

# Medication Distribution Problem

Schalliol, Kristen, Advisor: Herrmann, Jeffrey

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# **Medication Distribution Problem**

## **Kristen Schalliol**

### **Adviser**

Dr. Jeffrey W. Herrmann  
Associate Professor of Mechanical Engineering  
University of Maryland  
Institute of Systems Research

### **Research Partner**

Sara Lu  
ISR REU 2008 Participant

**The Institute for Systems Research**  
**University of Maryland**  
**College Park**

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## Introduction

### Abstract

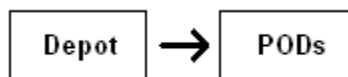
This Medication Distribution Problem was based on emergency preparedness for a potential bioterrorist attack against the public. If the event were to take place, efficient scheduling of truck routes would need to be available. Tour Solver was the software used to generate truck routes under different constraints. The results were then used to find the best routing schedule. Nine truck routes were successfully developed for different scenarios of the problem. These scenarios were then taken and further analyzed for scheduling. More scenarios can and should be generated and assessed in future research towards solving this vehicle routing problem.

### Purpose

#### General

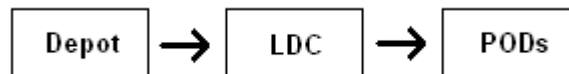
The need for this research was initiated by work done with public health officials dealing with emergency preparedness. The goal of the public health officials was to create an efficient plan involving the distribution of medication to points of dispensing (PODs) in the event of a bioterrorist threat against the public such as anthrax, bird flu, and other viruses.

In the event of an attack, officials will decide the timeline for the mass distribution of medication. On the local level, several pre-determined PODs will begin preparation for opening at the designated time. Personnel at the local level will also request the needed medication from the federal stockpiles, which will be delivered in waves to a state receipt, storage, and stage (RSS) facility; also known as a depot. The structure is shown in Figure. 1



**Figure. 1: Direct Delivery Structure**

Counties may choose to operate their own local distribution center (LDC) rather than using the state depot as their RSS, which will receive waves of medication from the state depot. The LDC will then prepare its own truck fleets and deliver the medication to the PODs in that county. Because an LDC can hire truck drivers and transportation managers from the area who are familiar with the county's roads, this county level RSS is considered desirable.



**Figure. 2: Delivery Structure with LDC**

The objective of this research was to develop a robust plan for maximizing the probability that all PODs receive enough medication and run successfully during their hours of operation. It is necessary to be prepared with trucks and medication in the event of an emergency, but it is also very important to work through the logistics of this kind of problem and develop optimal truck routes, quantity distribution and scheduling beforehand in case an actual outbreak ever takes place.

Inventory was regarded as a continuous variable; the number of pallets had to be an integer, with the known capacity of 11,200 regimens (measurement of medication per person) per pallet. All PODs have the same hours of dispensing, with loading and unloading times independent of the quantity. Additionally, resource limitations such as loading docks, available drivers and pallets, were ignored.

### **Specific: Vehicle Routing**

This report discusses the first step in this process, the vehicle routing problem. The second step concerned the development of an efficient scheduling plan for these routes, which is addressed in the report by Sara Lu. Tour Solver<sup>i</sup> is the software that was used to generate routes between a depot and PODs. The logistics of the software will be explained in further detail later in the report. The objective of this research was to use provided information and constraints, such as available trucks, truck capacity, regimen demand, time, etc. to formulate routes that reached the POD demands in the least amount of time possible.

## **Approach**

### **Tour Solver**

Tour Solver is a web-based computer software that uses an optimization algorithm to solve transportation routes. The software is provided for free by the Center for Disease Control. To see more details on how to use Tour Solver see Appendix A.

Tour Solver is a useful program that allows you to plug in numerous constraints specific to your need and helps you build your own solution. Some of the managing constraints are Pick up and Delivery Times, Vehicle capacity, Visit duration, Working and driving costs, and Legal driving constraints. Tour Solver provides two MS Excel templates. One template is for Customer information (PODs), which requires a street address, regimen demand, and fixed visit duration at each site. The second template is for Resources information (RSS or Depot), which requires the street address of the RSS (Depot/LDC), number of trucks, their capacities, and the Start and End times.

Once the spread sheets are uploaded and any other optimization settings are configured using the Tour Solver Wizard, the optimization will run for a few minutes using an interruptible search process that continually improves the solutions until the best outcome is produced. These results can be exported and viewed in Excel spreadsheets, displaying details of trucks used such as distance traveled, time traveled, etc. Maps and route itineraries with step-by-step instructions can also be exported and saved. To view an example of a map, please see Appendix B.

### **Scenarios/Alternatives**

The distribution problem gave information for three different counties and the conditions were analyzed with two alternatives: (1) using an LDC and (2) not using an LDC. These counties will be referred to as A, B, and C. All of the scenarios (discussed below) were developed around one of these two alternatives. The first alternative had PODs in counties A and C receive deliveries from the state depot, while PODs in county B received deliveries from an LDC, which previously obtained its

regimens from the state depot. The second alternative had all PODs in all three counties receive deliveries directly from the state depot, and no LDC was used. The first alternative needed to be carried out in a two step process, first the deliveries at the state level, and second, at the local level. The second alternative could be analyzed all at once.

Feasible scenarios needed to be created for distribution that could be compared and evaluated to use for scheduling. From the given timeline (a known constraint) which specified seven waves of distribution and the amount of regimens per wave, three possible scenarios were chosen to be evaluated. One scenario is the 'single wave' approach, where trucks are sent out to PODs after each shipment to the state depot; seven total. Another is the 'double wave' approach, where after every two shipments to the state depot, the trucks are sent out to PODs. And finally, the 'all at once' approach, which requires the state depot to wait until all seven shipments have arrived from the federal level and then send out the regimens in one mass delivery.

Because the first alternative is a two step process, and there are two alternatives, nine separate scenarios were generated:

**Alternative 1: ACldcB** – deliveries from state depot to PODs in counties A and C and the LDC in county B

**single wave**

**double wave**

**all at once**

**B** – deliveries from LDC in county B to all count B PODs

**single wave**

**double wave**

**all at once**

**Alternative 2: ABC** – deliveries from state depot to all PODs in all three counties

**single wave**

**double wave**

**all at once**

Single waves were allotted 2:00:00 to complete their routes to and from the RSS, double waves 4:00:00 and all at once 6:00:00. Each scenario was run through the Tour Solver software and produced a different set of results.

The seven shipments to the state depot varied in amounts, ranging between 313,600 regimens to 324,800 regimens. After running sample tests, it was determined that running seven separate optimizations for each alternative on Tour Solver was not time-efficient. The best option was to use the maximum shipment amount, 324,800, calculate proportional quantities to each POD demand and use those values for each wave. The calculations are shown in the Table 1.

<b>Max = (Using 324,800)</b>	<b>Percentage % (demand)</b>	<b>Max x %</b>	<b>Single POD demand</b>	<b>(Max x %) x (single POD demand)</b>
LDC/County B 1,040,000/2,220,800	0.468299712 46.80%	152,104	[1/130]	1171
County A 248,000/2,220,800	0.11167147 11.20%	36,271	[1/37]	981
County C 932,800/2,220,800	0.420028818 42%	136,426	[1/22]	6202

**Table 1: Quantity Calculations for POD demand**

Table 2 shows the different quantity demands for all locations in the problem.

<b>Single Wave Quantities/POD</b>	<b>Double Wave Quantities/POD</b>	<b>All at OnceWave Quantities/POD</b>
981	1,962	6,700
6,202	12,404	42,400
1,171	2,342	8,000
152,104	304,208	1,040,000

**Table 2: Quantities Distributed to PODs**

## Results

### Analysis of 9 scenarios

Each of the nine scenarios is analyzed in the section. Both alternatives and their scenarios are presented in summary tables along with brief comments on each scenarios performance.

#### [Alternative 1, step 1] State Depot → County A, County C, and LDC (ACIdcB)

**1. Single Wave (ACIdcB single):** *Make deliveries to PODs after each wave of distribution to state depot.* For the LDC in this case, it is treated as one POD and receives 152,104 regimens (from Table 2). Due to the far distance between the PODs and the depot, this could be a poor choice.

**2. Double Wave (ACIdcB double):** *Wait until two waves of regimens are delivered to state depot then begin distribution to PODs.* For this scenario, the numbers derived for a single wave were doubled for the new regimen quantity.

Due to the capacity constraint on the trucks, the LDC needs to be listed as two separate PODs with 152,104 regimens delivered each time. Each wave to the depot arrives every two hours; but in this case, we wait until two waves arrive at the State depot to begin deliveries.

**3. All At Once (ACIdcB all at once):** *Wait until all regimens arrive at state depot then distribute them to their respected PODs all at once.* The total given demand is 2,220,800 regimens. Because of truck capacity constraint (largest truck only capable of holding 24 pallets, 268,800 regimens total) the LDC needs to be listed as 4 separate PODs with 260,000 regimens delivered each time.

<b>[Alternative 1, step 1] State Depot → County A, County C, and LDC</b>			
<b>Trucks Available</b>	<b>PODs</b>	<b>Truck Capacities</b>	<b>Fixed Visit Time</b>
71	60	49;24 and 22;10*	15:00
<b>Scenario</b>	ACIdcB single wave	ACIdcB double wave	ACIdcB all at once
<b>Total Routes (Trucks Used)</b>	60	61	63
<b>Time Limit</b>	2:00:00	4:00:00	6:00:00
<b>Fastest Time</b>	01:12:55	01:12:55	01:12:55
<b>Longest Time</b>	03:17:27	03:17:27	03:17:27
<b>Average Time</b>	2:09:02	2:08:54	2:08:53
<b>Quantities - LDC</b>	152,104 (1)	304,208 (1)	1,040,000 (1)
<b>Quantities - A</b>	981 (37)	1,962 (37)	6,700 (37)
<b>Quantities - C</b>	6,202 (22)	12,404 (22)	42,400 (22)
<b>Stops per Route</b>	1	1	1

**Table 3. Alternative 1, step 1**

\*The values are presented in the format x;y. The value x represents the number of trucks available that have 'y' pallet capacity.



## [Alternative 1, step 2] LDC → County B

**1. Single Wave (B single):** *Make delivery to PODs after **each** wave of distribution to LDC.* Once the truck load arrives at the County B LDC from the state depot, the distribution can begin to the 130 PODs. Each wave of regimens will ideally arrive at the LDC every two hours. Due to the limited truck supply, this scenario cannot be completed within its constraint of two hours. With a short window of time to operate truck routes are forced to be shorter, reaching less PODs in one route, making each truck route range between five and ten stops each.

**2. Double Wave (B double):** *Wait until **two** waves of regimens are delivered to LDC then begin distribution to PODs.* The demand for each POD in this case is double the amount of the previous case since we are using two waves of regimens. The LDC receives its total regimen demand in two separate truck loads from the state depot; once they arrive, the deliveries begin. Ideally, the trucks to the LDC from the state depot will arrive every four hours. Routes have between one to eleven stops each.

**3. All At Once (B all at once):** *Wait until all regimens arrive at LDC then distribute them to their respected PODs all at once.* The total demand for County B is 1,040,000 regimens (from Table 2). Each truck route has between one and seventeen stops. The only constraint that has forces the scenarios to have different routes is the time limits. The quantities delivered to each POD are so small (less than one pallet for each scenario) that it doesn't affect the outcome of the routes. (This is true for all three scenarios; single, double, and all at once.)

<b>[Alternative 1, step 2] LDC → County B</b>			
<b>Trucks Available</b>	<b>PODs</b>	<b>Truck Capacities</b>	<b>Fixed Visit Time</b>
21	130	4;22* 10;10 7;6	15:00
<b>Scenario</b>	B single wave	B double wave	B all at once
<b>Total Routes (Trucks Used)</b>	21	21	21
<b>Time Limit</b>	2:00:00	4:00:00	6:00:00
<b>Fastest Time</b>	02:00:06	00:23:00	00:23:00
<b>Longest Time</b>	03:52:23	03:59:00	05:56:48
<b>Average Time</b>	2:33:53	2:27:46	2:25:01
<b>Quantities</b>	1,170	2,340	8,000
<b>Stops per Route</b>	5 to 10	1 to 11	1 to 17

**Table 4. Alternative 1, step 2**

\*The values are presented in the format x;y. The value x represents the number of trucks available that have 'y' pallet capacity.

**[Alternative 2] No LDC, State Depot → Counties A, B, and C**

**1. Single Wave (ABC single):** *Wait until all regimens arrive at state depot then distribute them to their respected PODs all at once.* Quantities are used from the same proportional calculations from the previous alternative. Due to limited Truck supply and distance between the Depot and some PODs, most deliveries are not completed in two hours or less.

**2. Double Wave (ABC double):** *Wait until **two** waves of regimens are delivered to state depot then begin distribution to PODs.* Quantities are double the amount of the single wave scenario. Routes are completed within time limit, yet some of the longer truck routes come in at the last minute which you can see in the table below.

**3. All At Once (ABC all at once):** Make delivery to PODs after *each* wave of distribution to state depot. Acceptable are also produced in this outcome, yet like the Double Wave, some of the longer truck routes are completed at the last minute.

<b>[Alternative 2] No LDC, State Depot → Counties A, B, and C</b>			
<b>Trucks Available</b>	<b>PODs</b>	<b>Truck Capacities</b>	<b>Fixed Visit Time</b>
71	189	49;24 and 22;10*	15:00
<b>Scenario</b>	ABC single wave	ABC double wave	ABC all at once
<b>Total Routes (Trucks Used)</b>	71	71	71
<b>Time Limit</b>	2:00:00	4:00:00	6:00:00
<b>Fastest Time</b>	01:44:17	01:08:24	01:08:24
<b>Longest Time</b>	03:59:22	03:59:55	05:59:18
<b>Average Time</b>	2:29:54	2:23:31	2:10:34
<b>Quantities - A</b>	981 (37)	1,962 (37)	6,700 (37)
<b>Quantities - B</b>	1,170 (130)	2,340 (130)	8,000 (130)
<b>Quantities - C</b>	6,202 (22)	12,404 (22)	42,400 (22)
<b>Stops per Route</b>	1 to 6	1 to 7	1 to 13

**Table 5. Alternative 2**

\*The values are presented in the format x;y. The value x represents the number of trucks available that have 'y' pallet capacity.

## **Implications and Future Work**

From examining the results there are a few recurring implications that have a negative effect on the outcomes. In the state level problems; the first step of the first alternative and also alternative two, the traveling distances force the routes to take longer then time allows, making the single wave approach a poor choice. At the local level, when using the LDC, there are simply not enough trucks available to make the routes feasible in less than two hours in the single wave approach and the longest routes in the double and all at once approach come very close to the time limit.

These issues can be remedied in several ways. Two changes could be increasing truck supply and/or making the location of the state level depot more applicable to all counties within the state. Increasing the number of available trucks allows for routes to be shorter and reach the demand at PODs more rapidly. Centrally locating the state depot or focusing on population density to locate a state depot will help avoid inconvenient distances between the PODs and the depot.

Please refer to Sara Lu's report for further analysis of the truck routes to develop an optimal scheduling plan.

## Appendix A

### Tour Solver Steps

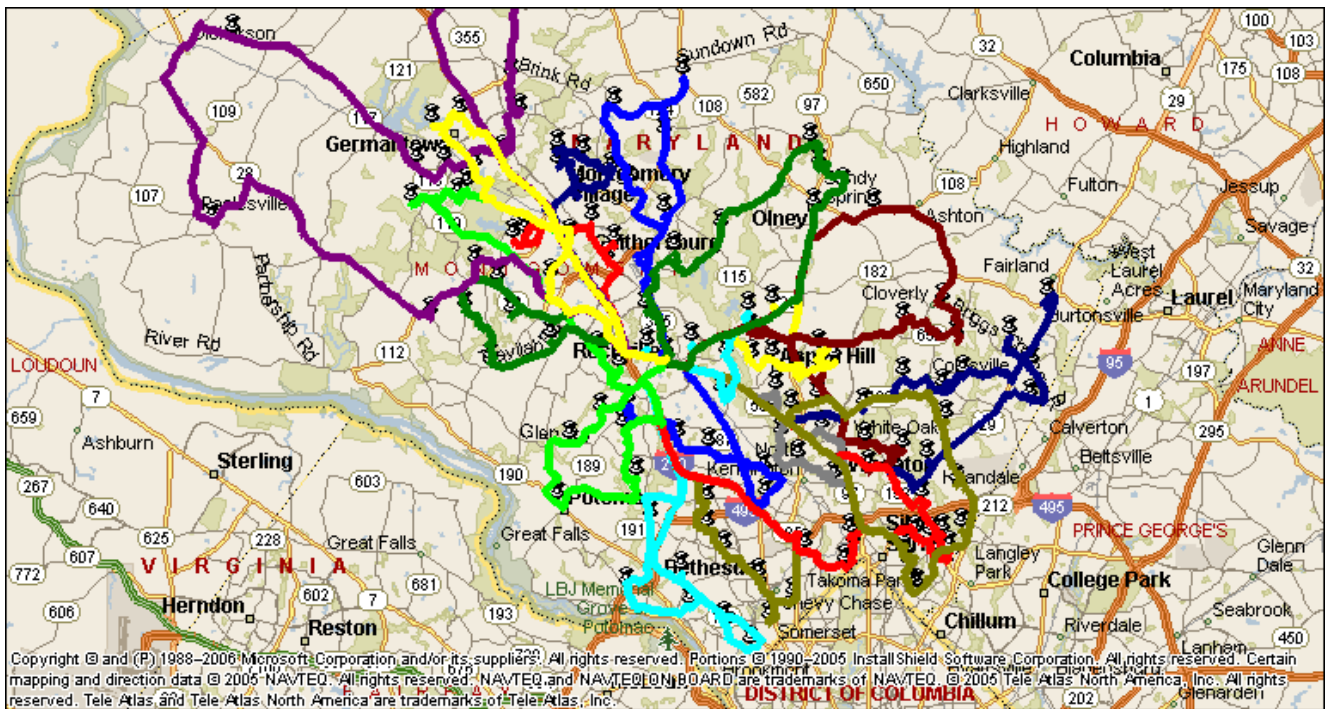
(Tour Solver software requires an internet connection to run. The stronger the connection, the faster your optimizations will run.)

1. Contact Rick Pietz at the CDC to obtain a username and password (404-639-2791; [eoj3@cdc.gov](mailto:eoj3@cdc.gov)) for access to Tour Solver software.
2. Download and install the Tour Solver Citrix client from the Message Center on the Tour Solver website; <http://cdcstockpilerouting.c2logix.com/Citrix/AccessPlatform/auth/login.aspx>. Once the Message Center has no errors reported, your computer is ready to run Tour Solver.
3. Download and review the SNS Tour Solver User Guide and contact the CDC for training.
4. A useful pre-recorded web seminar will be available for you to watch to help you get started. The link will be provided in the return email sent to you by Rick Pietz along with your username and password for your Tour Solver server access.
5. To access the User Guide and Templates, open up the Tour Solver website (above) and sign in with your username and password that you received from Rick Pietz. Once you've logged in, on the left-hand side of the screen will be a three links; click on the 'Tour Solver Manuals & Excel Templates' link. From there, you will be able to access all the documents you need to run Tour Solver.
6. Before you begin filling out the Excel Templates, decide whether a county is going to use a State Depot or a Local Distribution Center (LDC) for their RSS.
7. Choose designated Points of Distribution (POD) locations (i.e. elementary schools, high schools...).
8. Determine what trucks are going to be available for an emergency situation.
  - Must know how many trucks and their capacities based on pallet size.
  - The default setting for pallets size is 11,200 regimens/pallet.
9. Fill out needed information in Tour Solver Excel Templates, CustomersPOD and ResourcesRSS (which you can find in the 'Tour Solver Manuals & Excel Templates' link once you've logged into the Tour Solver website).
  - CustomersPOD needs street addresses and POD demand (total needed regimens)
  - ResourcesRSS needs street addresses of RSS (Depot/LDC), number of trucks and their capacities.
10. When filing out the Excel Templates I recommend using the Advanced Templates. They help speed up the optimization process and require less routine steps when using the Tour Solver Wizard. Also, from my own personal experience, it reduces error.
11. When using the Advanced Templates you'll need to know your fixed visit duration for each POD (i.e. 15 minutes) which you will fill in on the Customer spread sheet (disregard the default time for the "Unloading duration per unit"). Also, for the Resources spread sheet, you will need to specify the Start and End times (Start will be left at 00:00:00 and end time will vary depending on your scenario). In our scenarios our single wave ends at 02:00:00, double wave ends at 04:00:00 and all at once ends at 06:00:00). Keep the rest of the information set at default.
12. After filling out your spread sheets and saving them in an accessible folder, open Tour Solver through the Tour Solver website and signing in with your username and password. Once you've logged in, click on the Tour Solver application on the left side of the screen. It will take a few minutes to load. You will be prompted to fill out the 'Client File Security'; your answers should be 'Full Access' and 'Always ask me'.

13. The next step is to upload your Excel spreadsheets with RSS and POD data.
  - In the drop-down toolbar, click on 'Data', scroll down and click on 'Link Data Wizard'.
  - Upload Customers template first, Resources template second.
  - If you have trouble finding your server/hard drive, click on 'My Computer', 'C\$ on 'Client' (C:)', 'Documents and Settings', and then click on your own computer name and from there you can find your files.
14. When uploading your spread sheets you will be prompted with a series of questions. You're required to indicate which column will be used as the Primary Key. This column must have a unique value for each Customer. (The default setting should be fine.) The Map Type dialog box allows you to define the style of the map. Choose 'Pushpin'. The last dialog box allows you to select the symbol for the pushpins. Hit end to validate linking the data. Repeat this process for your Resource file. Choose the Resource ID field as unique resource ID (primary key) for each Resource. (The default setting should be fine.)
15. In the drop-down toolbar, click on 'Tools', scroll down to 'Tour Solver Wizard'. The Wizard will open up a series of screens where you will specify the constraints and parameters to be used in your routing.
16. First, under the Customers drop-down menu at the top, left side of the window, ensure that you select "CustomersPOD\_Template...". In our scenarios, when using the Tour Solver wizard, unclick the 'Unloading duration per unit' box under the 'Quantities' toolbar. Unclick the 'Cutting' box under the 'Time' toolbar (make sure 'Fixed visit duration' and 'Frequency' are the only boxes checked). Click 'Next' at the bottom of the wizard.
17. Second, under the Resources drop-down menu at the top, left side of the window, ensure that you select "ResourcesRSS\_Template...". In our scenarios, unclick the 'Lunch Break' box under the 'Time' toolbar (make sure the only boxes checked are 'Working Hours', 'Overtime' and Working days'). Under the 'Capacities' toolbar make sure the only box checked is 'Capacity', all others should be unchecked. And all other toolbars can be left alone; their default settings keep the optimization running in a normal pattern. Click 'Next' at the bottom of the wizard.
18. Third, make sure to select 'Route Optimize,' then select 'Automatic stop' under the 'Computing duration' toolbar. Under the 'Driving toolbar' you can select 'Open Library' and create your own driving parameters for your scenario, in our case, leave the speed limits at their default setting but create a new profile labeled 'RSS to POD deliveries' and use it every time.
19. The last page of the Wizard can be left alone. Click on 'Finish' and the optimization will begin. This will take anywhere between 5 to 30 minutes or more depending on how many PODs and Trucks you have, and also the strength of your internet connection.
20. If at anytime you want to stop the optimization and go back and check or change your settings, click on 'Pause' or 'Stop' up in the top, left corner, then click on 'Reoptimize' and make your changes.
21. Once the optimization is finished, you'll need to save your results. Do this by clicking on 'Excel Export' at the top of the page and save 'Separated Routes', 'Combined Routes' and/or 'Mileage Chart' (whichever you prefer) to your accessible folder.
22. Once you save those files, you can close Tour Solver. You may be notified and prompted to save your results because you didn't save a map of the routes, disregard this message and proceed to close Tour Solver.

## Appendix B

### Example of Tour Solver Export Map



## References

<sup>1</sup> Tour Solver provided by the Center for Disease Control – created by Magellan Ingénierie and DELIA.