CENTER FOR EMERGENCY RESPONSE ANALYTICS

RSS Analysis Project

Final Report

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1 Introduction

If terrorists attack the United States with biological weapons, operations to dispense medications to the affected population must begin immediately. Federal, state, and local agencies must quickly initiate supply chain operations to deliver materiel from the Strategic National Stockpile (SNS) to local points of dispensing (PODs).

The state role in the supply chain is central: receiving Strategic National Stockpile materiel at a receipt, store, and stage facility (RSS) and distributing it to PODs in the affected area.

The Centers for Disease Control and Prevention (CDC) contracted the Center for Emergency Response Analytics (CERA) to develop objective measures of RSS capability and to measure RSS capability in dozens of jurisdictions across the country.

CERA developed a standard attack/response scenario, RSS performance and cost metrics, and a methodology for designing and evaluating strategies for RSS operations. The methodology makes use of two CERA tools: the CERA Route Builder, which creates POD delivery routes, and the CERA RSS Simulator, which simulates RSS operations.

For each jurisdiction that participated in the RSS Analysis Project, CERA developed and simulated a set of RSS strategies; selected the most promising strategy; and measured the performance, cost, and robustness of the strategy.

Using its tools and techniques for designing and evaluating RSS strategies, CERA was able to identify an operational strategy for each jurisdiction that enabled the RSS to respond successfully to the study's anthrax attack scenario

CERA prepared 36 individual reports for the jurisdictions that participated in the study. This is the project's final report. It describes the project, CERA's tools, CERA's methodology, and the study's findings.

2 Project Details

2.1 Background

The response to a bioterrorist attack on the United States will require a coordinated effort from federal, state, and local governments.

- Federal agencies will ship materiel from the Strategic National Stockpile.
- States will receive SNS shipments at an RSS facility—usually a warehouse—and distribute the materiel to PODs.
- Local governments will manage dispensing operations at the PODs.

2.1.1 Federal Role: SNS

The CDC will manage the federal government's medical response to a bioterrorist attack. The CDC response may include the deployment of a **12-Hour Push Package** and the delivery of **managed inventory** (MI) to the affected state. The Push Package and managed inventory are elements of the SNS.

When federal and state governments make the decision to deploy the SNS, the exact nature of the attack may not be known. The biological agent (or agents) may not yet have been identified, the attack locations may not have been pinpointed, and the geographic area affected may not have been determined precisely.

The Push Package will enable a state to jumpstart its response to a public health emergency that is not yet clearly understood. It contains a wide selection of pharmaceuticals and medical supplies for countering a variety of threats. The Push Package will arrive at an affected state within 12 hours of the decision to deploy.

When specialists determine the appropriate medical response to the attack, the CDC can follow up with materiel from MI (medical material managed by the Division of Strategic National Stockpile and stored by DSNS or contracted vendors).

2.1.2 State Role: RSS

Federal authorities will deliver SNS materiel to an RSS in the affected state. (CDC requires each state to identify at least two RSS sites.) The state will receive the materiel, unpack it, reconfigure it for shipment, load it onto delivery trucks, and dispatch the trucks to community-based PODs.

The state will be responsible for staffing the RSS, managing its operations, providing or contracting a fleet of trucks, designing delivery routes, allocating inventory to PODs, assigning inventory to trucks, assigning trucks to routes, and dispatching the trucks along the routes.

The goal of each RSS is to assure that PODs can open on time and operate without supply interruptions. Since an RSS may serve hundreds of PODs, this is a challenging supply chain operation that requires careful advance planning.

2.1.3 Local Role: PODs

Typically, local governments will be responsible for dispensing medications at public PODs. In addition, state and local governments may work with large employers and health care organizations to support dispensing efforts at closed (i.e., private) PODs. Private dispensing efforts will lessen the burden on public facilities and may help reduce the amount of car traffic in the vicinity of public PODs.

2.2 Project Goals

The CDC needed metrics to help states measure RSS capability and determine the efficacy of state RSS plans. Did a state have enough trucks? Were they the right trucks? Was the RSS well located? Did it have enough loading docks? Enough floor space?

The CDC contracted CERA to develop metrics and to simulate RSS operations in selected jurisdictions across the country.

Initially the goal was to determine if an RSS could support 100%, 75%, or 50% of a jurisdiction's PODs. As CERA's tools and techniques improved, the project's focus shifted to strategy development and the goals broadened to include:

- identifying the most promising operational strategy for a jurisdiction's RSS,
- measuring the RSS's robustness (the ability to succeed, even when assumptions change),
- making recommendations for improving RSS performance, and
- developing and testing useful rules of thumb for planning and managing RSS operations.

2.3 Jurisdictions

CERA analyzed the plans of over three dozen jurisdictions. The study included four states. The remaining jurisdictions were regions within states, counties, metropolitan areas, and cities.

Most of the jurisdictions planned one-stage operations: the RSS would ship SNS materiel directly to PODs. Some jurisdictions planned two-stage operations: the RSS would ship materiel to local nodes, which would then ship to PODs. Nine of the study's jurisdictions involved either the first or second stage of a two-stage operation.

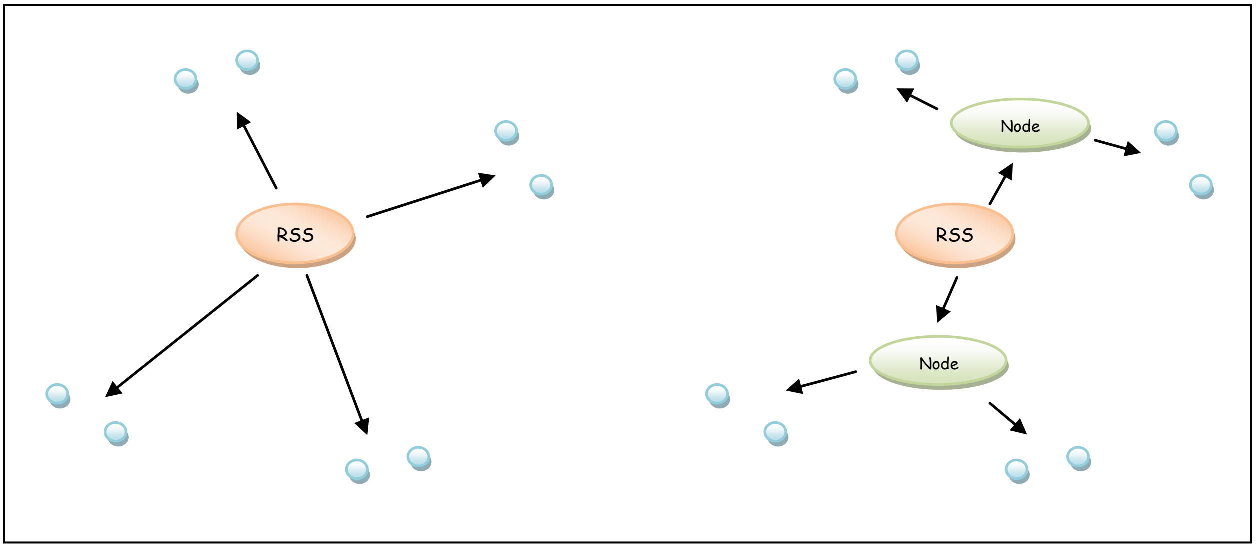

Figure 1. One-stage (left) and two-stage operations

Jurisdictions were quite different from one another. Table 1 shows the diversity of the jurisdictions included in the study. Populations ranged from 332,000 to more than 19 million. One jurisdiction had only six dispensing sites while another had 269 sites.

One jurisdiction had small PODs—the average POD serving only 5,628 people. Another jurisdiction was a state whose RSS supplied distribution nodes— the average node serving over 327,000 people.

The RSS for one jurisdiction was located in the midst of its PODs, separated by an average of only five miles. Another jurisdiction was served by a distant RSS, 234 miles away.

One jurisdiction was very compact having a site span of only 15 miles (site span is the distance between the two most widely separated PODs). Another jurisdiction was large, having a site span of 498 miles.

Characteristic	Minimum	Maximum
Population	332,100	19,318,751
PODs	6	269
Average POD Population	5,628	327,436
Average Miles RSS to POD	5	234
Site Span (Miles)	15	498
Delivery Routes Required	2	49
Trucks Available	8	245
Trucks Used	3	53
Docks Available	2	154
Docks Used	2	19

Table 1. Jurisdiction characteristics

2.4 The Study Scenario

Planning for a bioterrorist attack is difficult. An attack could take many forms, involve a wide variety of biological agents, and vary widely in geographic impact. An attack might involve multiple agents and might occur in the context of attacks in other locations. An attack might be accompanied by other types of actions intended to disrupt transportation and communications. Political pressure might force officials to expand operations beyond the geographic scope recommended by scientists and public health officials.

The broad nature of the threat has frustrated some officials, thwarting planning efforts. The use of a concrete scenario can set a planning exercise off in a productive direction. While it is unlikely that any real emergency would follow the scenario's script exactly, the scenario can provide a useful focus. Developing a scenario can be a valuable exercise in itself. The scenario can become more useful if planners can build a tabletop exercise around it. Computer simulation can add even more value, enabling experimentation, verification of resource levels, and "what-if" analyses.

The CDC and CERA constructed a bioterrorist attack and response scenario for this project. The scenario involves an aerosolized anthrax attack and assumes the timeline shown in Table 2.

Scenario Timeline		
Hour	**Time**	**Event**
-4	8/1/09 4:00 PM	Attack detected
0	8/1/09 8:00 PM	Federal and state decision to dispense
12	8/2/09 8:00 AM	Push pack trucks arrive
14	8/2/09 10:00 AM	MI arrives--wave 1
16	8/2/09 12:00 PM	MI arrives--wave 2
18	8/2/09 2:00 PM	MI arrives--wave 3
20	8/2/09 4:00 PM	MI arrives--wave 4
22	8/2/09 6:00 PM	MI arrives--wave 5
24	8/2/09 8:00 PM	PODs begin dispensing operations
		MI arrives--wave 6
48	8/3/09 8:00 PM	PODs scheduled to complete dispensing operations

Table 2. Scenario timeline

Here are some of the important assumptions that underlie the scenario timeline:

1. The biological agent used in the attack is anthrax. The response will involve dispensing antibiotics.
2. Dispensing operations should be completed within 48 hours of the decision to deploy.
3. Set-up will consume 24 of the 48 hours, leaving 24 hours for dispensing. Set-up tasks include mustering staff at RSS and PODs, readying the facilities, receiving inventory at the RSS, delivering initial inventories to PODs, implementing traffic and security plans, and initiating public awareness campaigns.
4. PODs will operate on the same schedule—starting operations at Hour 24 with the objective of completing operations at Hour 48.
5. The 12-Hour Push Package will arrive at the RSS at Hour 12. The Push Package will contain 324,000 regimens of antibiotics.
6. Managed inventory will arrive in six equal “waves.” There will be enough MI to treat the portion of the population that the Push Package does not cover.

2.5 Other Scenarios

Different emergencies may require different management techniques at the RSS. For example, the response to an anthrax attack will be more compressed than the response to a smallpox outbreak: 48 hours versus 10 days. A smallpox response might require a greater volume of materiel than an anthrax response: vaccine, needles, bandages, and other ancillary supplies. Smallpox vaccine requires special care and handling. Dispensing rates differ: smallpox vaccine must be administered to all individuals by professionals while antibiotics for an entire family can be handed off to a driver of a slow-moving car.

Geographic scope will also affect RSS operations. A contagious agent (like smallpox) would likely require a wider geographic response, but political pressure and uncertainty about an attack’s boundaries might widen the response to any type of an event.

These factors suggest that different types of emergency response might have significant differences in their requirements for RSS floor space, warehouse crews, and delivery fleets.

CDC chose an anthrax response for this study because its tight timeframe will be especially demanding of RSS managers, crews, and resources.

2.6 Data Requirements

The project required a small amount of accurate data about a jurisdiction, its PODs, and the RSS. Some information was optional (e.g., populations for individual PODs). Some jurisdictions had not yet made decisions about trucks and docks and sought recommendations.

A few jurisdictions that were eligible to participate in the study chose not to; some preferring not to divulge their data, others being unable to assemble the data.

Table 3 summarizes the project's data requirements.

Required data	RSS address	Required for delivery route design
	POD addresses	
	Jurisdiction population	
Optional data	POD populations	If unavailable, use (jurisdiction population) ÷ (# of PODs)
	Number of RSS loading docks	If unavailable, CERA provides recommendation
	RSS square feet available	CERA reports high water mark
	Available trucks and their capacities	If unavailable, CERA provides recommendation

Table 3. Required and optional data

2.7 Performance and Cost Metrics

CERA used its RSS Simulator to simulate RSS operations. During each simulation run, the simulator tracks and calculates a variety of performance and cost metrics.

2.7.1 Shipping Deadlines and Slack

Slack is the primary measure of RSS performance. It measures the ability of the RSS to beat its shipping deadlines. Every shipment that the RSS makes has a deadline. If the RSS ships before the deadline, then PODs receive their materiel on time. If the RSS ships after the deadline, PODs receive their materiel late and their operations are delayed or interrupted.

The RSS Simulator calculates shipping deadlines and slack in the following way:

1. Determine when a site will need to be supplied or re-supplied (*stock-out time*).
2. Determine how long it takes to travel to the site and unload the materiel (*reach time*).
3. Deadline = (stock-out time) – (reach time)
4. Slack = Deadline – Actual ship time

Slack is the difference between the deadline and the actual shipping time. It is measured in minutes. If slack is positive, then the RSS beat the shipping deadline. If slack is negative, the RSS missed the deadline.

For example, Table 4 shows that *POD 1* is scheduled to begin operating at 8 PM. It takes 15 minutes to drive from the RSS to *POD 1* and 15 minutes to unload at the POD, so the reach time is 30 minutes. That means that the shipping deadline for *POD 1* is 7:30 PM. In this simulation run, the RSS dispatched a truck at 10:40 AM: 530 minutes in advance of the deadline. Thus, slack for the shipment was 530 minutes—almost nine hours.

Location	Distance (Miles)	Cumulative Distance	Travel Time (Minutes)	Unload Time at POD	Cumulative Time (Reach Time)	POD Opening Time (Stock-out Time)	Shipping Deadline	Actual Ship Time	Slack (Minutes)
RSS									
POD 1	**15**	**15**	**15**	**15**	**30**	**8:00 PM**	**7:30 PM**	**10:40 AM**	**530**
RSS	15	30	15		45				

Table 4. Sample POD, deadline, and slack

Delivery routes that visit multiple sites complicate these calculations only slightly. Each site on a route has its individual shipping deadline. The route inherits the earliest of these deadlines. When the RSS Simulator dispatches a truck along the route, the simulator uses the route's deadline to calculate the shipment's slack.

Table 5 shows what might happen if *POD 1* were the first POD on a seven-POD delivery route. The seven PODs have the same stock-out times, but the reach times increase and shipping deadlines tighten from one POD to the next.

Location	Distance (Miles)	Cumulative Distance	Travel Time (Minutes)	Unload Time at POD	Cumulative Time (Reach Time)	POD Opening Time (Stock-out Time)	Shipping Deadline	Actual Ship Time	Slack (Minutes)
RSS									
POD 1	15	15	15	15	30	8:00 PM	7:30 PM	10:40 AM	530
POD 2	3	18	6	15	51	8:00 PM	7:09 PM	10:40 AM	509
POD 3	5	23	9	15	75	8:00 PM	6:45 PM	10:40 AM	485
POD 4	5	27	9	15	99	8:00 PM	6:21 PM	10:40 AM	461
POD 5	1	28	3	15	117	8:00 PM	6:03 PM	10:40 AM	443
POD 6	4	32	8	15	140	8:00 PM	5:40 PM	10:40 AM	420
POD 7	**4**	**36**	**9**	**15**	**164**	**8:00 PM**	**5:16 PM**	**10:40 AM**	**396**
RSS	12	47	16		180				

Table 5. Sample route, deadlines, and slack

POD 7, the last POD on the route, has the greatest reach time (164 minutes) and the tightest deadline (5:16 AM). The route inherits *POD 7*'s shipping deadline. The table shows that the RSS Simulator dispatched a truck along the route at 10:40 AM., giving the RSS 396 minutes of slack for the shipment.

Over the course of a response campaign, the RSS will make one or more shipments along each of its routes. Each shipment will have a deadline and a slack value. CERA uses the minimum of all of the slack values as an indicator of RSS success. If the RSS beats all of its deadlines, the minimum slack will be positive. The minimum slack is used to characterize the entire RSS campaign and is usually referred to simply as "slack." Table 6 summarizes shipping times, slack, and a few other values from a typical run of the RSS Simulator. Note that the simulator makes shipments in "deadline order."

The 12:40 PM shipment along Route 3 has the least amount of slack. Its 282 minutes of slack is used to characterize the entire RSS campaign.

Table 6 also shows that average slack was 549 minutes. Average slack shows how hurried the RSS is. While it is interesting, CERA does not view it as an indicator of success.

Shipping Time	Route	Miles	Deadline	Slack	Return To RSS
8:35 AM	Route 6	105	4:19 PM	464	1:09 PM
8:35 AM	Route 7	109	4:30 PM	475	12:48 PM
8:35 AM	Route 9	81	4:34 PM	479	12:26 PM
8:35 AM	Route 5	54	4:41 PM	486	12:24 PM
8:35 AM	Route 8	63	5:10 PM	515	11:48 AM
10:40 AM	Route 2	22	5:14 PM	394	1:38 PM
10:40 AM	Route 1	47	5:16 PM	396	1:40 PM
12:40 PM	**Route 3**	**19**	**5:22 PM**	**282**	**3:25 PM**
12:40 PM	Route 4	28	5:36 PM	296	3:23 PM
12:40 PM	Route 10	67	6:05 PM	325	4:17 PM
2:40 PM	Route 6	105	4:23 AM	823	7:14 PM
2:40 PM	Route 7	109	4:35 AM	835	6:53 PM
2:40 PM	Route 9	81	4:43 AM	843	6:31 PM
4:40 PM	Route 5	54	4:44 AM	724	8:29 PM
4:40 PM	Route 8	63	5:11 AM	751	7:53 PM
6:40 PM	Route 2	22	5:16 AM	636	9:38 PM
6:40 PM	Route 1	47	5:21 AM	641	9:40 PM
8:40 PM	Route 3	19	5:25 AM	525	11:25 PM
8:40 PM	Route 4	28	5:38 AM	538	11:23 PM
			Average	**549**	

Table 6. Route shipping times, deadlines, and slack

2.7.2 Outages and Extended Operating Hours

Negative slack indicates that the RSS missed a shipping deadline, caused a POD to run out of materiel, and interrupted operations at the POD. On resuming operations, a POD will have to make up for the interruption by either extending its operating hours or by increasing its throughput. In the study, CERA assumed that the operating hours would be extended. Note that in a real emergency, a lengthy interruption could worsen parking and traffic problems and reduce POD throughput or even bring operations to a halt.

2.7.3 Dock, Truck, and Floor Space Utilization

The RSS Simulator calculates and tracks cost metrics that relate to the use of RSS resources: trucks, docks, and RSS floor space. The simulator tracks the number of loading docks that are in use and their minutes of use. It tracks the number of trucks that are in use, their minutes of use, the miles they travel, and the time they wait for docks at the RSS. The simulator also tracks the amount of floor space occupied by antibiotics.

3 Tools

CERA used a variety of tools to carry out the RSS operations analysis, including:

- The CERA Route Builder, which uses a genetic algorithm to design effective delivery routes.
- Microsoft MapPoint (for building distance and travel time matrices)
- The CERA RSS Simulator simulates RSS operations and tracks RSS performance. The RSS Simulator was built using CERA's Simulation Laboratory. The Simulation Laboratory is also the platform for CERA's POD simulators, which model traffic and parking as well as dispensing operations.

3.1 Route Builder

CERA's Route Builder uses a genetic algorithm to create the delivery routes used by the RSS Simulator.

For the RSS Analysis Project, Route Builder was configured to divide sites into clusters and then create an efficient delivery sequence for each cluster.

A clustered route system is well suited to an RSS that receives its SNS materiel over an extended period of time: early-arriving materiel can be shipped to distant clusters and later-arriving inventory can be shipped to nearby clusters.

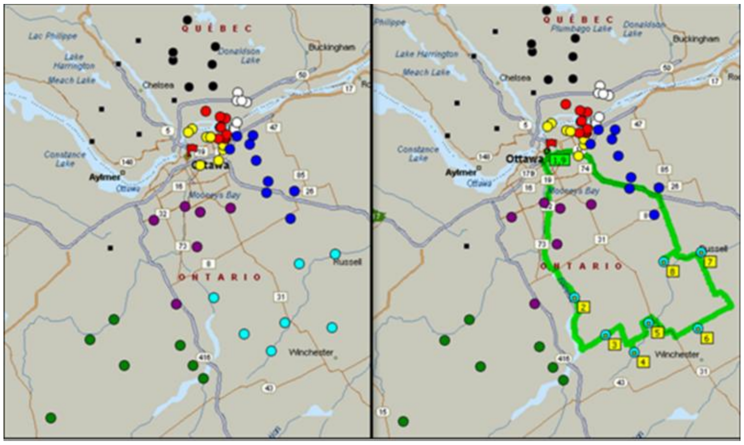

Figure 2. Dividing sites into clusters and sequencing them

3.2 RSS Simulator

The RSS Simulator is a discrete event simulator that works by moving work objects through a schematic. The schematic represents the RSS process and the work objects represent the SNS delivery trucks and the state's POD delivery trucks.

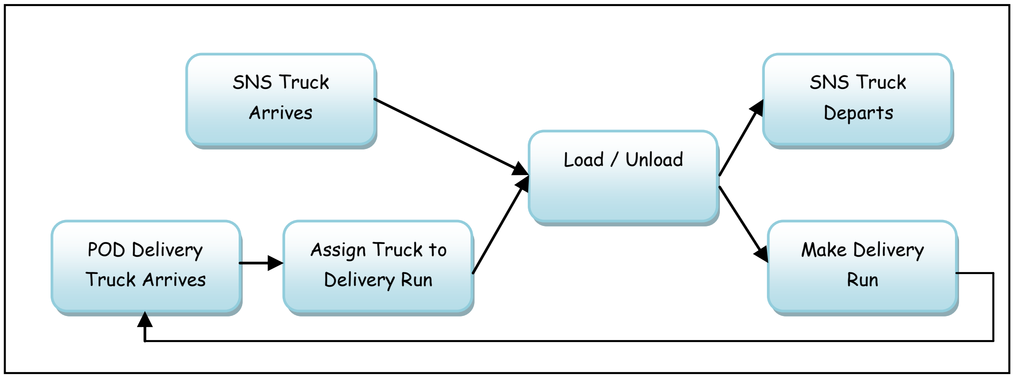

Figure 3. RSS Simulator schematic

The schematic's blocks represent tasks and decisions; the arrows show the direction in which the work objects flow. The RSS process is described below. Even if you are not interested in CERA's simulation model, you may find the discussion of RSS management and the underlying assumptions useful.

3.2.1 SNS Truck Arrives

SNS trucks, delivering the 12-Hour Push Package and MI, arrive at the RSS according to a schedule that is based on the jurisdiction's population. A truck waits until a load/unload dock becomes available.

CERA constructed an arrival schedule for SNS materiel for each jurisdiction. The schedule consists of seven events: the arrival of the 12-Hour Push Package (in eight trucks) and the arrival of six waves of managed inventory. The amount of materiel in each wave of MI depends on the jurisdiction's population.

Table 7 shows that 20 incoming trucks would be required for a jurisdiction with a population of 3,324,000.

The eight Push Package trucks contain, among other things, enough antibiotics to treat 324,000 people, leaving a requirement for 3,000,000 regimens of managed inventory.

MI is divided into six waves of roughly equal size. Each wave would arrive in two 53-foot trucks (each capable of holding 24 pallets of 11,200 regimens).

Total Regimens Required		**3,324,000**
Pushpack Regimens	-	**324,000**
Managed Inventory (MI) Regimens	=	**3,000,000**
Waves	÷	**6**
Regimens Per Wave	=	**500,000**
Regimens Per Standard Pallet	÷	**11,200**
Pallets/Wave	=	**45**
Max Pallets/Truck	÷	**24**
Trucks / Wave	=	**2**
Total MI Trucks		**12**
Pushpack Trucks		**8**
Total Incoming Trucks		**20**

Table 7. Calculating the number of incoming trucks

Table 8 shows the arrival schedule for the 20 trucks. Note that the Push Package is delivered in special rolling modules and includes no pallets. The RSS will require a stock of empty pallets in order to ship Push Package materiel and in order to ship partial pallets.

Time	Regimens	Pallets	Truck
8/2/2009 8:00 AM	40,500		PushPack 1
8/2/2009 8:00 AM	40,500		PushPack 2
8/2/2009 8:00 AM	40,500		PushPack 3
8/2/2009 8:00 AM	40,500		PushPack 4
8/2/2009 8:00 AM	40,500		PushPack 5
8/2/2009 8:00 AM	40,500		PushPack 6
8/2/2009 8:00 AM	40,500		PushPack 7
8/2/2009 8:00 AM	40,500		PushPack 8
8/2/2009 10:00 AM	257,600	23	Managed Inventory 1
8/2/2009 10:00 AM	246,400	22	Managed Inventory 2
8/2/2009 12:00 PM	246,400	22	Managed Inventory 3
8/2/2009 12:00 PM	257,600	23	Managed Inventory 4
8/2/2009 2:00 PM	246,400	22	Managed Inventory 5
8/2/2009 2:00 PM	246,400	22	Managed Inventory 6
8/2/2009 4:00 PM	257,600	23	Managed Inventory 7
8/2/2009 4:00 PM	246,400	22	Managed Inventory 8
8/2/2009 6:00 PM	246,400	22	Managed Inventory 9
8/2/2009 6:00 PM	257,600	23	Managed Inventory 10
8/2/2009 8:00 PM	246,400	22	Managed Inventory 11
8/2/2009 8:00 PM	246,400	22	Managed Inventory 12
	3,325,600	268	

Table 8. Sample SNS receipt schedule

3.2.2 POD Delivery Truck Arrives

POD delivery trucks arrive at the RSS for their first use as soon as the RSS opens. After completing a delivery run, a truck returns to the RSS for another assignment.

3.2.3 Assign Truck to Delivery Run

The RSS Simulator maintains a list of pending shipments sorted according to urgency. The shipment with the earliest shipping deadline is the most urgent; the one with the latest deadline is the least urgent.

When the RSS accumulates sufficient inventory for the most urgent shipment, the simulator will look for the smallest available truck capable of making the delivery run. If there is no such truck, the simulator will wait for one.

When a truck is assigned to a delivery run, it can enter the next loading dock that becomes available.

3.2.4 Load/Unload

Most RSS facilities will be located in warehouses with standard, truck-height loading docks. A few jurisdictions plan to locate their RSS in airplane hangars (without loading docks) and carry out load/unload operations with forklifts. In either case, there will be a limited number of load/unload crews.

An incoming SNS truck can enter the next available dock. When the truck has been unloaded, the simulator will add the truck's inventory to the RSS's inventory and the truck will depart.

A POD delivery truck that has been given an assignment can enter the next available dock. After loading the truck, the simulator will reduce the RSS's inventory by the appropriate amount and the truck will depart on its delivery run.

The simulator gives preference to outgoing trucks. This can provide earlier deliveries to PODS and it can reduce the floor space requirements at the RSS.

CERA configured the RSS Simulator to use the standard load/unload times shown in Table 9. These are aggressive operation times that can probably be achieved only by professional warehouse crews.

Load/Unload Operation Times (minutes)				
Operation		Loading Dock	No Loading Dock	
Unload 53-foot trucks	Push pack	20	60	Includes: positioning truck, opening truck, loading/unloading truck, closing truck, completing paperwork, and departing.
	Managed Inventory	25	60	
Load 48-foot, 53-foot trucks	Palletized	30	60	
Load 20-foot, 24-foot trucks	Palletized	15	30	
Load smaller trucks, vans	Palletized	15	30	
Unload truck at POD	Palletized	15	15	

Table 9. Load/unload times

3.2.5 Make Delivery Run

After it is loaded, a POD delivery truck will travel to each POD on its route. The simulator uses a matrix of travel times calculated by Microsoft MapPoint to determine how long it takes to travel from one location to the next.

The RSS Simulator allows 15 minutes for unloading at each POD. After unloading, the simulator updates the POD's inventory and calculates a new stock-out time for the POD. If the POD had run out of materiel, the simulator will permit it to resume operations at this point.

After unloading at the last POD on the route, the truck will return to the RSS to await its next assignment.

4 Project Methodology

CERA's methodology for carrying out this study focused on the development of a successful operational strategy for each RSS, called the baseline. The methodology consisted of several steps:

1. Clean up the state and local data: eliminate duplicate sites, correct erroneous addresses, etc.
2. Develop and test a set of baseline candidates.
3. Select the baseline—the most promising of the candidates.
4. Test the robustness of the baseline.

The baseline is an operational strategy for the RSS based upon a set of rules that would be easy to adjust and apply in a dynamic, chaotic situation. The baseline works within the context of geography, POD requirements, and RSS resource constraints. The baseline is not the only possible strategy. There may be thousands of operational strategies, some more effective in one respect or another, each with its own different delivery routes and schedules.

In order to find a good baseline, CERA developed and tested a set of baseline candidates using the following steps:

1. Make an educated guess about how many deliveries should be made to PODs.
2. Consider the truck fleet and make an educated guess about the maximum number of pallets to be loaded on each truck type.
3. Design a set of delivery routes using the CERA Route Builder. (This requires completion of steps one and two.) Each baseline candidate usually has its own unique set of delivery routes.
4. Use the RSS Simulator to measure the performance and the cost of the candidate.

Some candidates worked and some didn't. Study of a candidate would sometimes reveal a weakness that could be fixed by changing the number of deliveries, changing the number of pallets that could be loaded on a truck, or by limiting the maximum time allowed for a delivery run.

CERA selected the most promising candidate to be the baseline and subjected it to a detailed sensitivity analysis, evaluating its ability to succeed when underlying assumptions changed:

- The number of crewed docks was reduced.

- Load/unload operations took longer than forecast.
- The number of available trucks was reduced.
- Managed inventory was delivered late to the RSS.
- Drive times were elevated (due to traffic or weather).

If alerted in advance, RSS managers might avoid the first three problems by planning to staff more docks, drilling crews to improve efficiency, or arranging for a greater number of trucks and drivers.

CERA viewed sensitivity to managed inventory delays and elevated drive times as more serious problems; RSS managers would have far less influence over those factors. If an RSS's baseline strategy was too sensitive to managed inventory delays or elevated drive times, CERA would carry out "what-if" analyses to determine if adding trucks or docks could improve performance.

5 Findings

5.1 Strategy Development

CERA found an operational strategy for each jurisdiction that would enable success in the test scenario. Some strategies were harder to find than others and the strategies differed in the level of robustness (resistance to failure when things go wrong) that they provided their jurisdictions.

5.2 Readiness

Some jurisdictions that were eligible to participate in this study were unable to do so because they could not assemble the required data. Most jurisdictions that chose to participate had one or more of the difficulties described below. CERA identified these problems, reported them to the appropriate planning agencies, and resolved them.

- Inaccurate addresses: spelling errors, wrong street numbers, substitution of *Road* for *Avenue*, wrong town, incorrect zip codes, use of PO boxes
- Unrecognizable addresses—these are addresses that while technically correct, were not recognized by the mapping software that CERA used. Common causes for this problem were the use of village names, colloquial street names, and unusual street numbering conventions. One county uses a system of hyphenated street numbers composed of cross street and house number. While sensible and helpful in some contexts, this system baffled multiple mapping software packages and required a time-consuming translation effort. One fast growing city had POD addresses that weren't on any maps—CERA found the POD sites by examining recent satellite images.
- POD populations that did not sum to the jurisdiction's population
- Duplicate PODs
- Proximate PODs—these are PODs that seemed to be too close together. Some PODs were within yards of other PODs. Closely-spaced *pedestrian PODs* might be necessary in densely populated

areas. Closely-spaced *commuter PODs* create the risk of "dueling traffic jams." Some POD pairs appeared near town lines, giving the impression that neighboring towns were working too independently of one another.

Some planners minimized address issues ("Everybody knows where the Acme Center is!"), but the problem could be serious. If RSS managers plan to make use of any route design or management software, addresses must be correct, unambiguous, and recognizable by the software. This is not the type of problem that managers will want to discover in the midst of an emergency response campaign.

5.3 Jurisdictions Unique

Every jurisdiction that CERA studied was unique, having its own population, number of PODs, location of the RSS relative to PODs, and geographic range. Jurisdictions were unique with regard to their truck fleets and load/unload facilities. Jurisdictions also varied greatly on operational strategies; some opting for RSS facilities without docks, small neighborhood PODs, drive-through mega-PODs, or two-stage distribution schemes.

5.4 No Universal Formulas

The project failed to reveal any universally applicable rules such as, "You need a truck for every 100,000 people." Rather, the project exposed the complexities of the interactions among a large number of critical factors. The project also showed that each jurisdiction has its own mix of problems and that it is difficult to compare the capabilities of jurisdictions in responding to the same basic event.

5.5 Critical factors

Critical factors in planning for a bioterrorist attack include:

1. Population of the affected area
2. Strategic National Stockpile (SNS) schedule
3. Number of PODs; sizes of PODs
4. Loading docks
5. Training and quality of RSS crews
6. Nature of delivery truck fleet
7. Decisions about allocation, shipments, and routes

5.5.1 Population

If a jurisdiction's entire population can be served by the 12-Hour Push Package—which contains 324,000 regimens of antibiotics— then RSS operations are pretty simple: the RSS receives its entire allocation within 12 hours and can ship complete allotments to PODs immediately.

The complexity of the response operation increases as population increases—reliance upon managed inventory increases, staffing requirements increase, and the number of PODs grows.

5.5.2 SNS schedule

The receipt schedule for SNS inventory is critical, especially for jurisdictions with large populations. It is not possible to predict when managed inventory would arrive at an RSS during a real event and yet a detailed operational plan cannot be constructed until the schedule is known. SNS receipt times could be affected by many factors including the proximity of MI, the availability of trucks, traffic and weather conditions, and the competing needs of other jurisdictions.

In the study scenario, MI would arrive over a 10-hour period (starting two hours after Push Package arrival) in six waves of equal size. CDC and CERA selected this arrival pattern because it created a situation in which an RSS would be receiving materiel even as its PODs were opening for business. That would require the RSS to balance the incoming stream of materiel against the needs of its PODs (rather than make a single, complete delivery to the PODs).

Earlier arrival of managed inventory would make it easier for the RSS to meet its shipping deadlines. Later arrival would make it more difficult. Arrival in dribs and drabs over a long period of time could force the RSS to "spoon-feed" PODs by making a larger number of small shipments.

5.5.3 PODs

In most states, POD planning is carried out by local agencies, which might adopt different philosophies. Many cities plan to operate many small, neighborhood PODs to which residents would walk. Other communities plan to serve larger populations in a stadium or convention center, with large parking areas and access by public transportation. A few jurisdictions included huge mega-PODs intended to serve populations as large as one million. Some jurisdictions included drive-through PODs located on major highways.

An RSS might have many different POD types in its service area.

The complexity of RSS planning and operations generally grows as the number of PODs grows:

- Calculating allocations becomes more complicated.
- Receiving and shipping activities are harder to plan and coordinate.
- Designing delivery routes is more difficult.
- More routes are required.
- More trucks are required, increasing security and tracking requirements.

A few jurisdictions provided information about private dispensing sites managed by employers, universities, healthcare facilities, and prisons (these sites are sometimes referred to as "push sites"). Some push sites were quite large; others quite small.

One jurisdiction planned to ship materiel bound for push sites to a special depot, where push sites could pick it up. They preferred not to have private vehicles coming to the RSS.

Another jurisdiction was considering shipping each push site's materiel to the closest POD so someone from the site could pick it up.

Yet another jurisdiction planned to deliver to push sites, but using different trucks than for PODs. CERA found that this strategy was less effective than using a single truck fleet traveling routes that included both PODs and push sites.

5.5.4 Docks

Almost every RSS could work perfectly well with four or five docks. Even though some could succeed with only one dock, two docks is probably a prudent minimum (two docks facilitate cross-docking—transferring a pallet directly from an incoming truck to an outgoing truck).

Figure 4 shows a typical pattern of dock usage (the red plot line shows the maximum number of docks used during each hour; the blue plot line shows the average).

The chart shows seven bursts of activity: one when the Push Package arrives and one for each of the six waves of managed inventory. Each burst includes the arrival of incoming trucks and the departure of outgoing trucks.

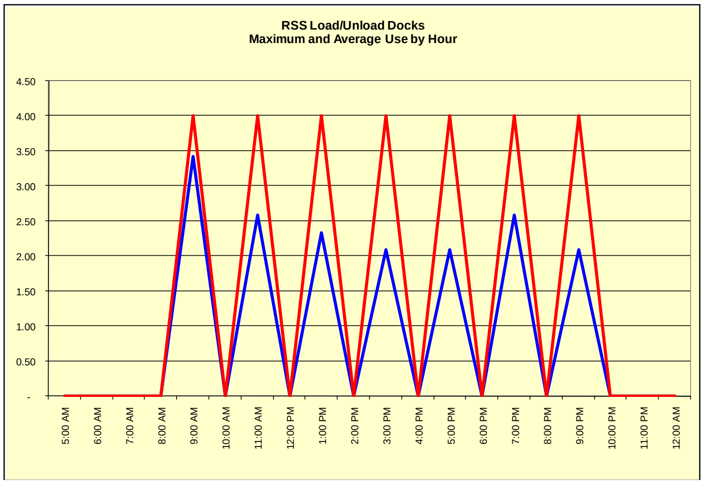

Figure 4. Typical loading dock use pattern

Figure 4's RSS has four docks, but the pattern would look about the same for an RSS with 10 docks. If the RSS had only two docks, the plot lines would be flatter, indicating a steadier level of work for the two dock crews. Operating with only two docks would increase wait times for trucks, delay some shipments, reduce slack, and perhaps create problems for some PODs.

A few states have located their RSS in airplane hangars that lack loading docks. One of these states planned to use forklifts for loading and unloading trucks. CDC studies have shown this to be a time-consuming practice, taking as much as three times as long as standard load/unload times. One state with a hangar-based RSS plans to use a special 4-pallet lift for load/unload operations. They estimate that operations would take only 10% longer than the standard operation times that CDC and CERA have adopted.

5.5.5 RSS Crews

Many states plan to staff their RSS with professional warehouse crews, but some plan to use health department workers and volunteers. The load/unload times used in this study are very aggressive and likely achievable only by professionals.

CDC strongly recommends that RSS be staffed with professionals. CERA's study confirms the important role professional crews would play in a successful RSS operation. In addition to working faster, professionals can work more accurately and safely.

5.5.6 RSS Floor Space

The study scenario required surprisingly little RSS floor space in most jurisdictions. This is because SNS materiel arrived over a period of 12 hours and, in most cases, materiel was shipped out as soon as it was received.

The average floor space required for antibiotics was about 1,200 square feet. This did not include space for the Push Pack, receiving area, shipping area, order preparation area, or blank pallet storage. The maximum floor space required by any jurisdiction for antibiotics was about 12,000 square feet (in an RSS that served a population of 19 million).

Floor space requirements could increase under a different SNS receipt schedule or if an RSS were served by too few docks or too few trucks.

5.5.7 Delivery Trucks

Different jurisdictions had different ideas about delivery truck fleets. Some jurisdictions planned to make hundreds of trucks available while others planned on just a few. Some jurisdictions planned to use 53-foot tractor trailer trucks (24-pallet capacity) while others planned for smaller trucks (three-pallet dump trucks or two-pallet pickup trucks).

CERA simulated the use of beverage trucks for one jurisdiction. The trucks had adequate capacity, but couldn’t accommodate standard-sized pallets. This required a time-consuming transfer of incoming materiel from standard pallets onto smaller pallets.

For another jurisdiction, CERA simulated the use of panel trucks. Again, the trucks had adequate capacity, but they were configured for boxes, not pallets. Pallets would have to be broken down into boxes, which could then be loaded individually onto the truck’s racks.

Important truck characteristics include:

- the ability to accommodate pallets,
- the ability to back up to a dock for loading at the RSS,
- a lift gate for easy unloading at PODs,
- maneuverability (for use in urban areas), and
- capacity.

Most of the jurisdictions that CERA studied fared best with truck capacities of 6 or 10 pallets. Larger trucks were not useful in most jurisdictions because:

- In the study scenario, inventory arrives at the RSS in dribs and drabs; it would take a long time to build up enough materiel (over 20 pallets) to fill a 53-foot truck. Instead of delivering materiel, these large trucks would be sitting at RSS loading docks waiting for a full load.
- Many jurisdictions have built their plans around small, neighborhood PODs. A large truck, fully loaded, would have to stop at 10 or 15 PODs in order to discharge 20 or 24 pallets of materiel.

Each stop would increase the delivery route’s drive time and unload time, elevating the reach times for PODs near the end of the route.

Large trucks could be useful if SNS materiel were to arrive at the RSS in bulk (rather than in waves) and if the RSS were shipping to a few very large PODs.

Smaller trucks—less than six pallets—might be useful in a jurisdiction with a small population. A larger jurisdiction might require too large a number of the smaller trucks, which could strain RSS dock crews and place an extra burden on security teams.

Truck Type	Capacity (pallets)	Lift Gate?	Best Use
53-foot tractor trailer	24	Rare	MI arrives early
48-foot tractor trailer	22		Large PODs with loading docks
24-foot box truck	10	Common	Appropriate for most situations
20-foot box truck			
12-foot cube truck	6	Some	MI arrives in stream
			Small PODs
			City driving

Table 10. Commonly used trucks

5.5.8 Allocating and Shipping Materiel

The study scenario, because of its SNS receipt schedule, required the RSS to balance an incoming stream of SNS materiel against the requirements of PODs of different sizes and different distances from the RSS. The RSS placed all the PODs “on allocation” and made partial shipments to them.

There are many reasons that it may not be possible (or desirable) for an RSS to provide each POD its entire allotment of SNS materiel in one shipment:

- The RSS may not receive its entire inventory early enough (as in the study scenario). In this case, shipping partial allocations may be the only way to enable all PODs to open on time.
- A POD’s entire allotment may not fit on one truck. For example, one jurisdiction’s million-person mega-POD would require four 53-foot trucks or nine 24-foot trucks.
- The RSS may not have enough trucks. In this case, it may be best to design routes that enable each truck to visit as many PODs as possible, delivering a small amount of materiel each.
- The RSS may not have enough docks. If dock time is precious, then it may be wasteful to occupy a dock with a truck that will visit too few PODs.
- POD requirements may be uncertain. Some PODs may serve more people than estimated while others may serve fewer.
- RSS managers may want to retain flexibility to respond to an expansion in geographic scope by not over-committing inventory.

CERA adopted two allocation practices that simplified RSS planning and operation without sacrificing performance.

1. Break up a POD’s allotment into some number of equal shipments: a 24,000-person POD might receive two shipments of 12,000 regimens, or three shipments of 8,000 regimens.

CERA experimented with other, more complicated schemes such as providing each POD with a small initial shipment followed by one or more larger shipments. While there may be some situations in which such measures are necessary or beneficial, they provided little or no benefit in CERA's tests.

2. Make the same number of shipments to all PODs. The nominal number of shipments would work fine for most normal sized PODs. Large PODs (such as the million-person mega-POD) might require more than the nominal number of shipments.

   Here again, CERA experimented with more complicated schemes such as making more shipments to nearby PODs than to distant PODs or making fewer shipments to small PODs. The added complication did improve performance or lower costs significantly.

Most jurisdictions worked well with two shipments per POD. One jurisdiction, whose RSS was a few hours distant from its PODs, worked best with four shipments per POD.

5.5.9 Delivery Routes

The three aspects of RSS operation that planners and managers have the most control over are: allocation strategy, truck load sizes, and the delivery route system.

The allocation and truck load decisions are prerequisites for route system design because RSS managers need to know how much materiel they're shipping to PODs and how many pallets they can put on trucks before they can design delivery routes for the trucks.

An effective set of delivery routes was critical to the success of most of the jurisdictions that CERA studied. Note that the meaning of *effective* may differ from application to application. A route system that minimizes cost—like a package delivery company would employ—might not be effective for POD delivery, where on-time delivery to all PODs on all routes is paramount.

CERA created routes with its Route Builder software, which divides PODs into clusters and creates an efficient sequence of PODs for each cluster (see page 11). CERA also experimented with routes based on ZIP codes and routes created by TourSolver, which judges route effectiveness differently from Route Builder. The ZIP code routes can perform adequately, but vary in effectiveness from jurisdiction to jurisdiction. TourSolver and Route Builder created good route systems. Route Builder's routes may have an advantage when traffic affects drive times.

Factors that heightened the importance of delivery routes and made routes difficult to design included:

- a large number of dispensing sites,
- dispensing sites spread over a large geographic area, and
- a distant RSS.

5.5.9.1 Time-Limited Routes

As RSS-to-POD travel times increase it becomes more difficult for an RSS to meet its shipping deadlines. The critical factor is really "reach time," which includes both drive times and unload times for PODs along the route.

While high reach times are unavoidable for PODs far from the RSS, the layout of delivery routes can even elevate the reach times of nearby PODs:

- Long POD-to-POD drives will elevate reach times.
- Including many PODs on a route will require more unload operations, which will elevate reach times.

CERA's Route Builder tries to minimize reach times and minimize the number of routes required to serve a jurisdiction. It tries to maximize truck utilization with routes that make the best use of truck capacities (e.g., put 10 pallets on a 10-pallet truck). These goals can conflict and result in route systems that cause an RSS to fail.

The most difficult delivery route systems to design were those that included many small PODs in a large geographic area. In order to maximize truck utilization, Route Builder might string PODs together into lengthy routes that require a lot of drive time and a lot of unload time. In order to control this effect, CERA enhanced Route Builder with two methods constraining route lengths:

1. Limiting the total amount of inter-POD travel time on a route was useful in cases where there were dense clusters of PODs far from the RSS.
2. Placing a limit on the maximum reach time was useful where there were sparsely scattered PODs far from the RSS.

Each of these methods could improve RSS performance at the cost of an increased number of routes and an increased number of trucks.

5.5.9.2 Mixed Fleets and Route Capacities

CERA characterizes route capacity in terms of pallets—a 10-pallet route can be used to deliver two pallets to each of five PODs, five pallets to two PODs, three pallets to three PODs, and so on.

CERA found that it was difficult to tailor routes to the individual truck types in a mixed fleet. Creating a mixed-capacity route system that included 24-pallet routes, 10-pallet routes, 6-pallet routes, and 2-pallet routes was complicated and produced results that were no better than did a uniform route system (e.g., all 10-pallet routes).

For most jurisdictions, CERA looked for a common route capacity. Ten-pallet routes worked well for many jurisdictions; the routes could be served by 20-foot and 24-foot trucks (as well as partially-loaded tractor trailers, if needed). Six-pallet routes worked well for some smaller jurisdictions and in some jurisdictions where the RSS was far away from the PODs.

5.5.9.3 Route Design and Management Conventions

CERA adopted a number of conventions that supported and simplified the methodology for developing RSS strategies. They would also simplify the execution of an operational strategy.

1. Delivery routes were not changed during an RSS campaign.

   A strategy that deliberately requires routes to change adds complexity for the planners who design the routes, the crews who prepare shipments, the drivers who travel the routes, and the teams who track and provide security for the trucks. Planners and managers may encounter situations that require route changes, but they should not design a strategy that requires them.

2. Each POD was on one and only one route. This is a sensible limitation that can help planners and managers avoid unnecessary complexity.

3. The same number of deliveries was made to each POD on a route.

   If a jurisdiction required that some PODs receive more deliveries than other PODs, CERA divided PODs into groups: all of the “2-delivery PODs” in one group, “3-delivery PODs” in another, and so on. A route could include members of only one group, thus assuring that all PODs on a route would receive the same number of deliveries.

   A large group of PODs can generally yield a more effective set of routes than a small group of PODs. That is why CERA tried to find a nominal number of deliveries that could serve the largest possible portion of PODs.

4. The RSS Simulator shipped exactly the amount of materiel called for by the allocation strategy. If 10 pallets were to be delivered to the PODs on a route and the RSS had only nine pallets, the truck would be held until the 10th pallet could be loaded on the truck..

5.6 Two-Stage Operations

Most of the RSS operations that CERA studied were one-stage operations in which the RSS dispatched trucks directly to PODs. A few were two-stage operations in which the RSS supplied materiel to distribution nodes, which shipped the materiel to PODs.

Some of the reasons planners have cited for adopting a two-stage strategy are:

- It is a political requirement.
- It reduces costs.
- It divides one big planning and management problem into a set of smaller, more manageable problems.
- The RSS doesn’t have enough trucks, truck security, or docks to execute a one-stage strategy.

The two-stage plans that CERA studied may have met political requirements, but they failed to provide either cost or performance benefits in the study scenario. The problems that CERA encountered were:

1. Total costs could increase rather than decrease.
2. The extra handling of materiel at local nodes was time consuming and resulted in delayed deliveries to PODs.
3. A two-stage campaign was more difficult to manage because RSS managers would need to know about the internal operations of all the nodes.

5.6.1 Two-Stage Operations Could Increase Costs

A two-stage operation can lower operational costs at the RSS by reducing truck mileage, the number of trucks, and the burden on loading docks. The savings may come at the expense of the nodes, each of which must operate its own docks and trucks. The total cost of a two-stage operation may exceed the single-stage cost.

CERA studied a jurisdiction whose RSS delivered to local nodes in four adjoining counties. The nodes delivered to a total of 87 PODs. CERA found a successful two-stage strategy, but the operation was not robust; it was highly sensitive to elevated drive times.

Table 11 shows results from a "what if" analysis that CERA carried out to see what would happen if the RSS served the 87 PODs directly. The one-stage operation outperformed the two-stage operation significantly, was far more robust, and cost less.

Metric	Two-stage Baseline	One-stage What-if	Difference
Slack	**109**	**265**	143%
Trucks Used	32	24	-25%
Truck Hours	267	234	-12%
Miles Traveled	5,925	6,107	3%
Docks Used	19	5	-74%
Loading Dock Hours	99	73	-27%

Table 11. Comparing two-stage and one-stage operations

5.6.2 Two-Stage Management Could Be More Difficult

CERA studied a state's two-stage plan: the entire RSS-to-node operation and one county's node-to-POD operations. CERA ran two series of simulation tests:

1. RSS managers operated independently of the nodes and were aware only of node locations and populations.
2. RSS managers were aware of the study node's operations and took the node's shipping deadlines into account.

In the first tests, RSS managers used their limited knowledge to make sensible decisions, shipping to distant nodes first. The RSS worked well, appearing to provide nodes with ample time to carry out their distribution operations. But when CERA fed the RSS simulation results into the simulation of the study node, CERA found that the node could barely meet its shipping deadlines. The node would fail if traffic increased drive times even slightly.

In the second tests, the RSS managers knew study node's shipping deadlines and accelerated shipments to help the node meet its deadlines. The study node's performance and robustness improved dramatically, but the improvement came at a price: deliveries to other nodes would be delayed. CERA did not have any information about the other nodes, so it was impossible to determine whether or not they would succeed or fail.

Table 12 summarizes the results of the experiment. Operating independently (with no knowledge of the study node), the RSS performed with 277 minutes of slack. It was able to beat its shipping deadlines by an average of 680 minutes. The study node was able to receive materiel from the RSS, repackage it, ship it out, and beat its tightest deadline by only 46 minutes (too close for comfort).

When RSS managers took the study node's shipping requirements into account, the study node's slack increased to a very comfortable 270 minutes. The RSS was still able to beat its tightest deadline by 275 minutes, but its average slack dropped to 521 minutes (possibly causing failures at other nodes).

Metric	Independent Operations		RSS Knows About "Study Node"	
	RSS to Other Nodes	"Study Node" to PODs	RSS to Other Nodes	"Study Node" to PODs
Minimum Slack	277	46	275	270
Average Slack	680	332	521	512

Table 12. Two-stage "what-if"

Two-stage operations are not necessarily bad and they may be the only way for some states to succeed. CERA's experiments show that an RSS manager must take node operations into account in order to give the nodes the opportunity to be successful.

6 Conclusions and Future research

Over the course of this project, CERA studied RSS operations as they might be carried out in dozens of jurisdictions. The large number of case studies enabled CERA to refine its methodology for designing operational strategies and enhance its software tools with new features and capabilities as new situations and problems were encountered. While the methodology and tools were tested and refined against particular RSS scenarios, they are general enough to be applied to a broad range of distribution operations.

Planning and managing an RSS response to a biological attack will be a severe challenge. Due to the dozens of unknowns, assembling a logistics plan for the RSS will not be possible until an emergency actually occurs. The unknowns include the biological agents (which will dictate the appropriate pharmaceutical response and the response timeframe), the locations of the attack, the timing of the attack (day or night, weekday or weekend), the geographic area affected, and the receipt schedule for SNS materiel.

Given the short time that will be available to assemble a plan and the difficulty of the planning task, it is absolutely essential that planners be well prepared. Preparedness includes:

- Having **agreements in place** for POD facilities, the RSS facility, a professional RSS staff (if possible), and sufficient trucks and drivers to carry out distribution operations
- Having all of the **required data in the proper forms for use by staff and by computer software** —including RSS and POD addresses and POD population estimates

- **Mastery of all software tools by at least one or two staff members.** Many software tools require a database (for example, TourSolver requires a set of validated POD addresses). All such databases should be prepared and validated in advance to assure that response operations can begin without delay.
- **Planning capability**—Planners should have completed at least one end-to-end planning exercise in the context of a realistic scenario. Tabletop exercises can play an important role in developing planning capability.

The cases studied in the project demonstrate that each jurisdiction is unique (population, number of PODs, geographic distribution of PODs, location of the RSS, etc.). For that reason, the project failed to yield formulas for determining the required number of trucks or docks for a given population or number of PODs.

For example, it is possible to calculate certain values, such as the minimum number of truckloads an RSS must ship under a particular operational strategy. But there is no simple calculation to determine how many round trips an individual truck could make or how many trucks, in total, would be required to execute the strategy.

Many of the rules of thumb discussed in the project's reports (this document and the 36 individual reports) are procedural—relating to a set of steps that planners could use to assemble an effective operational strategy.

The sensitivity analyses that CERA carried out provided concrete examples of the "physics" of RSS operations: the impact that changing one factor can have upon performance and cost metrics. Many of the analyses exposed tipping points and circular effects. For example:

1. Increased drive times (due to traffic) can delay deliveries to PODs and increase RSS floor space requirements
2. Adding trucks can mitigate the effects of increased drive times and reduce floor space requirements
3. Adding trucks can increase the amount of time trucks wait for loading docks
4. Long waits at loading docks can reduce the number of trucks that can be used effectively

While the RSS Analysis Project produced some important initial results, much work remains to be done:

- The project studied a simple supply chain that delivered one type of product to dispensing sites. How well would an RSS perform delivering multiple products obtained from different sources?
- Which of the many strategies for designing delivery routes best meets the goals of a specific RSS? Does another strategy work best for a different RSS?
- Some states will use two-stage distribution operations. How can the RSS assure that local distribution nodes are successful?
- CERA used specialized tools to design operational strategies. Are there easier ways to create acceptable strategies?
- How should an RSS respond if POD population estimates are wrong or if PODs experience surges and lulls in client arrival rates?

- The project studied only “push” distribution operations in which the state trucks transfer materiel from the RSS to PODs or nodes. Some states are planning to carry out “pull” operations in which POD managers send trucks to the RSS to pick up materiel. How do pull operations compare to push operations in terms of performance and cost?

These questions may all be worthy of a future research project.

7 The Center for Emergency Response Analytics

The Center for Emergency Response Analytics (CERA) develops and applies software tools for the design, analysis, and management of large-scale emergency response campaigns. CERA has helped governmental agencies at federal, state, and local levels to develop, measure, and improve processes for responding to bioterrorist attack.

CERA has conducted simulation studies of emergency distribution and dispensing operations for CDC; Hartford, CT; the State of New Hampshire; the State of Maine; the Uncas (CT) Health District; the City of New London, CT; and the Ledge Light Health District (CT). CERA has deployed POD simulation products in 8 jurisdictions in including the City of Houston and Harris County, Texas.

Appendix

	Area	Observations, practices, recommendations
1	Allocation	The SNS receipt schedule may force you to place PODs on allocation.
2	Allocation	An allocation strategy that enables equal-sized deliveries to a POD is easiest to manage.
3	Allocation	Try to settle on a nominal number of deliveries for PODs that works well with the SNS receipt schedule.
4	Allocation	Try to use the same nominal number of deliveries for as many PODs as possible--you can create more effective routes that way.
5	Fleet	Trucks should be configured for pallets, not boxes.
6	Fleet	Trucks should right height for standard loading docks.
7	Fleet	Trucks equipped with lift gates can speed unload operations at PODs.
8	Fleet	Ten-pallet trucks worked best in the study scenario for most jurisdictions: appropriate capacity and good manueverability.
9	Fleet	Large (48-foot and 53-foot) tractor trailer trucks may be useful in jurisdictions with a small number of very large PODs.
10	Management	Ship to PODs in deadline order (distant routes first).
11	Management	Dispatch the smallest available truck on a delivery route.
12	Management	RSS planning is easier for a jurisdiction with a few large PODs than many small PODs.
13	Management	The RSS should favor outgoing trucks.
14	Management	Multi-stage operations require more handling of materiel, reduce performance, can increase costs, and are more difficult to manage.
15	Management	Optimizing utilization of resources is not as important as providing on-time deliveries to PODs.
16	Routes	Including many PODs on a delivery route can work well for dense clusters of PODs.
17	Routes	Reducing the number of PODs on a delivery route can improve performance when POD-to-POD drive times are high.
18	Routes	Placing time limits on delivery routes can lead to better route systems in large geographic areas.
19	Routes	Try to use the same route system throughout a campaign. Avoid strategies that require dynamic route systems.
20	Routes	Place each POD on one and only one route.
21	RSS	Better RSS performance from a standard warehouse than a hangar that lacks docks
22	RSS	Four or five loading docks usually enough. Two is a prudent minimum.
23	RSS	RSS floor space requirements were low in the study scenario, but many factors could increase requirements.
24	RSS	Professional warehouse crews are an important success factor. They are faster, safer, and more accurate.
25	RSS	Palletizing POD shipments saves loading and unloading time; usually requires extra empty pallets.