Weill Cornell Medicine

Cornell Institute for Disease & Disaster Preparedness (CIDDP)

Vaccine Dispensing Locations Allocator

User Guide

For use with *Vaccine Dispensing Locations Allocator - v1-1,V1-2*

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Introduction

Supply chains for distributing vaccines consist of three types of locations. The first is the *manufacturer's warehouse*, which receives the production of vaccines. The second set of locations we call *distribution warehouses*. These warehouses receive shipments directly from the manufacturer's warehouse. There may be one manufacturer's warehouse, but there are likely to be hundreds of distribution warehouses located throughout the United States, for example. Each of these distribution warehouses is responsible for supplying a collection of locations at which vaccines are administered, which we designate as *dispensing locations*. There are or will be many thousands of such locations. The number of both distribution warehouses and dispensing locations per distribution warehouse will vary by country.

The purpose of the following comments is to provide insight into the spreadsheet tools that can be employed to determine daily allocations of available supplies from the manufacturer's warehouse to distribution warehouses, and from Distribution Warehouses to Dispensing Locations. The model is designed to be executed every day as conditions change. These allocations are determined considering:

1. Uncertainty in demand each day at each dispensing location.

2. Lead times associated with the transfer of stocks from one location to another.

3. The manufacturer's vaccine box quantity (doses of vaccine per box).

4. The available stock at the manufacturer's warehouse and distribution warehouses.

5. The on-hand stock at each dispensing location.

6. The desired level of service at each location in the distribution system.

By including service level targets, we provide the user with the flexibility to prioritize allocations to the most vulnerable patient communities served by each dispensing location. As we will see, the spreadsheet user is asked to provide data pertaining to all these parameters. While it seems to be a substantial task to enter these data, we will also see that it is not a daunting one. Once entered, the best possible allocations are determined by running the model. The mathematics used to determine the allocations can be found in our paper [Application of Supply Chain Principles to Pandemic Planning.](#)

In this document, we focus on a spreadsheet tool for making allocations from one distribution warehouse to a collection of dispensing locations. We call this spreadsheet the "Vaccine Dispensing Locations Allocator". In another document (titled "Vaccine Distribution Warehouse Allocator User Guide", we show how to employ a similar spreadsheet for making allocations from a manufacturer's warehouse to a collection of distribution warehouses.

Why Use the Vaccine Dispensing Locations Allocator?

The Vaccine Dispensing Locations Allocator is based on fundamental supply chain principles that have a long pedigree in the field of operations research. It applies a supply chain distribution method that maximizes "vaccinated person-days", a concept that refers to the number of days patients have protection from the virus that the vaccine targets. While it was developed as a response to Covid-19, the method is equally applicable to other pandemic supply chain responses that may arise.

By maximizing vaccinated person-days, we minimize the time from a manufacturer's production of vaccines to the time patients receive shots in their arms. In other words, it provides the most protection, for the most patients, in the least amount of time. By doing so, it both minimizes each patient's risk of becoming ill and reduces the chances of virus variants from occurring. It accomplishes the latter result by vaccinating more people, more quickly, than when using other allocation strategies.

In summary, when vaccine supplies can be allocated and distributed as suggested by the Vaccination Dispensing Locations Allocator, people get vaccinated sooner, supplies are used up faster, fewer people experience COVID symptoms, fewer people are hospitalized, and fewer people will succumb to the disease.

We illustrate the concept of vaccinated person-days using a simple example. Suppose a vaccination dispensing site receives 100 doses of vaccine on a Monday. If the site vaccinates 100 people on Monday, 100 x 5 days = 500 vaccinated person-days occur over a five day time horizon. If the site is capable of only vaccinating 20 persons per day for 5 days, the corresponding number of vaccinated person-days over that five-day period would be 20 x 5 + 20 x 4 + 20 x 3 + 20 x 2 + 20 x 1 = 300 days. By administering the vaccine as soon as it arrives, 67% more days of coverage are provided for those 100 patients. The model's imbedded algorithms allocate vaccine supplies so that vaccinated person-days are maximized, with priority given to sites having higher service level targets.

During the Covid-19 pandemic, it has not been uncommon for some dispensing sites to be allocated more supply than they could quickly use, while other locations had more patients seeking vaccinations than they had supply. The Vaccination Dispensing Locations Allocator can avoid these misallocations by using updated estimates of patient vaccine demand levels and vaccine administration capacities. The model incorporates uncertainty of daily demand at each dispensing location. To incorporate uncertainty in the spreadsheet, the user provides the minimum, maximum, and most likely doses needed at each dispensing location. For dispensing locations that are already operational, these estimates should be easy to obtain from historical vaccination data.

As we have stated, when vaccine supplies are allocated efficiently and effectively, people get vaccinated sooner, supplies are used up faster, fewer people experience COVID symptoms, fewer people are hospitalized and fewer people will succumb to the disease. The easy-to-use Vaccine Dispensing Locations Allocator and its companion Vaccine Distribution Warehouse Allocator ensures such allocations occur. Furthermore, the tool requires no specialized knowledge or skill to use. It is

helpful however to have basic familiarity with Microsoft Excel and rudimentary knowledge of statistics.

Model Assumptions

The Vaccine Dispensing Locations Allocator is based on the following assumptions:

1. The supply of vaccines at distributor warehouses is a single vaccine type, e.g., Pfizer-BioNTech, or Moderna, or Johnson & Johnson, or another. If dispensing sites use vaccines from multiple manufacturers, separate "Vaccine Dispensing Locations Allocator" spreadsheets must be used for each. Demand estimates must then be provided for each manufacturer's vaccine independently. The model will not "mix" vaccines from multiple suppliers.

2. Dispensing sites are served from a single source of supply. One distributor provides all supply of a particular vaccine type to each dispensing site.

3. Vaccines are distributed in whole boxes only. The model does not accommodate dividing single boxes of vaccines among multiple dispensing locations. If some dispensing sites do not have the capacity to use an entire box very quickly, those boxes will generally be allocated to the sites that have greater daily dispensing capacity so that the time between allocation and use is minimized. Allocating vaccines in smaller box sizes to smaller dispensing capacity sites is recommended. That is why Pfizer Covid vaccine in boxes of 975 doses, which require extreme refrigeration, are best allocated to larger scale vaccination sites whereas Moderna vaccines in boxes of 100 doses, which have less stringent storage requirements, are best allocated to lower capacity dispensing sites. Again, vaccines from different manufacturers must be allocated in separate "Allocation for Dispensing" spreadsheets.

4. Vaccine supplies cannot be shared between locations. The model does not accommodate re-allocation of excess supply at one dispensing location to another. In practice, if excess from one location does get shipped to another, enter the Supply on Hand from the sending location to the receiving location in Column D when preparing the inputs for the next planning period's allocation worksheet.

5. Patient demand quantities are not known with certainty. For this reason, the model requires estimates of the "Minimum", "Maximum" and "Most Likely" quantities to be needed at each dispensing location.

Spreadsheet Overview

The above sample spreadsheet contains all required input data needed to make allocations to dispensing locations. The cells shaded in **green** are those in which input data are required. The cells colored *gold* and **gray** have computed values in them. All other cells contain data that result from executing the allocation algorithm. We will next discuss the content of each of the **green** cells.

Column B "**Dispensing Locations**" contains the names of the dispensing sites; input your Dispensing Location site names in this column. In this example, there are 9 such locations.

Cell C9 "Expected doses of supply to allocate" indicates that a supply of 8,000 doses of vaccine is available to allocate from the distribution warehouse, and the "Box Size" in *Cell C11* is 100 doses.

Expected doses of supply to allocate	8000	doses
Box Size	100	doses
Expected number of boxes to be allocated	80	boxes

The data in rows 17 through 25 in *column C* "Target probability of not running out of stock" indicate the target probability of not running out of stock on the following day at the corresponding Dispensing Location. This number must be a number between 0 and 1, but less than 1. By setting this value, you set priorities for allocating the available supply. In our example, we set this value to .91 for each dispensing location.

Target probability of not running out of stock
0.9100
0.9100
0.9100
0.9100
0.9100
0.9100
0.9100
0.9100
0.9100

Caution: when supplies are constrained, care should be taken in setting the target probability of running out of stock too close to 1. That can result in high levels of expected excess being "trapped" at some locations and unavailable for use at other locations where there might be shortages. Users are advised to run the model with various combinations of targets until a desired balance between expected shortages and expected excess quantities are achieved at all dispensing locations.

The number of doses on-hand at the corresponding Dispensing Location before making the allocation decision is displayed in *column D* "Supply on Hand in Doses".

Supply on Hand in Doses
100
48
27
20

In the same rows in *columns E through G*, enter the minimum, maximum and most likely patient demand you expect to have on the following day at the corresponding Dispensing Location.

Minimum	Maximum	Most Likely
1900	2100	2000
1900	2100	2000
1900	2100	2000
150	250	200
150	250	200
150	250	200
10	25	20
10	25	20
10	25	20

In the example shown above there are 9 dispensing sites: 3 large, 3 medium and 3 small ones. The spreadsheet can accommodate up to 200 Dispensing Locations served by one distribution warehouse. There are no restrictions on naming conventions. Assigning a number is not required. However, you are not permitted to enter dispensing locations with zero or blank demand estimates between locations with positive demand estimates.

After you have entered these data, click the large "**Allocate Vaccine to Dispensing Locations**" button:

Allocate Vaccine to Dispensing Locations

For most scenarios, the model runs very quickly, and results are displayed almost immediately. In some scenarios, for example when box sizes are large and supplies are constrained, there may be some delay in displaying results while the calculations are performed. When the model completes calculating and posting its results, a done message will appear:

Microsoft Excel   ×

Done! See column I & J

OK
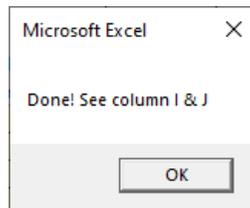
Upon completion, click the "OK" button to view results.

The results of the allocation decision will be displayed in *columns I through P*:

Allocation in doses	Allocation in boxes	Doses Available for Dispensing	Expected Shortages in doses	Expected Excess Supply in doses	Expected Vaccination (Fill) Rate	Target Stock Level in doses	Target Safety Stock in doses
2000	20	2100	0.0	100.0	1.0000	2058	58
2100	21	2100	0.0	100.0	1.0000	2058	58
2100	21	2148	0.0	148.0	1.0000	2058	58
300	3	300	0.0	100.0	1.0000	229	29
300	3	327	0.0	127.0	1.0000	229	29
300	3	300	0.0	100.0	1.0000	229	29
100	1	120	0.0	101.7	1.0000	23	5
100	1	100	0.0	81.7	1.0000	23	5
100	1	100	0.0	81.7	1.0000	23	5

Based on the available stock to allocate from the distribution warehouse, the target probabilities of not running out of stock and the minimum, maximum, and most likely demand parameter values for each dispensing location (rows 17 – 25 in the sample spreadsheet), there corresponds an expected number of potential patients that would not be accommodated (*column L*), the expected number of doses remaining unused at the end of the following day (*column M*), the expected vaccination or fill rate (*column N*), the target stock level (*column O*) and target safety stock level (*column P*).

The vaccination rate is defined to be 1 – expected number of potential patients that would not be accommodated / total expected demand for all dispensing locations. Note that while 8,000 doses were available for allocation, only 7,400 were shipped to dispensing sites. This occurred because the target probability of not running out of stock, .91, at each dispensing location was achieved without allocating all the stock. Note also that although the target probability of not running out of stock was .91 at all dispensing sites, the expectation was that all persons desiring vaccinations would receive them (vaccination rate = 1).

Expected doses of supply to allocate	8000	doses
Box Size	100	doses
Expected number of boxes to be allocated	80	boxes

	195	6180	7125	6660	6655.0	7400	74	7595.0	0.0	940.0	1.0000	6930	275
		Estimated Vaccine Demand for the Planning Period in Doses											
Target probability of not running out of stock	Supply on Hand in Doses	Minimum	Maximum	Most Likely	Expected	Allocation in doses	Allocation in boxes	Doses Available for Dispensing	Expected Shortages in doses	Expected Excess Supply in doses	Expected Vaccination (Fill) Rate	Target Stock Level in doses	Target Safety Stock in doses
0.9100	100	1900	2100	2000	2000.0	2000	20	2100	0.0	100.0	1.0000	2058	58
0.9100		1900	2100	2000	2000.0	2100	21	2100	0.0	100.0	1.0000	2058	58
0.9100	48	1900	2100	2000	2000.0	2100	21	2148	0.0	148.0	1.0000	2058	58
0.9100		150	250	200	200.0	300	3	300	0.0	100.0	1.0000	229	29
0.9100	27	150	250	200	200.0	300	3	327	0.0	127.0	1.0000	229	29
0.9100		150	250	200	200.0	300	3	300	0.0	100.0	1.0000	229	29
0.9100	20	10	25	20	18.3	100	1	120	0.0	101.7	1.0000	23	5
0.9100		10	25	20	18.3	100	1	100	0.0	81.7	1.0000	23	5
0.9100		10	25	20	18.3	100	1	100	0.0	81.7	1.0000	23	5

A Few Notes About Using the Worksheet

Most of the instructions contained in this user guide are also contained in the worksheet itself, as summarized by the statement in row 5:

Enter data in green cells. Other cells contain model outputs.　See explanations in notes fields. Click "Allocate Vaccine to Dispensing Locations" button to run the model.

The worksheet is protected. All but the green cells are locked, preventing any accidental input into cells intended for model outputs. To further aid the user, if an invalid number is entered in any of the green cells, error messages pop up. Informative messages guide the user to what values are valid. For example, if anything but a whole number greater than zero is entered in the "Expected doses of supply to allocate" field in cell C9, the following error message will appear:
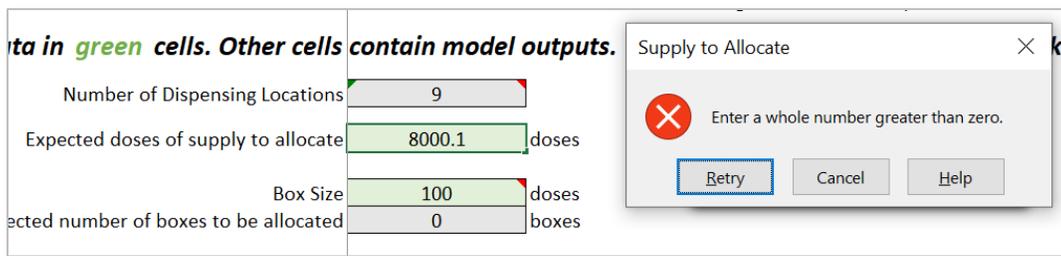
The spreadsheet contains information about both data input and data output fields at the top of the columns of data. The notes appear by hovering over any cell with a red triangle "◥" in the upper right portion. For example, when hovering over the "Expected doses of supply to allocate" field in cell C9, the following explanatory note appears:

Each note follows a similar convention: a short description of the field is provided at the top of the note, a more detailed discussion follows. In the example above, we provide a short description of "Enter the expected supply for the planning period". In the discussion section, we explain how to run the model and how the model allocates the supply.

As stated previously, one worksheet represents the distribution of a single manufacturer's vaccine type from a single source of supply, for a single planning period. To prepare multiple planning periods or multiple sources of supply, the worksheets can be copied and renamed within a single workbook and/or multiple workbooks can be copied and saved:
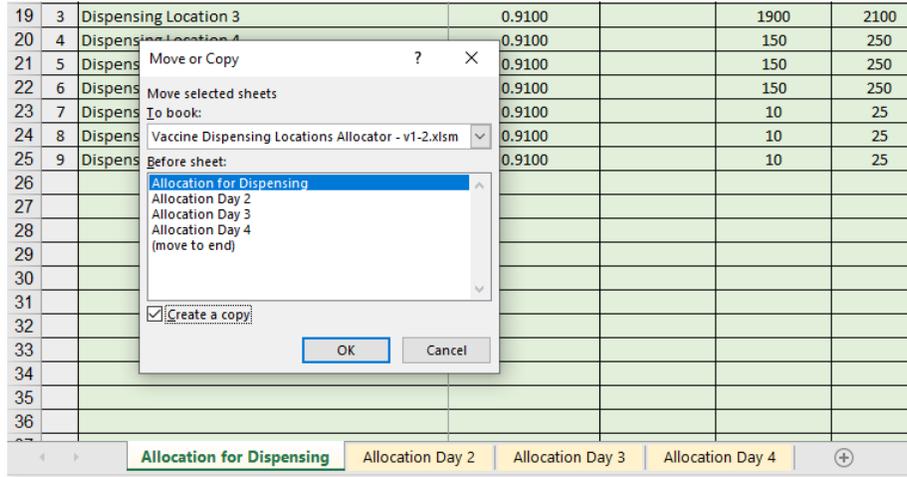
In the example above, the expected excess supply in doses from Day 1 were entered as the supply on hand for Day 2, and an assumption of a reduced supply to allocate from 8,000 to 6,000 doses was applied to Day 2. Due to the reduced supply, expected shortages increased from 0 on Day 1 to 54 on Day 2. Another observation is that the small dispensing sites received no allocations on Day 2 because they had enough left over from the single boxes allocated on Day 1 to fulfill their demands on Day 2 (and enough for 5 days, since their expected demands are 20 doses per day). Note that the vaccination rate remains very high at .9919, which means there would be sufficient supply to vaccinate 99.19% of patients requesting a vaccine. Although the target probability of not running out of stock is .91, when demand at Dispensing Location 1 is 2100 (a very low probability event), with a supply of 2000, the vaccination rate would be 2000/2100 or 95%. Hence vaccination rates are considerably higher than the probabilities of not running out of stock when using high throughput capacity dispensing locations.

How to Report Problems or Suggestions

Comments and questions may be sent to ciddp@med.cornell.edu. We will strive to answer your questions in a timely manner, but our resources are limited and responses are not guaranteed.