USER GUIDE

Route Optimization Tool (RoOT)

FEBRUARY 29, 2020

RoOT is an Excel-based tool to determine optimal routes for vehicles to deliver vaccines and medical supplies to health centers efficiently.

VillageReach® Starting at the Last Mile

UNIVERSITY of WASHINGTON

www.villagereach.org // info@villagereach.org

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Route Optimization Tool (RoOT)

Download RoOT:

https://github.com/villagereach
https://github.com/lpetroia/RoOT

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Route Optimization Tool (RoOT): User Guide

1. Introduction to the Route Optimization Tool (RoOT)

VillageReach and the Industrial and Systems Engineering Department at the University of Washington developed an Excel-based distribution routing tool, called Route Optimization Tool (RoOT), that optimizes routing for distribution of vaccines and medical supplies.

The tool is designed to incorporate issues such as vehicle availability and reliability, road conditions, and cold storage of vaccines. For example, certain roads may not be accessible due to rain or flooding, and a different route may need to be used during the rainy season or in the event of cyclones. Furthermore, untimely delivery may affect the potency of vaccines. For example, if a vehicle breaks down en route or gets stuck in the mud, the temperature of the vaccines in cold storage may violate the recommended range, which would impact the potency of the vaccines.

The optimization model allows the user to optimize on transit time or minimize risk to the vaccines due to poor road or vehicle conditions, or any combination of the two objectives. A user may want to optimize on transit time only, and then separately optimize on risk only and compare the resulting routes and adjust with their own local knowledge. Or a user can choose to optimize with a 50% weight on transit time and a 50% weight on risk to determine an optimal route that balances transit time with risk. The weight used in the two objectives is an input determined by the user.

RoOT does not allow multi-day routes. This tool only considers one-day routes, however, the length of the day (8 hours, 10 hours, up to 23 hours) is possible to specify using the start time and return time (same day) for a vehicle. RoOT does allow multiple vehicles to be used in the routing plan. The vehicles start at a location at the start time and must return to the same location by the specified return time. When the distribution cannot be completed in one day with all of the available vehicles, then each vehicle is assigned a second route until all of the demand is satisfied.

The route optimization tool can be used at any time, e.g., daily, weekly, or whenever a new distribution is being planned. The tool can be used for routine operations, in emergency situations, or to evaluate the effect of changes in the situation (such as new or closed health centers, additional or fewer vehicles, new products, or new refrigerators).

RoOT input data is easily modified, and can be updated with the availability of roads, vehicles, and medical products to distribute. RoOT reads an Excel input file (described in Section 4) and produces output in another Excel file (described in Section 5). Several use cases are described in Section 6, to assist users in answering typical questions that arise in route planning.

Objectives: The objectives of this user guide are to:

- provide an overview of RoOT and its different uses and functions;

- empower users to access and use RoOT; and
- impart users with knowledge regarding how to modify inputs and interpret outputs.

Audience: This RoOT User Guide is aimed at individuals that assist in route planning for distribution of vaccines and other medical products. Users of the tool should have a Windows computer with Microsoft Excel version 2007 or later.

Using this guide: This user guide provides detailed explanations of the inputs and outputs of RoOT. It also describes how to download and run RoOT, and provides several use cases to assist users in general route planning.

Troubleshooting: Contact VillageReach at info@villagereach.org with any questions or comments.

2. Download and Install RoOT

RoOT is an open-source tool available online for free. The current tool runs on a Windows computer, 64-bit, with Microsoft Excel version 2007 or later. To check if your computer is 64-bit, go to "Display Settings" and scroll down to find "About" on the left menu. When you click on "About," you can see: "System type: 64-bit operating system." There are no specific RAM requirements, but the RoOT folder needs about 1.1 GB of memory.

a. To download RoOT, open an Internet browser, such as Chrome, Internet Explorer or Mozilla Firefox, and go to the link:
https://github.com/villagereach or https://github.com/lpetroia/RoOT.

   To download the zip file named RoOT-master.zip, click on the green button labeled "clone or download" on the right and select "Download ZIP". See Figure 1. The download can take a few minutes, depending on the internet connection. For an internet speed of over 50 Mbps, the download takes one to two minutes. For an internet speed of about 3 Mbps, the download may take up to an hour. All of the contents of the page will be downloaded in a zip file named "RoOT-master.zip."

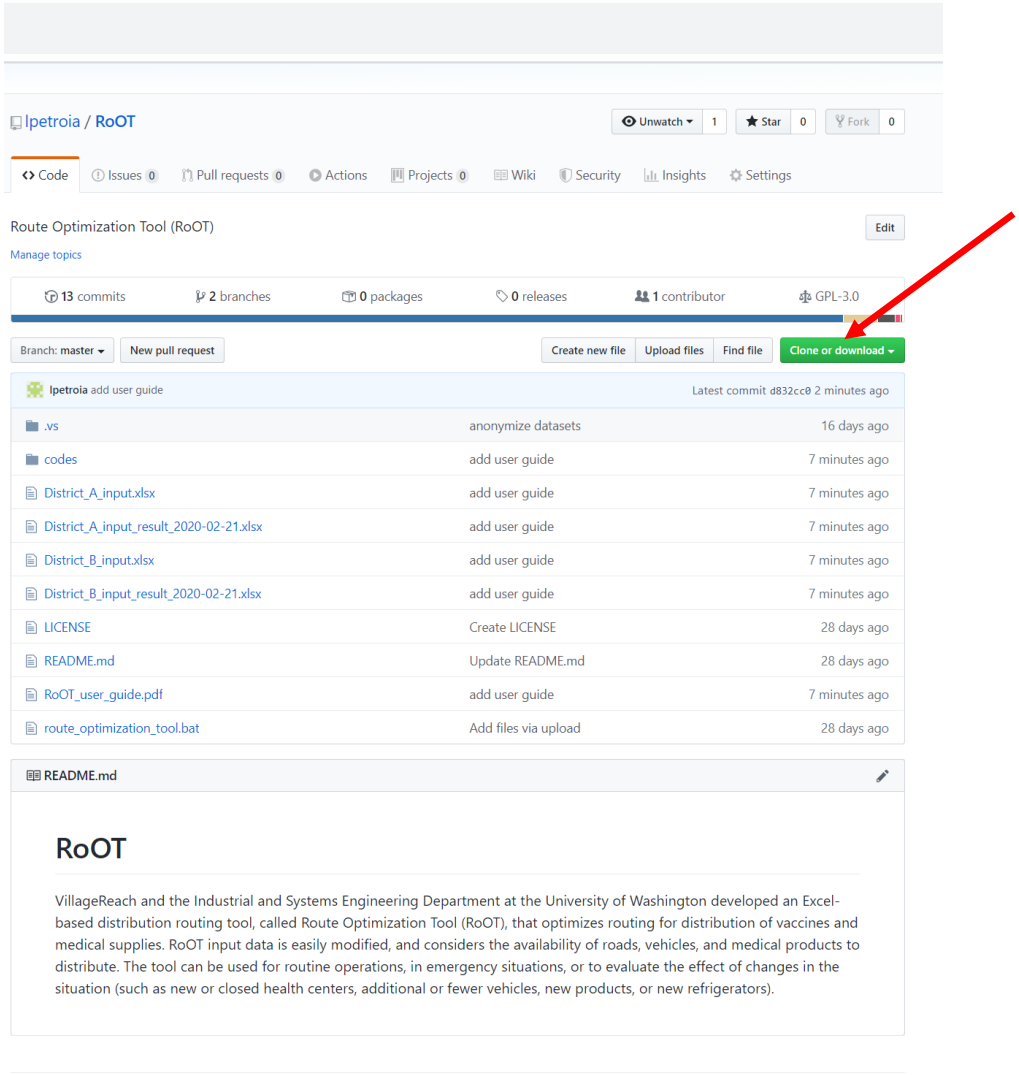


Figure 1. Screen shot of the github page, https://github.com/lpetroia/RoOT

b. Once the zip file is downloaded, left click and select “Extract All…” to unzip the file RoOT-master. The Extract feature allows the user to select the location of the unzipped folder. It may take five minutes to unzip the file, depending on the computer. A new folder will be created called “RoOT-master” that needs about 1.1 GB of memory. In the folder, there are several files as shown in Figure 2, including:
   - A “route_optimization_tool” batch file that executes the tool.
   - A pdf file for the user guide called “RoOT_user_guide.pdf.”
   - Two Excel input files (District_A_input and District_B_input).

- Two Excel output files (District_A_input_result_2020-02-21 and District_B_input_result_2020-02-21).
- A folder called codes. Do not edit this folder.
- The license file that includes the GNU General Public License (e.g., open-source).
- A readme file.

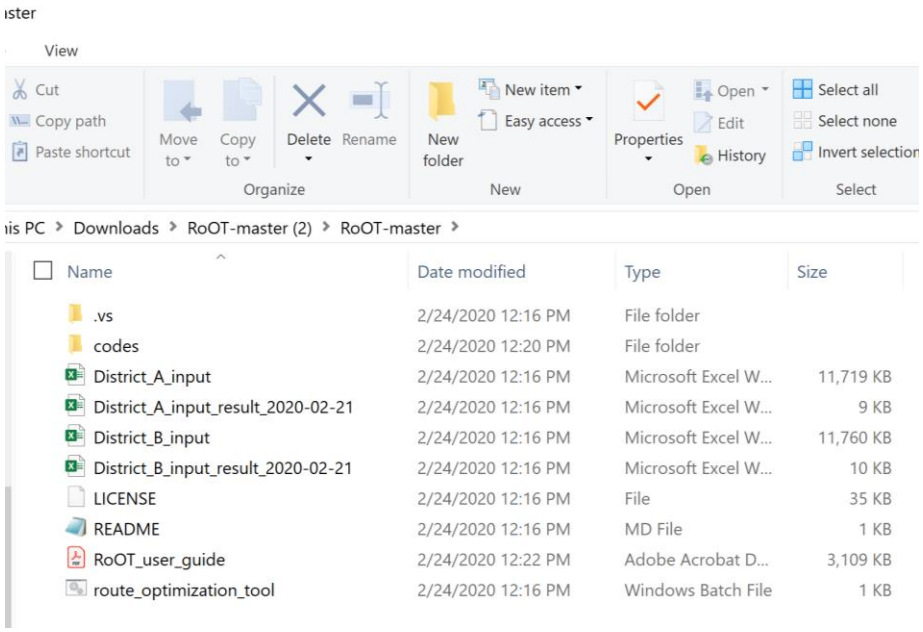


Figure 2. Content of RoOT-master folder

3. Testing RoOT

To run the Route Optimization Tool:

a. Double click on the batch file called **route_optimization_tool**. It is possible that your computer gives a warning, as shown in Figure 3. To ignore this, click on "More info" and select "Run anyway."
b. A black window will open up automatically, as shown in Figure 4. This may take several minutes if it is the first time you are running the tool. You do not need to do anything. Wait for the black terminal window (Figure 4). Do not close the black terminal window for the entire duration of running the tool.

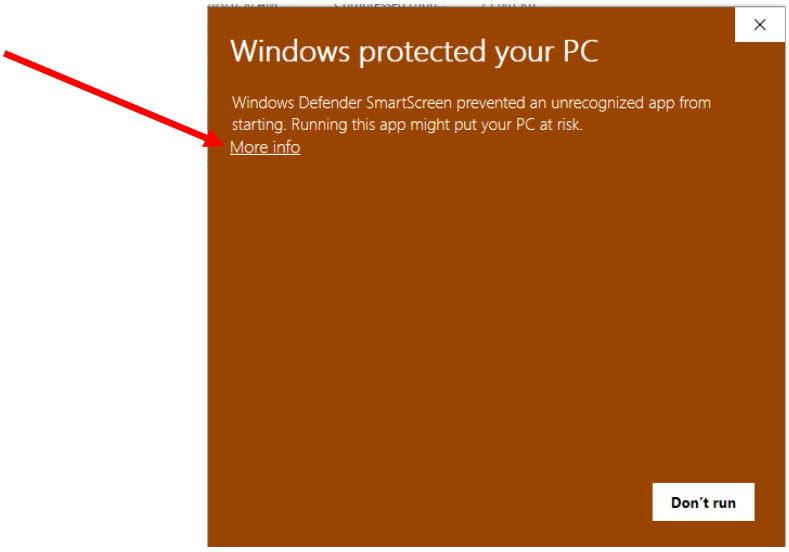


Figure 3. Warning that can be ignored

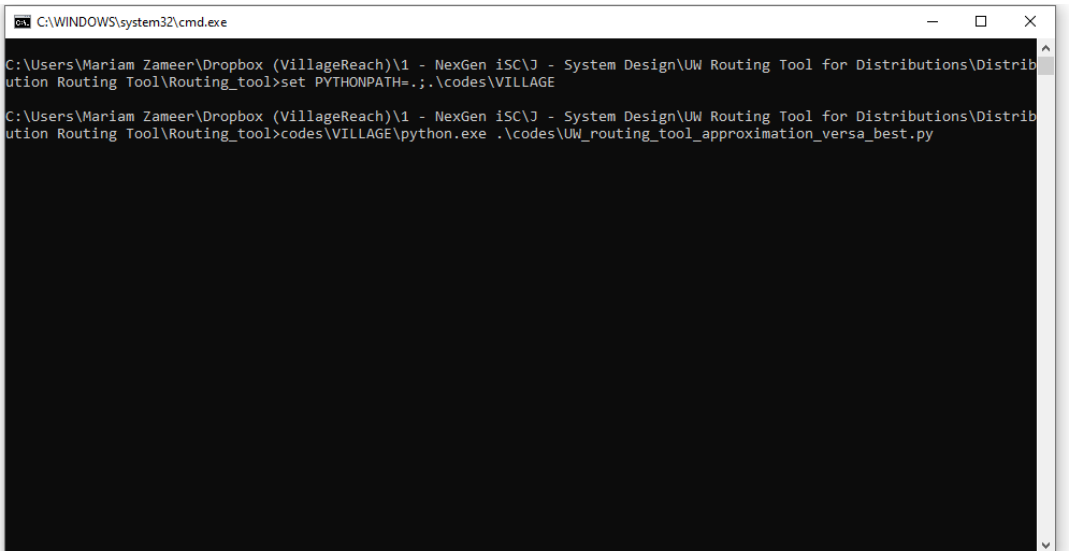


Figure 4. Black terminal window

c. After the black terminal window opens, another window, as shown in Figure 5, will open. Click on “Choose an input file for route optimization”.

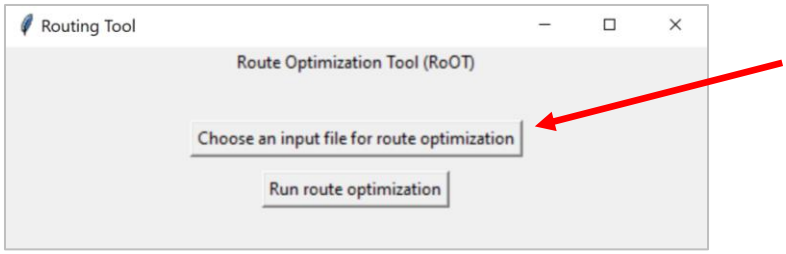


Figure 5. Window to select input file

d. A Windows explorer box will open allowing you to select the Excel input file that you want to run (Figure 6). Choose the file, and click "open". Note that the input file must be closed (not open in Microsoft Excel) for the tool to read it.

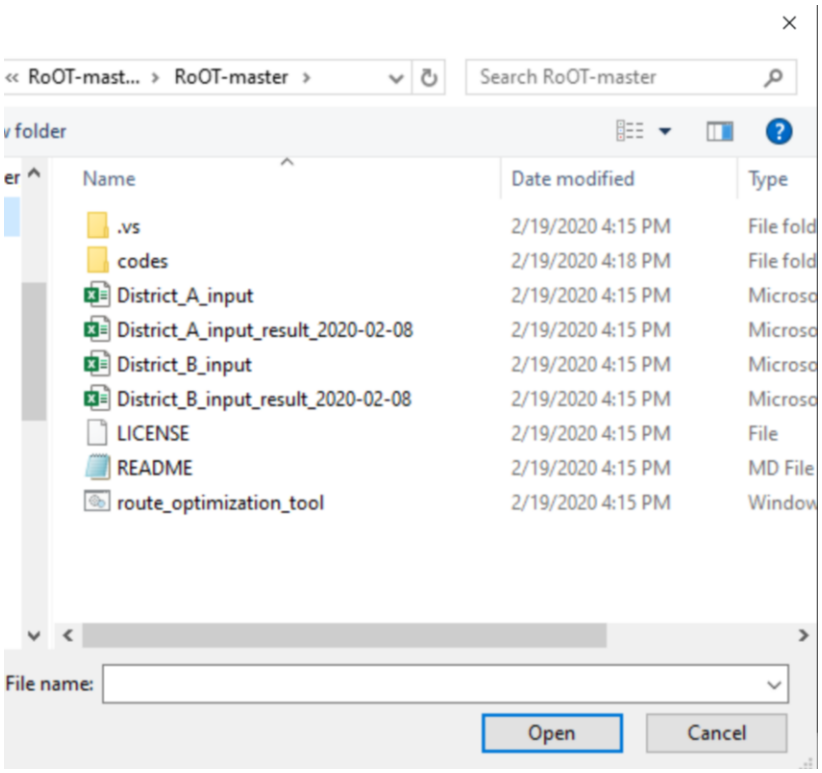


Figure 6. Window explorer box to select Excel input file, for example, District_A_input

e. Once you have selected an input file, click on "Run route optimization" to execute the tool (Figure 7).

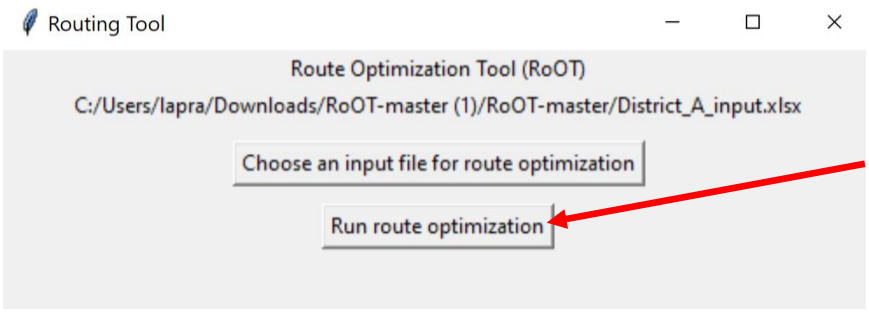


Figure 7. Window to run route optimization

f. **The tool can take a few minutes to run**, depending on the size (number of centers and available vehicles) of the input file. The black terminal window will show "Loading data, please wait, it will take a few seconds" while it reads the input file. Then the black terminal window will show "Processing" and keep displaying dots to indicate the tool is running (see Figure 8). Do not close the black terminal window. For the example files, the runtime should take less than five minutes.

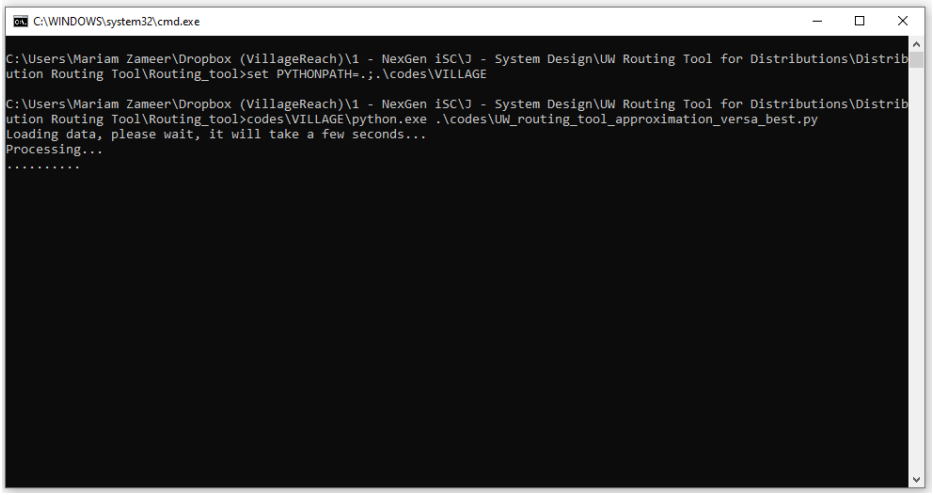


Figure 8. Black terminal window indicating that the program is running

g. After the tool has finished running, another window will open automatically indicating that the results are ready, and show the file path for the location of the output file (Figure 9). The output filename will have the name of the input file with "__result_YYYY-MM-DD.xlsx" appended. The output file will appear in the same folder as your input file, e.g., for input file "District_A_input" the output file will be named "District_A_input_result_2020-02-21.xlsx" indicating that it was run on February 21, 2020.

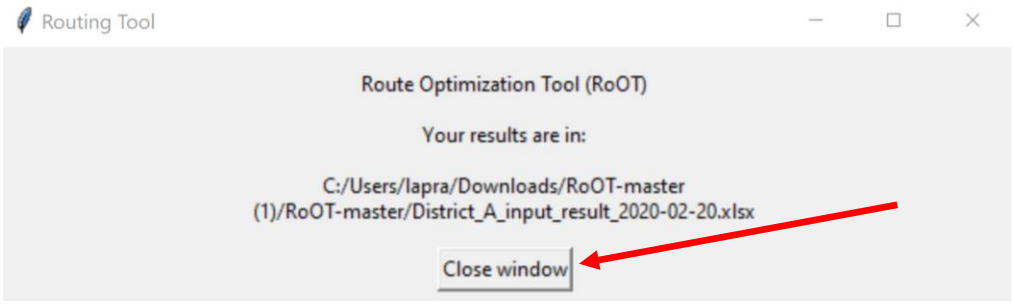


Figure 9. Window showing results are complete and file path for output file

h. When the window in Figure 9 appears, the tool has finished, and you can click on "close window," which also closes the black terminal window. Then open the result file in Excel to view the results. (If you want to run the same input file again for testing purposes, the input file and associated output file must be closed, in order for the tool to update it.)

4. Inputs for RoOT

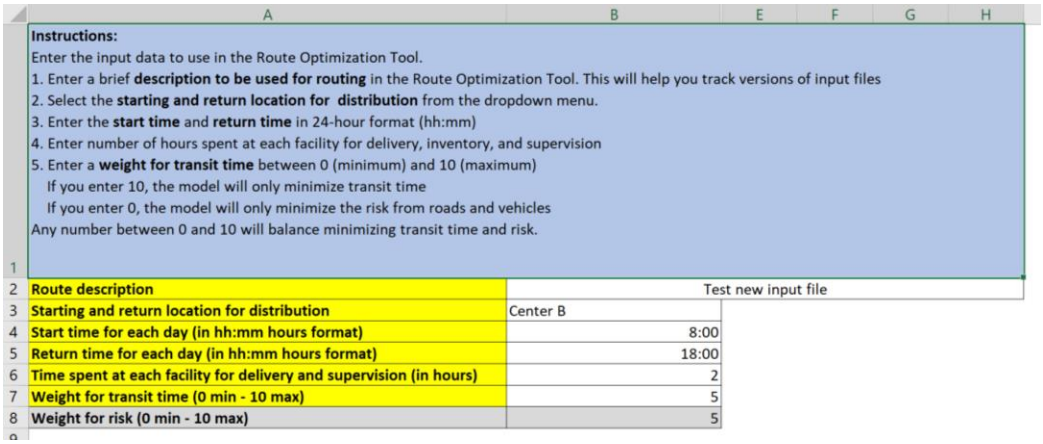
The input file is a Microsoft Excel file with seven worksheets. Each sheet has brief instructions in the first row highlighted in blue. The fields highlighted in yellow require input from the user. Gray cells contain equations and are locked.

The seven input sheets with the following names on the tabs are:

- *parameters*
- *products*
- *center_capacities*
- *demand*
- *vehicle*
- *distance_data*
- *road_condition*

The following sections discuss the fields on the input sheets.

A. PARAMETERS SHEET



	A	B	E	F	G	H
1	**Instructions:** Enter the input data to use in the Route Optimization Tool. 1. Enter a brief **description to be used for routing** in the Route Optimization Tool. This will help you track versions of input files 2. Select the **starting and return location for distribution** from the dropdown menu. 3. Enter the **start time** and **return time** in 24-hour format (hh:mm) 4. Enter number of hours spent at each facility for delivery, inventory, and supervision 5. Enter a **weight for transit time** between 0 (minimum) and 10 (maximum) If you enter 10, the model will only minimize transit time If you enter 0, the model will only minimize the risk from roads and vehicles Any number between 0 and 10 will balance minimizing transit time and risk.					
2	**Route description**	Test new input file				
3	**Starting and return location for distribution**	Center B				
4	**Start time for each day (in hh:mm hours format)**	8:00				
5	**Return time for each day (in hh:mm hours format)**	18:00				
6	**Time spent at each facility for delivery and supervision (in hours)**	2				
7	**Weight for transit time (0 min - 10 max)**	5				
8	**Weight for risk (0 min - 10 max)**	5				

Figure 10. Example of the parameters sheet input

The *parameters* sheet is responsible for defining the general parameters for the route plan, see Figure 10.

The user must input values for six parameters.

- *Route description* - Enter a brief description of the input data in this file to use in the Route Optimization Tool. This description will help the user keep track of different versions of input files.
- *Starting and return location for distribution* - Select the starting location for distribution from the dropdown menu. The vehicle will be scheduled to return to this location by the end of the route. The dropdown menu is constructed from the list of centers in the *center_capacities* sheet. If the center you want to select is not in the dropdown menu, go to the *center_capacities* sheet to add it.
- *Start time for each day* - Enter the start time for beginning a route in 24-hour format (hh:mm). This indicates the time that vehicles can leave the selected location.
- *Return time for each day* - Enter the time by which each vehicle must return to its starting location in 24-hour format (hh: mm). In this version of the tool, the return time must be the same day as the start time.
- *Time spent at each center for delivery and supervision:* Enter the total number of hours spent at each facility for delivery, inventory management, supervision, and other tasks.
- *Weight for transit time* - Enter a weight for transit time between 0 (minimum) and 10 (maximum). The weight is used to balance minimizing transit time with the minimizing risk calculated with penalties for using roads or vehicles that can be risky to the product due to their condition. If the user enters 10, the model will only

minimize transit time. If the user enters 0, the model will only minimize the risk from roads and vehicles.

- *Weight for risk* - This value is locked and calculated automatically by the sheet, so that the sum of the weight for transit time plus the weight for risk equals ten. For example, if the user inputs 6 for transit time, then the sheet automatically assigns a weight of 4 for risk.

B. PRODUCTS SHEET

The *products* sheet (Figure 11) lists the products to be distributed and their volume, such as doses per vial or number of syringes, and storage conditions, i.e., cold or ambient temperature storage.

	B	C	D	E	F
1	**Instructions:** Enter the products in the supply chain. 1. Enter the name of the product. You can enter up to 100 products. 2. Indicate if the product **requires cold storage**, by selecting "Yes" or "No" in the dropdown menu. 3. For *vaccines* enter the **doses per vial** and the **volume per dose** (in cm3). The volume for a vaccine dose should include the volume for diluent needed. If another refrigerated product requires cold storage, such as antibiotic liquids, enter 1 for doses per vial and its total volume (in cm3). 4. For *non-refrigerated* products, such as syringes or medicines, enter the **volume per unit** (cm3).				
2	**Products**	**Requires cold storage?**	**Quantity of doses per vial**	**Refrigerated product volume per dose (cm3)**	**Non-refrigerated product volume per unit (cm3)**
3	G.A Mensal (0-11 meses)	Yes	10	1.2	
4	BCG (old policy)	Yes	10	1.2	
5	VAP-10	Yes No	10	11.3	
6	VAP-20		10	11.3	
7	Penta-1	Yes	10	11.3	
8	Penta-10	Yes	10	11.3	
9	PCV10	Yes	10	13.8	
10	VAS	Yes	10	2.4	
11	G.A. Mensal VAT MIF's	Yes	10	3.11	
12	VAT Gravida Mensal	Yes	10	3.11	
13	Seringa 0.5 ml	No			56.7
14	Seringa 0.05 ml	No			37.5
15	Seringa 5 ml	No			66.3
16					

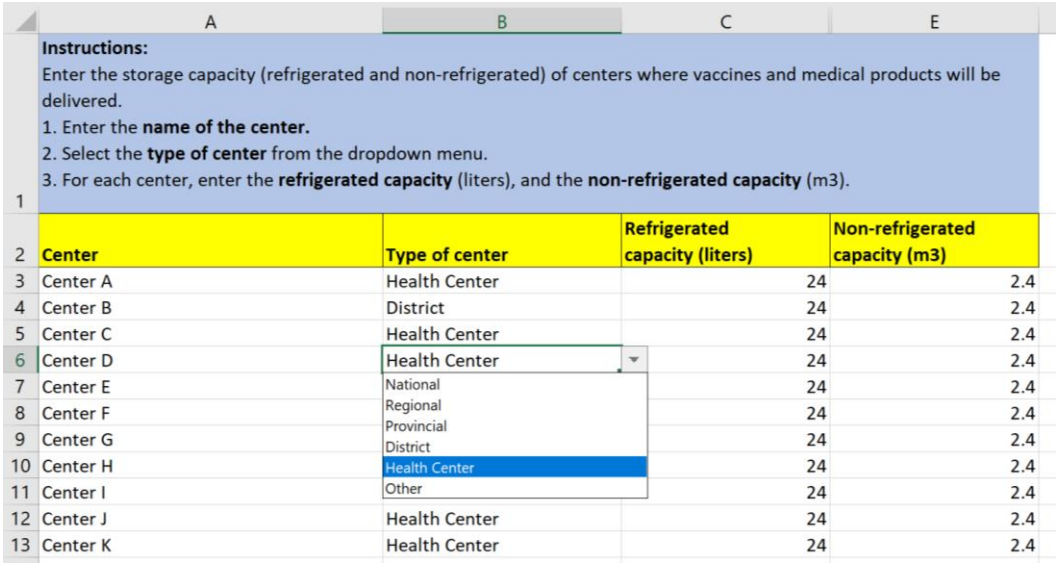
Figure 11. Example of the products sheet input

The user needs to input the following information:

- *Products* – Enter the name of the product (vaccines and medical supplies) to be distributed.
- *Requires cold storage?* - Indicate if the product requires cold storage (e.g., refrigeration or a cold box for transport) by selecting "Yes" or "No" in the dropdown menu.
- *Quantity of doses per vial* - For products requiring cold storage (e.g., vaccines), enter the doses per vial. It is possible to add products other than vaccines that require refrigeration. If a non-vaccine product requires cold storage, such as antibiotic liquids, enter 1 for doses per vial.

- *Refrigerated product volume per dose (cm3)* – This cell is used if the product requires cold storage. Enter the volume per dose in cm3. The volume for a vaccine dose should include the volume for diluent needed. For a non-vaccine product that requires cold storage, enter its volume per unit in cm3.
- *Non-refrigerated product volume per unit (cm3)* - For products that do not require refrigeration, such as syringes or essential medicines that can stay in the ambient temperature, enter the volume per unit in cm3.

C. CENTER_CAPACITIES SHEET



	A	B	C	E
1	**Instructions:** Enter the storage capacity (refrigerated and non-refrigerated) of centers where vaccines and medical products will be delivered. 1. Enter the **name of the center.** 2. Select the **type of center** from the dropdown menu. 3. For each center, enter the **refrigerated capacity** (liters), and the **non-refrigerated capacity** (m3).			
2	**Center**	**Type of center**	**Refrigerated capacity (liters)**	**Non-refrigerated capacity (m3)**
3	Center A	Health Center	24	2.4
4	Center B	District	24	2.4
5	Center C	Health Center	24	2.4
6	Center D	Health Center	24	2.4
7	Center E	National	24	2.4
8	Center F	Regional	24	2.4
9	Center G	Provincial	24	2.4
10	Center H	District	24	2.4
11	Center I	Health Center	24	2.4
12	Center J	Other	24	2.4
13	Center K	Health Center	24	2.4

Figure 12. Example of the center_capacities sheet input

The *center_capacities* sheet (Figure 12) has health center information (name and type), and storage capacities for refrigerated products and non-refrigerated products. When a user enters a new center name on this sheet, it is automatically added to the other sheets. The user needs to input four types of information:

- *Center* – Enter the name of the center.
- *Type of center* - Use the dropdown menu to classify the center. It can be national, regional, provincial, district, health center, or other.
- *Refrigerated capacity (liters)* – Enter the center's cold storage capacity (e.g., refrigerated capacity) in liters at each center.
- *Non-refrigerated capacity (m3)* – Enter the center's storage capacity at ambient temperature (e.g., non-refrigerated capacity) in m3 at each center.

D. DEMAND SHEET

Instructions:
Use this sheet to enter the demand for the vaccines and medical products.
1. For each center, enter the **demand** for vaccines and other refrigerated products (in doses), and for non-refrigerated goods and/or medical supplies (in units).

There are two **warning** columns that indicate if the requested demand for refrigerated and non-refrigerated products exceeds center capacity. The **utilization** of capacity (in percentage) is calculated.

If the demand **exceeds** the center capacity, the warning column will turn from green to **red.** If you see the warning, adjust the demand to make sure the center has capacity to store it. The Route Optimization Tool can still be run even with the warning.

	Warning for refrigerated capacity	Warning for non-refrigerated capacity	PR1	PR2	
Centers	Utilized refrigerated capacity	Utilized non-refrigerated capacity	G.A Mensal (0-11 meses)	BCG (old policy)	VAP-10
Center_A	17.6%	1.8%	49	10	
Center_B	42.8%	4.1%	100	20	
Center_C	1.2%	5.0%	0	0	
Center_D	13.0%	2.0%	67	13	
Center_E	30.0%	4.8%	185	37	
Center_F	22.0%	3.9%	159	32	
Center_G	47.2%	3.4%	34	7	
Center_H	36.1%	3.4%	74	15	
Center_I	23.2%	2.0%	41	8	
Center_J	63.6%	7.6%	237	47	
Center_K	21.5%	3.9%	160	32	
Center_L	16.8%	2.7%	97	19	
Center_M	28.2%	4.4%	235	47	
Center_N	5.3%	1.1%	41	8	
Center_O	135.4%	32.7%	1513	303	
Center_P	0.0%	0.0%	0	0	

Figure 13. Example of the demand sheet input

In the *demand* sheet (Figure 13), the user enters the demand for each product to be distributed. It is possible for a center to have zero demand. For example, the starting location may have zero demand. The demand for vaccines is in number of doses. If the demand exceeds the center capacity, the warning column B will turn from green to red. If there is a warning, the user should adjust the demand to make sure the center can store the delivered vaccines. Similarly, the demand for non-refrigerated products is entered, and a warning is calculated in column C. The Route Optimization Tool can still run even with the warning. This may be the case when centers have alternate means of storage.

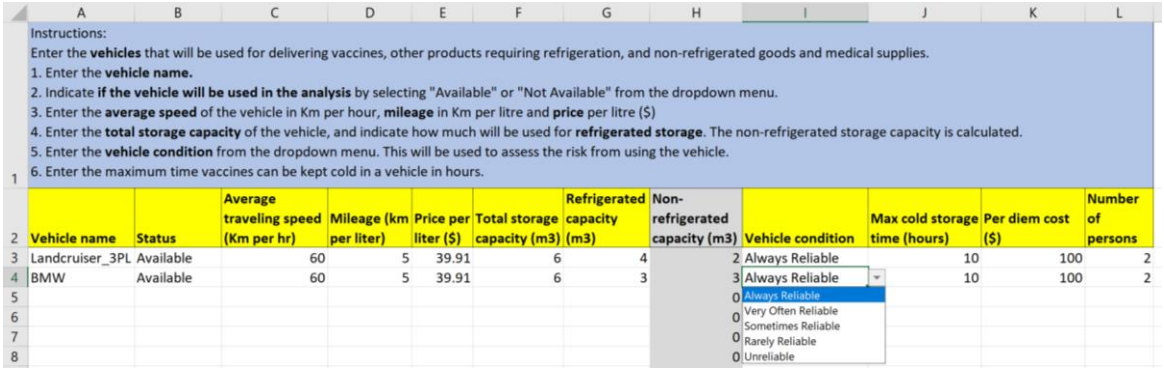
The user needs to input the demand for each product by center, using other demand planning tools. The center and product names are added automatically from the *center_capacities* and *products* sheets.

- *Centers* – This is locked, and the center name is added automatically after the user enters its name in the *center_capacites* sheet.
- *Warning for refrigerated capacity* and *Utilized refrigerated capacity* – This is locked, and the utilized cold capacity is automatically calculated using the capacity in the *center_capacities* sheet and the product demand after the user enters it. If the total demand volume for cold products is higher than the center's refrigeration capacity,

the utilization exceeds 100%, and the cell turns red. This warning considers the quantity of doses per vial.

- *Warning for non-refrigerated capacity* and *Utilized non-refrigerated capacity* – The utilized non-refrigerated capacity (i.e., at ambient temperature) is automatically calculated using the capacity in the *center_capacities* sheet and the product demand after the user enters it. If the total demand volume for non-refrigerated products is higher than the center's non-refrigerated capacity, the utilization exceeds 100%, and the cell turns red.
- For each center (row), enter the demand for vaccines in number of doses, and for non-refrigerated goods and/or medical supplies in units.

E. VEHICLE SHEET



Instructions:
Enter the **vehicles** that will be used for delivering vaccines, other products requiring refrigeration, and non-refrigerated goods and medical supplies.
1. Enter the **vehicle name.**
2. Indicate **if the vehicle will be used in the analysis** by selecting "Available" or "Not Available" from the dropdown menu.
3. Enter the **average speed** of the vehicle in Km per hour, **mileage** in Km per litre and **price** per litre ($)
4. Enter the **total storage capacity** of the vehicle, and indicate how much will be used for **refrigerated storage**. The non-refrigerated storage capacity is calculated.
5. Enter the **vehicle condition** from the dropdown menu. This will be used to assess the risk from using the vehicle.
6. Enter the maximum time vaccines can be kept cold in a vehicle in hours.

	Vehicle name	Status	Average traveling speed (Km per hr)	Mileage (km per liter)	Price per liter ($)	Total storage capacity (m3)	Refrigerated capacity (m3)	Non-refrigerated capacity (m3)	Vehicle condition	Max cold storage time (hours)	Per diem cost ($)	Number of persons
3	Landcruiser_3PL	Available	60	5	39.91	6	4	2	Always Reliable	10	100	2
4	BMW	Available	60	5	39.91	6	3	3	Always Reliable	10	100	2
5								0	Always Reliable			
6								0	Very Often Reliable			
7								0	Sometimes Reliable			
8								0	Rarely Reliable			
									Unreliable			

Figure 14. Example of the vehicle sheet input

In the *vehicle* sheet (Figure 14), the user enters the vehicle details that will be used for delivering vaccines and medical supplies. The user can input up to 50 vehicles, and will enter the following information:

- *Vehicle name* – Enter the vehicle name.
- *Status* – Indicate if the vehicle will be used for this distribution, and if it should be included in the route plan by selecting "Available" or "Not Available" from the dropdown menu. All available vehicles are used in the route optimization.
- *Average traveling speed (km per hr)* – Enter the average speed of the vehicle in km per hour.
- *Mileage (km per liter)* – Enter the average mileage in km per liter of the vehicle.
- *Price per liter ($)* – Enter the fuel price per liter (in any currency).
- *Total storage capacity (m3)* – Enter the total storage capacity of the vehicle in m3.
- *Refrigeration capacity (m3)* – Enter how much of the total storage capacity will be used for cold storage (refrigerated or cold box) in m3.

- *Non-refrigeration capacity (m3)* – The remaining storage capacity for medical products that do not require refrigeration is automatically calculated.
- *Vehicle condition* – Choose the vehicle condition from the dropdown menu. This condition will be used to assess the risk of using the vehicle. The options are: always reliable, very often reliable, sometimes reliable, rarely reliable, and unreliable. These options are converted into penalties in the tool.
- *Max cold storage time (hours)* – Enter the maximum time vaccines can be kept at ideal cold temperature in a vehicle in hours.
- *Per diem cost ($)* – Enter the cost (in any currency) per person that will do the distribution using this vehicle.
- *Number of persons* – Enter how many people will do the distribution using this vehicle.

F. DISTANCE_DATA SHEET

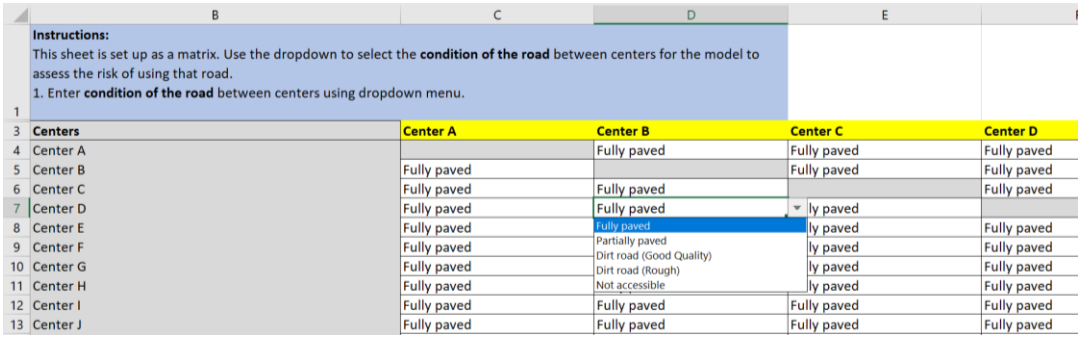
	B	C	D	E	F
1	**Instructions:** This sheet is set up as a matrix. Enter the distance between centers for the model to calculate the optimal route. 1. Enter the **distance** (km) between each center.	0	#		
3	**Centers**	**Center A**	**Center B**	**Center C**	**Center D**
4	**Center A**		30	36	
5	**Center B**	30		54	
6	**Center C**	36	54		
7	**Center D**	12	42	36	
8	**Center E**	48	33	81	
9	**Center F**	18	39	54	
10	**Center G**	39	18	69	
11	**Center H**	15	21	33	
12	**Center I**	15	24	51	
13	**Center J**	69	60	105	
14	**Center K**	27	54	24	

Figure 15. Example of the distance_data sheet input

The *distance_data* sheet (Figure 15) displays the distance between centers as a matrix. The center names are populated from the *center_capacities* sheet. The user needs to input the distance between all centers. To provide flexibility in representing one-way roads, the distance matrix does not need to be symmetric. The gray diagonal is empty because it represents the center distance to itself. It is a one-time set-up that should be updated if there is a change in the road, such as a new road with shorter distance.

- Enter the distance (km) between each center, considering the centers defined by the respective row and column. The user needs to complete the whole table. The center names appear after completing the *center_capacities* sheet.

G. ROAD_CONDITION SHEET



	B	C	D	E	
1	**Instructions:** This sheet is set up as a matrix. Use the dropdown to select the **condition of the road** between centers for the model to assess the risk of using that road. 1. Enter **condition of the road** between centers using dropdown menu.				
3	**Centers**	**Center A**	**Center B**	**Center C**	**Center D**
4	Center A		Fully paved	Fully paved	Fully paved
5	Center B	Fully paved		Fully paved	Fully paved
6	Center C	Fully paved	Fully paved		Fully paved
7	Center D	Fully paved	Fully paved	ly paved	
8	Center E	Fully paved	Fully paved	ly paved	Fully paved
9	Center F	Fully paved	Partially paved	ly paved	Fully paved
10	Center G	Fully paved	Dirt road (Good Quality)	ly paved	Fully paved
11	Center H	Fully paved	Dirt road (Rough)	ly paved	Fully paved
12	Center I	Fully paved	Not accessible	Fully paved	Fully paved
13	Center J	Fully paved	Fully paved	Fully paved	Fully paved

Figure 16. Example of the road_condition sheet input

The *road_condition* sheet (Figure 16) defines the condition of the road between centers for the model to assess the risk to products of using that road. The center names are populated from the *center_capacities* sheet. The gray diagonal is empty because it represents the center road to itself. It is a one-time set-up that should be updated if there is a change in the road condition, such as a flood.

- Enter the condition of the road between centers using the dropdown menu. The options are fully paved, partially paved, dirt road (good quality), dirt road (rough), not accessible.

5. Outputs

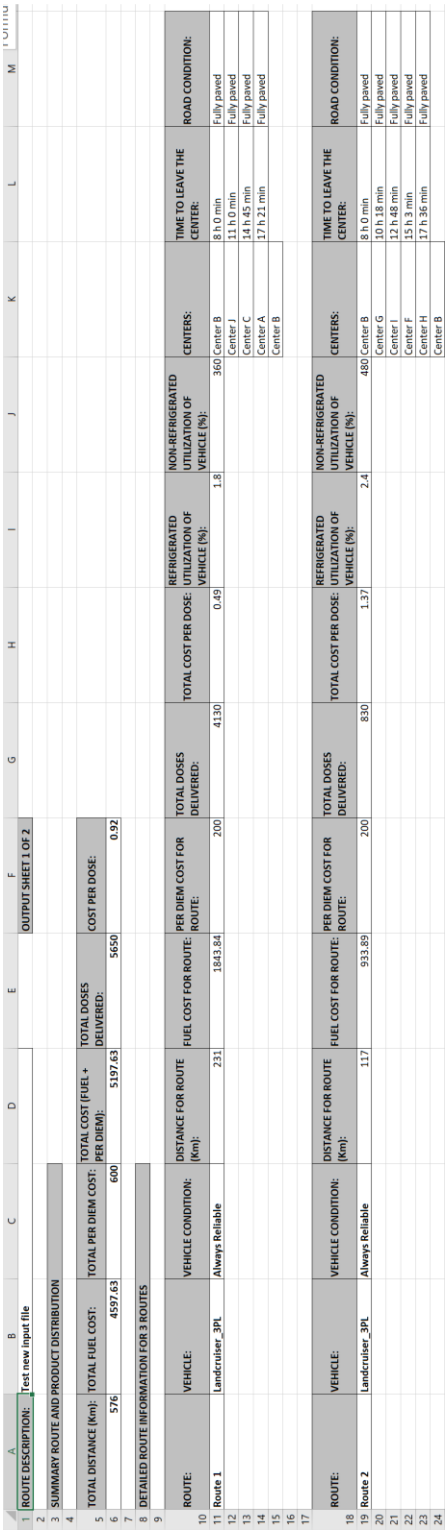
After the tool has finished running, a file with the name of the input file and "__result_YYYY-MM-DD.csv" appended (e.g., "District_A_input_result_2020-01-24.xlsx") will appear in the same folder as your input file.

The route plan uses all of the available vehicles to do the delivery. The optimization tool chooses routes to minimize transit time and/or minimize risk, depending on the weights chosen in the *parameters* sheet. Each vehicle may need to be used multiple times, so multiple routes for each available vehicle may be constructed by the tool. For example, a second route will not be assigned to any vehicle until all available vehicles have a least one route.

This tool does not include multi-day routing, so each route must start and end on the same day at the location specified in the *parameters* sheet.

The output file has two sheets: *Routes* and *Products*.

A. ROUTES SHEET



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ROUTE DESCRIPTION:	Test new input file				OUTPUT SHEET 1 OF 2							
2													
3	SUMMARY ROUTE AND PRODUCT DISTRIBUTION												
4													
5	TOTAL DISTANCE (Km):	TOTAL FUEL COST:	TOTAL PER DIEM COST:	TOTAL COST (FUEL + PER DIEM):	TOTAL DOSES DELIVERED:	COST PER DOSE:							
6	576	4597.63	600	5197.63	5650	0.92							
7													
8	DETAILED ROUTE INFORMATION FOR 3 ROUTES												
9													
10	ROUTE:	VEHICLE:	VEHICLE CONDITION:	DISTANCE FOR ROUTE (Km):	FUEL COST FOR ROUTE:	PER DIEM COST FOR ROUTE:	TOTAL DOSES DELIVERED:	TOTAL COST PER DOSE:	REFRIGERATED UTILIZATION OF VEHICLE (%):	NON-REFRIGERATED UTILIZATION OF VEHICLE (%):	CENTERS:	TIME TO LEAVE THE CENTER:	ROAD CONDITION:
11	Route 1	Landcruiser_3PL	Always Reliable	231	1843.84	200	4130	0.49	1.8	360	Center B	8 h 0 min	Fully paved
12											Center J	11 h 0 min	Fully paved
13											Center C	14 h 45 min	Fully paved
14											Center A	17 h 21 min	Fully paved
15											Center B		
16													
17													
18	ROUTE:	VEHICLE:	VEHICLE CONDITION:	DISTANCE FOR ROUTE (Km):	FUEL COST FOR ROUTE:	PER DIEM COST FOR ROUTE:	TOTAL DOSES DELIVERED:	TOTAL COST PER DOSE:	REFRIGERATED UTILIZATION OF VEHICLE (%):	NON-REFRIGERATED UTILIZATION OF VEHICLE (%):	CENTERS:	TIME TO LEAVE THE CENTER:	ROAD CONDITION:
19	Route 2	Landcruiser_3PL	Always Reliable	117	933.89	200	830	1.37	2.4	480	Center B	8 h 0 min	Fully paved
20											Center G	10 h 18 min	Fully paved
21											Center I	12 h 48 min	Fully paved
22											Center F	15 h 3 min	Fully paved
23											Center H	17 h 36 min	Fully paved
24											Center B		

Figure 17. Example of the routes sheet in the output file

The *routes* sheet (Figure 17) gives the suggested routes to deliver all products to centers. Below is the information given in the sheet.

Summary route and product distribution:

- *Route description* – Copies the route description entered in the input *parameters* sheet to help match the version of the input file with the output file.
- *Total distance (Km)* – Gives the total distance driven for all routes.
- *Total fuel cost* – Gives the total fuel cost for all routes
- *Total per diem cost* – Gives the total per diem cost for all personnel on all routes.
- *Total cost (fuel + per diem)* – Gives the total cost of the route, summing fuel and per diem costs.
- *Total doses delivered* – Gives the total number of vaccine doses that are distributed in all routes.
- *Cost per dose* – Gives the total cost (fuel + per diem) per dose of vaccine distributed.

Detailed route information for each route in the route plan:

- *Route* – Gives a route number to differentiate each route.
- *Vehicle* – Gives the vehicle that will be used for the respective route.
- *Vehicle condition* – Gives the vehicle condition, based on the condition defined in input *vehicle* sheet.
- *Distance for route (Km)* – Gives the total distance of the respective route.
- *Fuel cost for route* – Gives the total fuel cost for the route.
- *Per diem cost for route* – Gives the total personnel cost for the route.
- *Total doses delivered* – Gives the total quantity of vaccine doses distributed in the route.
- *Total cost per dose* – Gives the total cost (fuel + personnel) divided by the quantity of vaccine doses distributed for the route.
- *Refrigerated utilization of vehicle (%)* – Gives the percentage of the vehicle's refrigerated storage capacity utilized during the route.
- *Non-refrigerated utilization of vehicle (%)* - Gives the percentage of the vehicle's non-refrigerated storage capacity utilized during the route.
- *Centers* – Gives the order of each center visited in the route, starting and returning to the location specified in the input *parameters* sheet.
- *Time to leave the center* – Gives the time that the vehicle should leave each center. This takes into account the time spent at the center for delivery, inventory management, and supervision, as defined in the input *parameters* sheet.
- *Road condition* – Gives the road condition between the current center and the next one to be visited based on the information entered in the input *road_condition* sheet.

B. PRODUCTS SHEET

	A	B	C	D	E	F	G	H
1	ROUTE DESCRIPTION:	Test new input file				OUTPUT SHEET 2 OF 2		
2								
3	PRODUCTS DELIVERED							
4								
5	ROUTE:	Route 1		ROUTE:	Route 2		ROUTE:	Route 3
6	VEHICLE:	Landcruiser_3PL		VEHICLE:	Landcruiser_3PL		VEHICLE:	Landcruiser_3PL
7	STARTING LOCATION:	Center B		STARTING LOCATION:	Center B		STARTING LOCATION:	Center B
8								
9	CENTER:	Center J		CENTER:	Center G		CENTER:	Center D
10	REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	21.14		REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	4.38		REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	6.49
11	NON-REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	1.89		NON-REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	0.56		NON-REFRIGERATED UTILIZATION AT HEALTH CENTER (%):	0.61
12	PRODUCT:	QUANTITY (DOSE OR UNITS)		PRODUCT:	QUANTITY (DOSE OR UNITS)		PRODUCT:	QUANTITY (DOSE OR UNITS)
13	G.A Mensal (0-11 meses)	60		G.A Mensal (0-11 meses)	10		G.A Mensal (0-11 meses)	20
14	BCG (old policy)	20		BCG (old policy)	10		BCG (old policy)	10
15	VAP-10	30		VAP-10	10		VAP-10	10
16	VAP-20	20		VAP-20	10		VAP-20	10
17	Penta-1	220		Penta-1	30		Penta-1	60
18	Penta-10	30		Penta-10	10		Penta-10	10
19	PCV10	30		PCV10	10		PCV10	10
20	VAS	10		VAS	10		VAS	10
21	G.A. Mensal VAT MIF's	350		G.A. Mensal VAT MIF's	50		G.A. Mensal VAT MIF's	100
22	VAT Gravida Mensal	20		VAT Gravida Mensal	10		VAT Gravida Mensal	10
23	Seringa 0.5 ml	600		Seringa 0.5 ml	200		Seringa 0.5 ml	200
24	Seringa 0.05 ml	250		Seringa 0.05 ml	40		Seringa 0.05 ml	70
25	Seringa 5 ml	30		Seringa 5 ml	10		Seringa 5 ml	10

Figure 18. Example of the products sheet in the output file

The *products* sheet (Figure 18) gives the quantity of each product distributed to each center in each route. It can easily be printed for the distribution team to take for the route.

Consolidated Information:

- *Route description* – Copies the route description entered in the input *parameters* sheet to help match the version of the input file with the output file.

Information per route (a column for each route):

- *Route* – Gives a route number to differentiate each route.
- *Vehicle* – Gives the vehicle that will be used for the respective route.
- *Starting location* – Gives the name of the center that is the starting and final location for the route.

Information per center on a route:

- *Center – Gives the name of the center visited.*
- *Refrigerated utilization at health center (%)* – Gives the percentage of the center's refrigeration (cold) storage capacity utilized by the products delivered.
- *Non-refrigerated utilization at health center (%)* – Gives the percentage of the center's non-refrigerated (ambient temperature) storage capacity utilized by the products delivered.
- *Product* – Gives the name of the product delivered to the center.

- *Quantity (dose or units)* – Gives the quantity of doses or units per product distributed.

6. Use cases

Below are several use cases that arise from commonly asked questions that the tool can answer.

A. WHAT IF MY MAIN DISTRIBUTION CENTER CHANGES LOCATION?

To change the starting and return location for distribution, in the *parameters* sheet, select the desired center in the dropdown menu. Use the scroll bar in the menu to find the desired location. If the center is not in the list, it must be added in the *center_capacities* sheet (see Section 6.III).

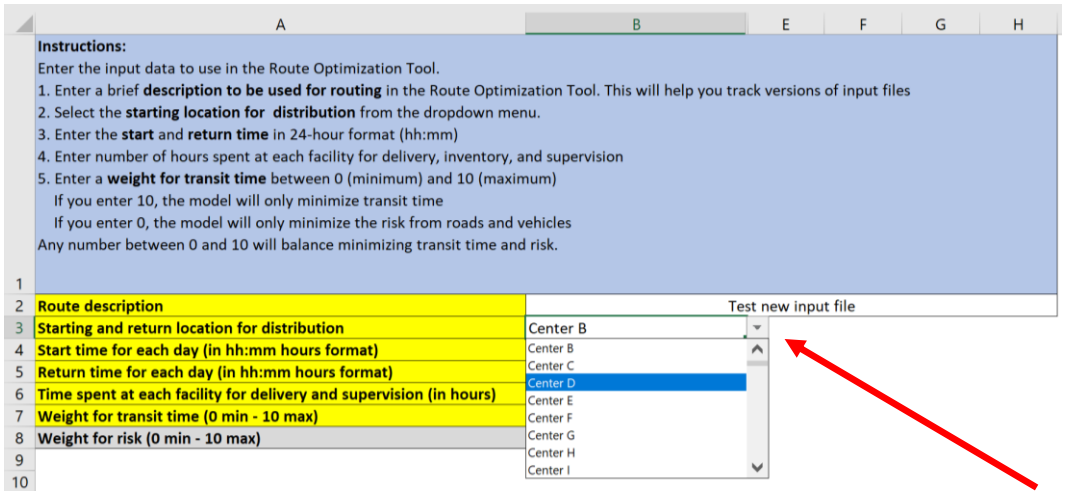


Figure 19. Change products origin

B. WHAT IF A NEW VACCINE OR PRODUCT IS ADDED FOR DISTRIBUTION?

To add a new product, to to the *products* sheet, and add the name of the product in the first empty row. Define whether it requires cold storage (with yes/no dropdown menu), the quantity of doses per vial (if applicable), and volume (Figure 20). Then go to the *demand* sheet and add the demand for that product (Figure 21).

Products	Requires cold storage?	Quantity of doses per vial	Refrigerated product volume per dose (cm3)	Non-refrigerated product volume per unit (cm3)
G.A Mensal (0-11 meses)	Yes	10	1.2	
BCG (old policy)	Yes	10	1.2	
VAP-10	Yes	10	11.3	
VAP-20	Yes	10	11.3	
Penta-1	Yes	10	11.3	
Penta-10	Yes	10	11.3	
PCV10	Yes	10	13.8	
VAS	Yes	10	2.4	
G.A. Mensal VAT MIF's	Yes	10	3.11	
VAT Gravida Mensal	Yes	10	3.11	
Seringa 0.5 ml	No			56.7
Seringa 0.05 ml	No			37.5
Seringa 5 ml	No			66.3
NEW PRODUCT 1	Yes	10	5	
NEW PRODUCT 2				
	Yes			
	No			

Figure 20. Add new products

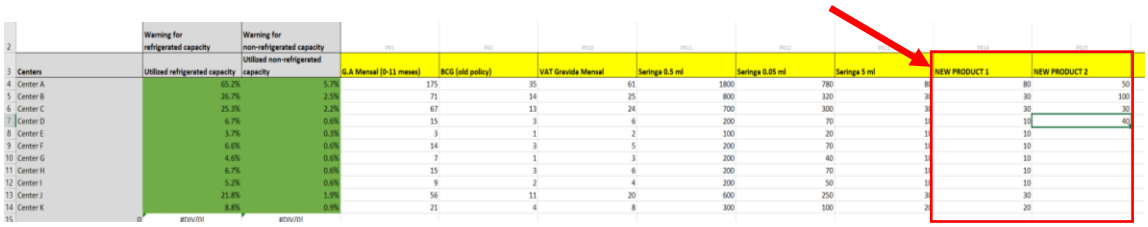


Figure 21. Add demand for a new product

The user should not delete previously entered products. If a product will not be distributed, then enter **zero** on the *demand* sheet for that product. In this case, the product demand should be equal to zero (Figure 22).

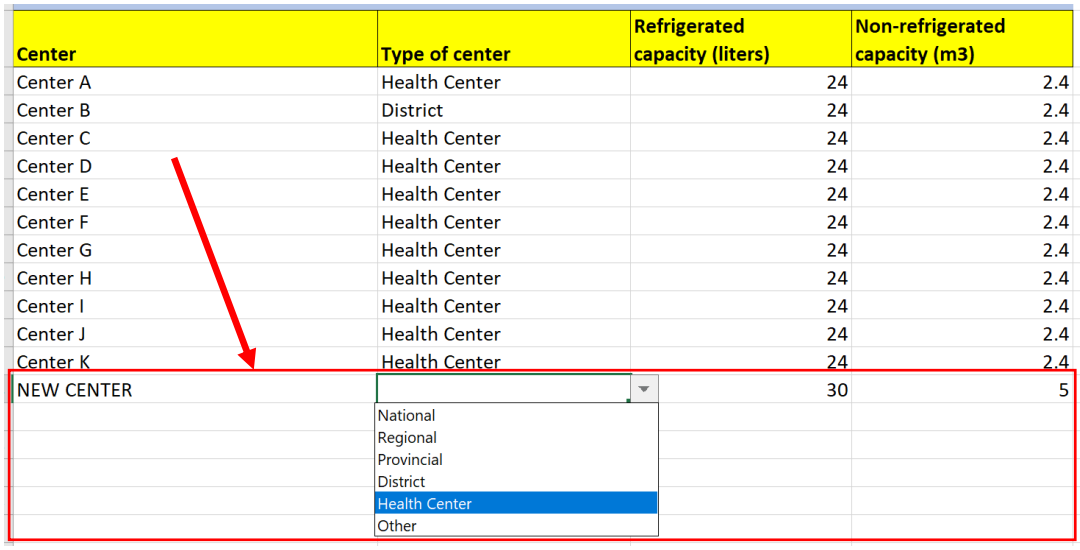
		Warning for refrigerated capacity	Warning for non-refrigerated capacity				
	Centers	Utilized refrigerated capacity	Utilized non-refrigerated capacity	G.A Mensal (0-11 meses)	BCG (old policy)	VAP-10	VAP-20
4	Center A	63.3%	5.7%	175	0	95	
5	Center B	26.0%	2.5%	71	0	38	
6	Center C	24.6%	2.2%	67	0	36	
7	Center D	6.4%	0.6%	15	0	9	
8	Center E	3.5%	0.3%	3	0	2	
9	Center F	6.3%	0.6%	14	0	8	
10	Center G	4.3%	0.6%	7	0	4	
11	Center H	6.4%	0.6%	15	0	9	
12	Center I	4.9%	0.6%	9	0	6	
13	Center J	21.0%	1.9%	56	0	30	
14	Center K	8.3%	0.9%	21	0	12	
15	0	#DIV/0!	#DIV/0!				

Figure 22. Do not deliver a product

C. WHAT IF A NEW CENTER IS ADDED TO MY ROUTE?

To add a new center, go to the *center_capacities* sheet, and add the center in the first empty row. Also, define its type, and storage capacities (Figure 23). When a new center is added to the *center_capacities* sheet, that center name is automatically added to three sheets, and the user must also update the data on these three sheets:

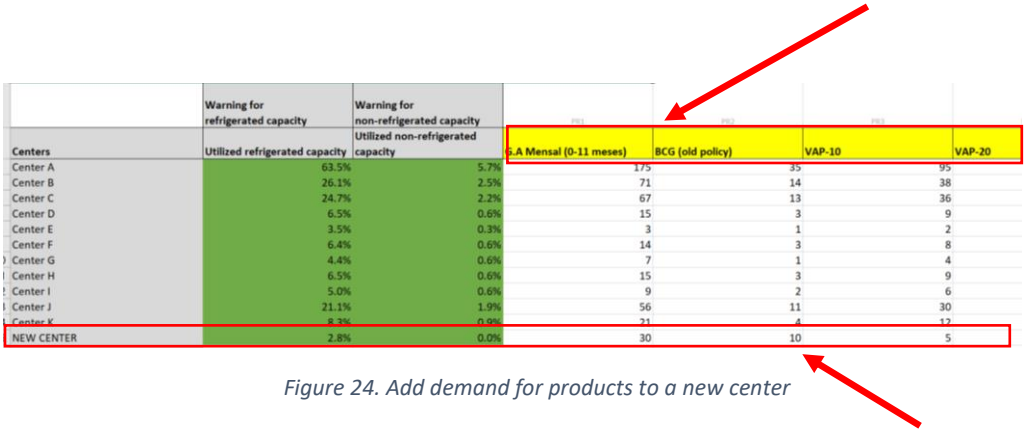
- *demand* sheet
- *distance_data* sheet
- *road_condition* sheet



Center	Type of center	Refrigerated capacity (liters)	Non-refrigerated capacity (m3)
Center A	Health Center	24	2.4
Center B	District	24	2.4
Center C	Health Center	24	2.4
Center D	Health Center	24	2.4
Center E	Health Center	24	2.4
Center F	Health Center	24	2.4
Center G	Health Center	24	2.4
Center H	Health Center	24	2.4
Center I	Health Center	24	2.4
Center J	Health Center	24	2.4
Center K	Health Center	24	2.4
NEW CENTER		30	5

Figure 23. Add a new center

The new center is also added to the dropdown menu on the *parameters* sheet, so it is eligible to be the *start and return location*. Figure 24 shows adding demand to a new center.

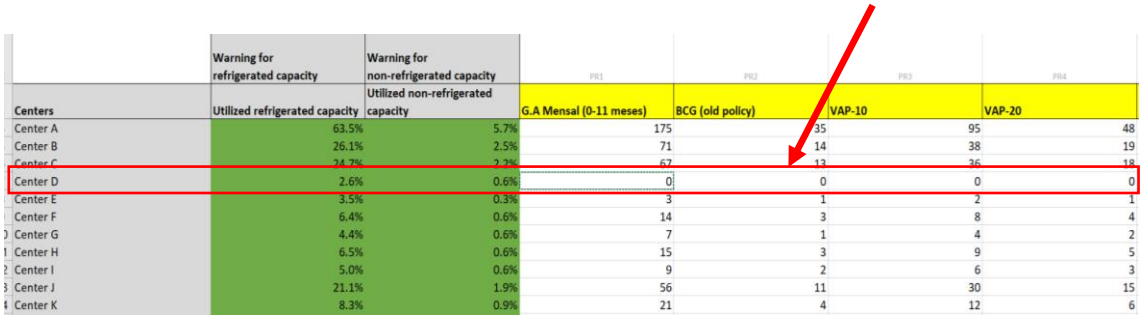


	Warning for refrigerated capacity	Warning for non-refrigerated capacity				
Centers	Utilized refrigerated capacity	Utilized non-refrigerated capacity	G.A Mensal (0-11 meses)	BCG (old policy)	VAP-10	VAP-20
Center A	63.5%	5.7%	175	35	95	
Center B	26.1%	2.5%	71	14	38	
Center C	24.7%	2.2%	67	13	36	
Center D	6.5%	0.6%	15	3	9	
Center E	3.5%	0.3%	3	1	2	
Center F	6.4%	0.6%	14	3	8	
Center G	4.4%	0.6%	7	1	4	
Center H	6.5%	0.6%	15	3	9	
Center I	5.0%	0.6%	9	2	6	
Center J	21.1%	1.9%	56	11	30	
Center K	8.2%	0.9%	21	4	12	
NEW CENTER	2.8%	0.0%	30	10	5	

Figure 24. Add demand for products to a new center

If an existing center will not be used, then its demand should be set to zero (Figure 25). The user should not delete a center.

When adding a new center, the user must also update the *distance_data* sheet and the *road_condition* sheet, which is discussed in the next section (6.D).



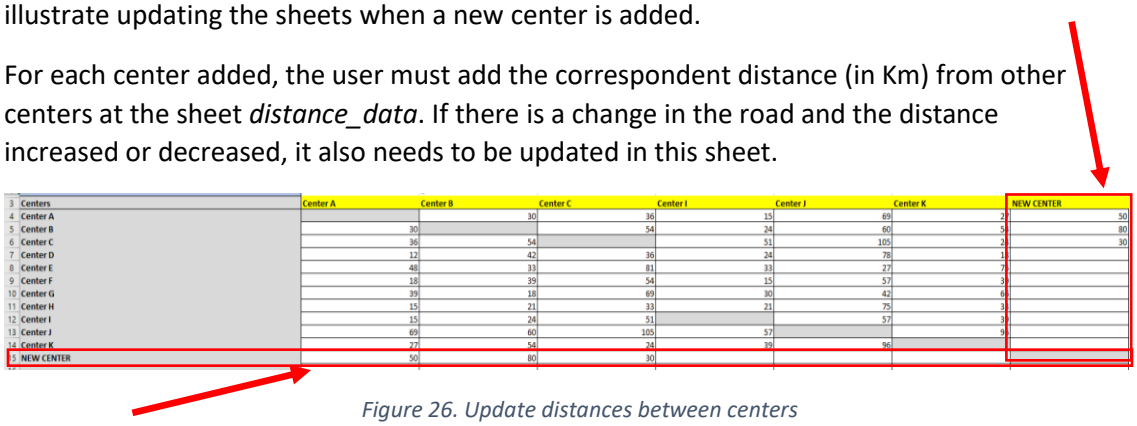
Centers	Warning for refrigerated capacity Utilized refrigerated capacity	Warning for non-refrigerated capacity Utilized non-refrigerated capacity	G.A Mensal (0-11 meses)	BCG (old policy)	VAP-10	VAP-20
Center A	63.5%	5.7%	175	35	95	48
Center B	26.1%	2.5%	71	14	38	19
Center C	24.7%	2.2%	67	13	36	18
Center D	2.6%	0.6%	0	0	0	0
Center E	3.5%	0.3%	3	1	2	1
Center F	6.4%	0.6%	14	3	8	4
Center G	4.4%	0.6%	7	1	4	2
Center H	6.5%	0.6%	15	3	9	5
Center I	5.0%	0.6%	9	2	6	3
Center J	21.1%	1.9%	56	11	30	15
Center K	8.3%	0.9%	21	4	12	6

Figure 25. Do not deliver to a center

D. WHAT IF I AM USING A NEW ROAD BETWEEN TWO CENTERS?

If there is a new road between two existing centers, or if a new center is added, the *distance_data* sheet and the *road_condition* sheet must be updated. Figures 26 and 27 illustrate updating the sheets when a new center is added.

For each center added, the user must add the correspondent distance (in Km) from other centers at the sheet *distance_data*. If there is a change in the road and the distance increased or decreased, it also needs to be updated in this sheet.



Centers	Center A	Center B	Center C	Center I	Center J	Center K	NEW CENTER
Center A		30	36	15	69	27	50
Center B	30		54	24	60	51	80
Center C	36	54		51	105	24	30
Center D	12	42	36	24	78	18	
Center E	48	33	81	33	27	72	
Center F	18	39	54	15	57	39	
Center G	39	18	69	30	42	66	
Center H	15	21	33	21	75	33	
Center I	15	24	51		57	24	
Center J	69	60	105	57		90	
Center K	27	54	24	39	96		
NEW CENTER	50	80	30				

Figure 26. Update distances between centers

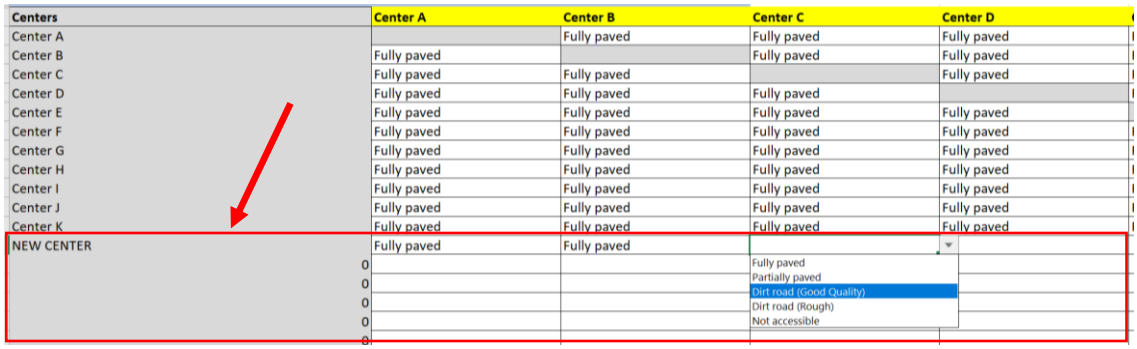


Figure 27. Update road conditions between centers

For each center added, the user must classify the road conditions from the dropdown menu in the sheet *road_condition*, see Figure 27.

E. WHAT IF A ROAD IS UNAVAILABLE OR IF THE ROAD CONDITION CHANGES (E.G. RAINS, FLOOD, CONFLICT OR NATURAL DISASTER)?

If the road condition changed due to a flood or a road improvement, it also needs to be updated in this sheet using the dropdown menu, see Figure 28.

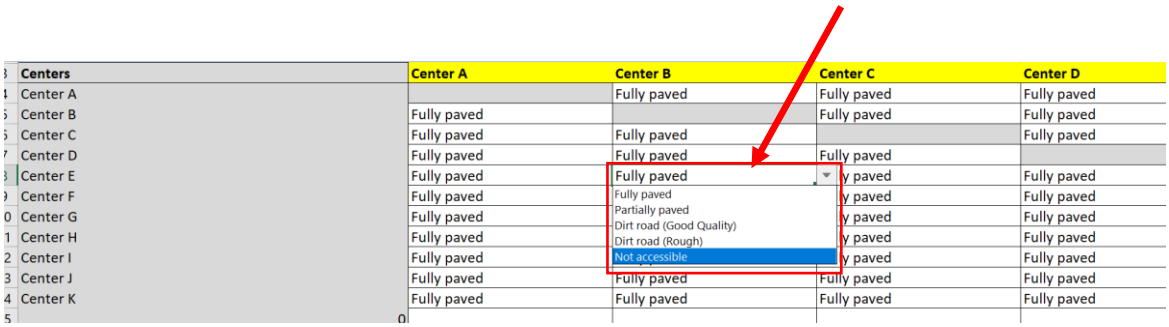


Figure 28. Change road condition

F. WHAT IF THE COLD STORAGE CAPACITY AT A HEALTH CENTER IS REDUCED OR IF NEW REFRIGERATORS ARRIVE?

To change the storage capacity of a health center, at the *center_capacities* sheet, change the value on the "*Refrigerated capacity (liters)*" column or the "*Non-refrigerated capacity (m3)*" column; use the units indicated in the heading.

	Center	Type of center	Refrigerated capacity (liters)	Non-refrigerated capacity (m3)
3	Center A	Health Center	24	2.4
4	Center B	District	24	2.4
5	Center C	Health Center	24	2.4
6	Center D	Health Center	50	2.4
7	Center E	Health Center	24	2.4
8	Center F	Health Center	24	2.4
9	Center G	Health Center	24	2.4

Figure 29. Change storage capacity at a center

G. WHAT IF I ADD A NEW VEHICLE TO MY FLEET OR IF ONE OF MY VEHICLES BREAKS DOWN?

To add a vehicle, enter its name and characteristics in the first empty row in the *vehicle sheet* (Figure 30).

The user should not delete a vehicle. If a vehicle is not available, the user should change its status to “not available” in the dropdown menu, instead of deleting it.

	Vehicle name	Status	Average traveling speed (Km per hr)	Mileage (km per liter)	Price per liter ($)	Total storage capacity (m3)	Refrigerated capacity (m3)	Non-refrigerated capacity (m3)	Vehicle condition	Max cold storage time (hours)	Per diem cost ($)	Number of persons
3	Landcruiser_3PL	Available	60	5	39.91	6	4	2	Always Reliable	10	100	2
4	NEW VEHICLE	Available	60	5	39.91	6	4	2	Always Reliable	10	100	2
5								0				
6								0				
7								0				
8								0				

Always Reliable
Very Often Reliable
Sometimes Reliable
Rarely Reliable
Unreliable

Figure 30. Add a new vehicle

H. WHAT IF THERE IS AN OUTBREAK AND NEED FOR IMMEDIATE DISTRIBUTION?

In the event of an emergency, many types of data may need to be modified. It may be necessary to change the start and return location to a new center, add new centers, omit distribution to some centers, add products, omit products by entering zero demand, modify demand, update the distances, and update road conditions between all centers. All these changes are possible in the Route Optimization Tool.