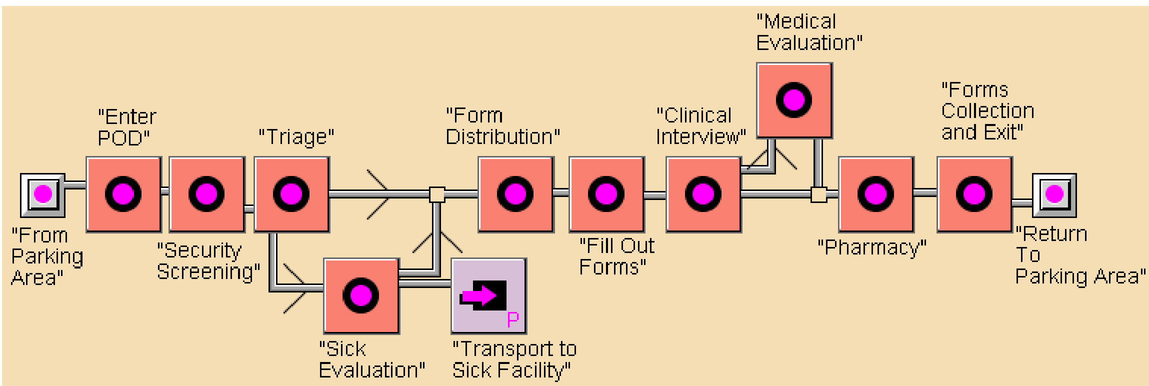


Figure 1. Bay Island dispensing process.

Each of the blocks in the figure represents one or more "stations" where part of the dispensing process is carried out. There are security stations, form distribution stations, pharmacy stations, and so on.

Families will arrive, park their cars, walk to the POD, and go through the process together, moving from station to station. They will undergo security screening and triage, receive educational materials and forms, and take them to a special area to fill out. Staffers will roam the area answering questions. (Formal orientation is impractical, given the enormous throughput requirements of the dispensing operation.)

Clinical interviewers review each family's forms in order to identify clients with allergies, potential interactions with other drugs, and special dosage requirements. If a family has special problems, the interviewer will direct them to one of the medical evaluation stations.

The pharmacy will prescribe and dispense the appropriate medications for each family member.

Exit interviewers will collect each family's forms and provide final instructions.

Families will return to their cars and depart.

Pattern of Arrivals

Many mass dispensing plans rely upon a flow of clients that begins conveniently when the POD opens its doors and remains constant for the duration of the operation.

It is far more likely that families will begin arriving before the POD opens and

[3] CDC, Annex 3 – Guidelines for Large Scale Smallpox Clinics, http://www.bt.cdc.gov/agent/smallpox/response-plan/files/annex-3.pdf

that arrivals will follow a pattern of surges and lulls.

If planners are not prepared for this type of arrival pattern, they will not be able to move people through the process fast enough to keep their parking lots from overflowing. Traffic will back up along the access roads, families will abandon their cars, operations will get off to a terrible start, and everybody will have a really bad day.

We assumed that families would start arriving a couple of hours before the POD opened and that arrivals would be heavier during the day than at night.

Simulation showed us the effect that different surge patterns would have on dispensing operations and enabled us test strategic alternatives.

How Many PODs?

State and local officials identified a primary and a secondary POD site.

Bay Island High School is the primary POD site. Its large cafeteria and gymnasium provide a good layout for dispensing operations. It has a 462-car parking lot. Nearby athletic fields can accommodate an additional 1,250 cars and a heliport.

The high school is located on an isolated stretch of Bay Road, a two-lane road.

The driveway that serves as the only entrance and exit to the campus is a likely bottleneck.

Bay Road can easily be turned into a one-way road, providing right-turn-only access to the school and a right-turn-only exit from the school. This could double

Parking

Because of its compressed timeframe, an anthrax response requires enormous amounts of parking—for staff and emergency vehicles as well as clients.

Bay Island's primary POD site had a 462-space parking area—big for a high school, but not even big enough for the POD's staff. POD managers would need to use four adjacent athletic fields as parking areas.

We were suspicious of rules of thumb, like "108 cars per acre." Wouldn't a field's capacity depend on the its dimensions rather than its area?

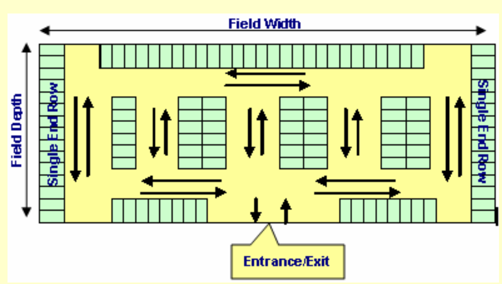
The answer is, "Yes."

To see that this is true, imagine a 43,560-foot long field that was one foot wide. It's an acre, but you can't park any cars in it.

In order to determine the capacity of the fields, we needed to know the dimensions and we needed to design a parking configuration. We also needed to know how tightly we could pack the cars.

We developed a spreadsheet model that enabled us to experiment with field parking by adjusting dimensions, configurations, and densities.

We settled on the following parking configuration because of its capacity, the ease of setting it up, and its flexibility—you can create entrances and exits just about anywhere.



the throughput of the road-driveway intersection.

Our simulation model showed that under a convenient, steady flow of arrivals, the high school could serve as the sole POD.

However, when we simulated operations under more realistic arrival patterns, we found that even a moderate morning surge could overwhelm the POD so that it would never recover.

The parking lot filled quickly and access roads backed up into nearby villages. Cars, emergency vehicles, and delivery vehicles were unable to enter or exit the POD.

What Standard of Care?

The standard of care that dispensing operations can or should provide is a hot topic of discussion.

Those who argue for a high standard would like to see PODs that educate families thoroughly, question clients about allergies and other medications, prescribe accurate pediatric doses, personally instruct each family in the use of medications, and perform lot tracking.

At the other end of the spectrum are those who argue for a "Chicklets approach." They say that it is important to dispense medications quickly by any means (e.g., drive-through PODs, Postal Service delivery, etc.) and attend to the details later.

The tradeoffs among cost, service, and safety are likely to be different for each bioterror agent and each set of medications.

Providing a high standard of care requires more staff and more physical space. By increasing the time that clients spend in the POD it also increases POD populations and parking requirements.

Converting Bay Road into a one-way road eased the gridlock only slightly—POD traffic still backed up into the island's largest village.

Local officials estimated that if two PODs were available, 70% of the island's population would go to the primary POD and 30% would go to the secondary POD.

Our simulation model showed that two PODs could serve Bay Island with only brief backups during the morning surge.

Modeling and Simulation

POD operations are complicated. The complex interactions among the process layout, staffing levels, physical limitations of the POD site, client transportation, and supply chain operations defy analysis by static tools and techniques such as spreadsheets and mathematical models.

CERA uses dynamic simulation to evaluate operational alternatives. CERA has developed a modeling toolkit for dispensing operations using ReThink, a discrete-event modeling and simulation package from Gensym Corporation in Burlington, MA (www.Gensym.com).

Using ReThink and the CERA toolkit, we simulate dispensing operations by moving "family objects" through a schematic that depicts the POD process, parking lots, and access roads. Each simulated family stops at each "station" in the schematic, waits for the service that is provided at that station, and then moves to the next station. The simulator collects statistics relating to the families, the services, and the resources that provide the services.

The CERA models are like virtual laboratories enabling us to experiment with the process, the scenario, and the staffing plan.

We can determine the effects of adding or removing parking capacity, adding or removing entrances or exits to the parking areas, changing two-way roads into one-way roads, adding or deleting steps in the process, adding or removing staff, changing the lengths of shifts, or changing the pattern of client arrivals.

We evaluate the effectiveness of the dispensing operation by measuring key indicators of process performance.

The aspects of process performance that interest us the most include:

- How long does it take a family to get through the process?
- How long do families sit in traffic?
- How far does car traffic back up?
- What is the client population in the POD?
- Where in the POD do lines form?
- How busy is the POD staff?

Staffing Requirements

Offering a high standard of care to 80,000 people in a 24-hour dispensing operation requires a large number of people—healthcare and public safety professionals as well as volunteers from the community.

Bay Island's PODs will each operate for three eight-hour shifts. We expect the PODs to be at their busiest during the first half of the first shift.

Table 1 shows the station requirements for POD 1. We divided the first shift into two four-hour periods.

POD 1 Stations				
Function	**Shift 1**		**Shift 2**	**Shift 3**
Security/Triage	60	45	45	30
Sick Evaluation	3	3	3	2
Form Distribution	15	12	12	8
Form Review	45	34	34	23
Medical Counseling	21	16	16	11
Pharmacy	30	23	23	15
Form Collection	30	23	23	15

Table 1. POD 1 station requirements.

Table 2 shows the non-management personnel requirements for Bay Island's PODs. In order to minimize the overall personnel requirements, we assumed that Shift-1 workers would able to staff Shift-3.

Staffing Requirements			
Function	**POD 1**	**POD 2**	**Total**
Security/Triage	121	52	173
Sick Evaluation	8	4	12
Form Distribution	32	15	47
Form Review	92	40	132
Medical Counseling	44	21	65
Pharmacy	62	27	89
Form Collection	62	27	89
Helpers in "Forms Area"	52	22	74
Flow Monitors	62	27	89
Parking & Traffic Attendants	30	15	45
Roving Security	40	40	80
Total	**605**	**352**	**957**

Table 2. POD staffing requirements.

POD Performance

The key measure of POD performance is "time-in-process." That is, the length of time it takes families to complete the process—from the time they enter the stream of traffic to get into the POD to the time they exit the POD parking lot.

Time-in-process depends upon dozens of factors including:

- Parking capacity.

- The throughput of the parking area entrances and exits.
- The amount of "nuisance traffic" (not headed for the POD) on the roads.
- The time it takes families to walk from the car to the POD and then to find their cars after exiting the POD.
- The speed at which breakdowns, accidents, and abandoned cars are removed.
- Time-in-POD.

Likewise, time-in-POD (the amount of time a family spends in the POD) depends upon dozens of additional factors including the design of the process, the physical constraints of the POD, and the staffing plan.

Figure 2 shows the time-in-process that we expect at POD 1 over its 24 hours of operations. It also shows the increase in time-in-process that we would see if client parking capacity were reduced from 1,200 cars to 1,000 cars.

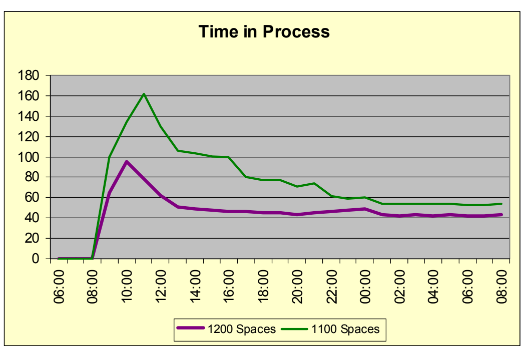


Figure 2. POD 1 time-in-process.

Figure 3 shows POD 1's arrivals and the resulting client population over the course of operations. The initial spike occurs when the POD begins operations at 8 AM. The POD will finish working through the initial morning surge by about noon.

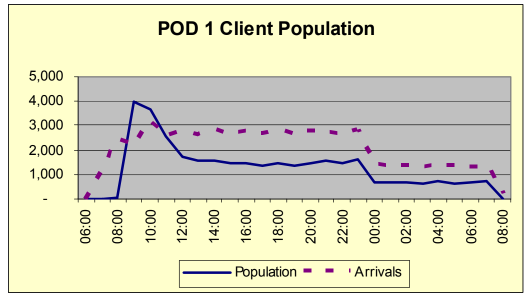


Figure 3. POD 1 population.

Figure 4 shows the extent of the traffic backup waiting to enter POD 1's parking area. Traffic peaks at around 9 AM and drops to a more acceptable at level around 11:30.

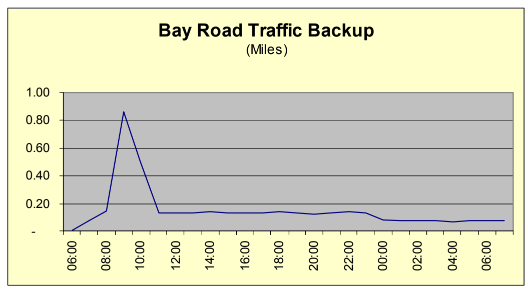


Figure 4. POD 1 traffic backup.

In our analysis we assumed that there would be 10% nuisance traffic. That means that for every 10 cars headed for the POD, there is one car that bypasses the POD. Our experiments showed that nuisance traffic had a surprisingly small effect.

Robustness

Planners make hundreds of assumptions when designing an emergency response plan. Some of the assumptions are bound to be wrong. If a plan is robust, it can be carried out successfully anyway.

We assessed the robustness of the Bay Island response plan by carrying out a series of sensitivity analyses. We perform a sensitivity analysis by changing one of our assumptions, re-running the simulation, and observing the effect upon our three most important performance metrics: time-in-process, POD population, and traffic backup.

Table 3 summarizes a few of the sensitivity tests that we ran on our Bay Island plan for POD 1.

Sensitivity Analyses		
Modify Assumption	**Factor**	**Impact**
Increase Nuisance Traffic	25%	Low
Allow 2-way Traffic		High
Reduce Intersection Throughput	10%	Low
Increase Initial Surge	25%	Medium
Reduce Client Parking Capacity	6%	High
Reduce Family Size	10%	High
Increase POD "Dwell Times"	10%	Low

Table 3. Sensitivities.

More than a Medical Problem

Preparing a complete and robust plan for responding to a bioterror attack is an enormously complex "systems problem" that requires the integration of clinical and administrative processes, client logistics, and supply chain operations.

A community will have so little time to respond to an anthrax attack that last-minute planning and on-the-job training are not options. Officials must plan meticulously and develop plans that are flexible and robust.

The CERA simulation models provide a good "anvil against which to hammer hypotheses, establish requirements, and test the validity of different strategies."

Creating the Bay Island simulation models helped us to develop a more complete plan—modeling required us to make explicit assumptions where we might have been tempted to hand-wave.

Simulation showed which assumptions were important and which were not; helped determine if our goals were achievable; enabled us to compare alternatives, and demonstrated how the plan would work even if some assumptions were wrong.

The tools and techniques that we have developed will apply equally well to second-wave dispensing, other locations, other threats, larger-scale responses, and more complex supply chain operations.