Introduction to Vaccine Supply Chains:

Using a Systems Approach & Systems Modeling

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Introduction to Vaccine Supply Chains: Using a Systems Approach & Systems Modeling

A course on vaccine supply chains, supply chain modeling and how to use HERMES *(A Highly Extensible Resource for Modeling Supply Chains)*

What is a supply chain?

A supply chain is the complex system of equipment, vehicles, personnel, policies and processes needed to deliver a product from its point of origin to the consumer or population.

Why are vaccine supply chains important?

As described in **"The importance of vaccine supply chains to everyone in the vaccine world",** [1,2] even the most effective vaccine cannot have any impact on human health without a properly functioning supply chain. Understanding and addressing this system is critical to ensuring the full impact of vaccines. Everyone involved in vaccine decision-making plays a role in this system, from manufacturers who develop and package the vaccine to funders who finance the vaccines to policymakers and public health officials who help ensure a healthy population. For each of these groups, taking the supply chain into account can guide informed decisions about the design of vaccines and vaccine programs to better match the system.

Focusing extra attention on supply chains has led to advancements in other industries. Many companies in the food and retail industries employ or consult supply chain experts regularly to ensure that their supply chains run effectively and efficiently. Additionally, product design often occurs with supply chains in mind. The packaging, size, shape and composition of the product facilitates its storage and delivery. Examples include furniture stores developing pieces that can be shipped in component parts more readily and food manufacturers adding preservatives and developing dried and compact versions of food.

By contrast, evidence suggests that vaccine supply chains have not received the same degree of extra attention. Studies have shown that many vaccine supply chains around the world have substantial constraints and bottlenecks and are not delivering vaccines to many of the people who need them.[3] Supply chain issues have hindered efforts to control, eliminate or eradicate diseases such as polio and measles.[4] While supply chains in many low and middle income countries may have the most substantial problems, many vaccine supply chains in high income countries face challenges as well.

Why is computation simulation modeling needed to better understand vaccine supply chains?

Unaided by technology, humans can struggle to appreciate and understand complex systems.[5] Modeling is essentially using mathematical equations or computational programs to represent the components, relationships and processes in a system. A computational model can then serve as a "virtual laboratory" to help better understand how a system operates and test the effects of different changes within the system. Using data and information on storage, transport, vaccines and personnel along with data on how these factors work together, a user can use our HERMES software to create a computational simulation model that represents all of the components and processes of the vaccine supply chain to help users view the system as a whole. Without this computational system, it is far more difficult to diagnose system vulnerabilities, coordinate operations, develop solutions and anticipate the impact of changes in the system or new technology. HERMES can project what may happen if things stay the same or circumstances change so that appropriate modifications can be made.

What is HERMES?

HERMES is a software program that allows users to generate a detailed computer simulation model of a supply chain. The model can serve as a "virtual laboratory" for users to evaluate a supply chain and test the effects of implementing different potential policies, interventions, practices and technology changes. The vaccine supply chain is one example of the various supply chains HERMES can be used for. HERMES for vaccine supply chains can help decision makers (e.g., policymakers, decision-makers and planners within health ministries, vaccine supply chain logisticians, vaccine manufacturers, and funders that deal with vaccine supply chains) answer a variety of questions such as:

- What will be the impact of introducing new technologies?
- What are the effects of altering the characteristics of health products?
- How does the configuration and the operations of the supply chain (e.g., storage devices, shipping frequency, personnel or ordering policy) affect performance and cost?
- What may be the effects of differing conditions and circumstances (e.g., power outages, delays, inclement weather, etc.)?
- How should one invest or allocate resources most effectively resources (e.g., adding refrigerators vs. increasing transport frequency)?
- How can product delivery be optimized?

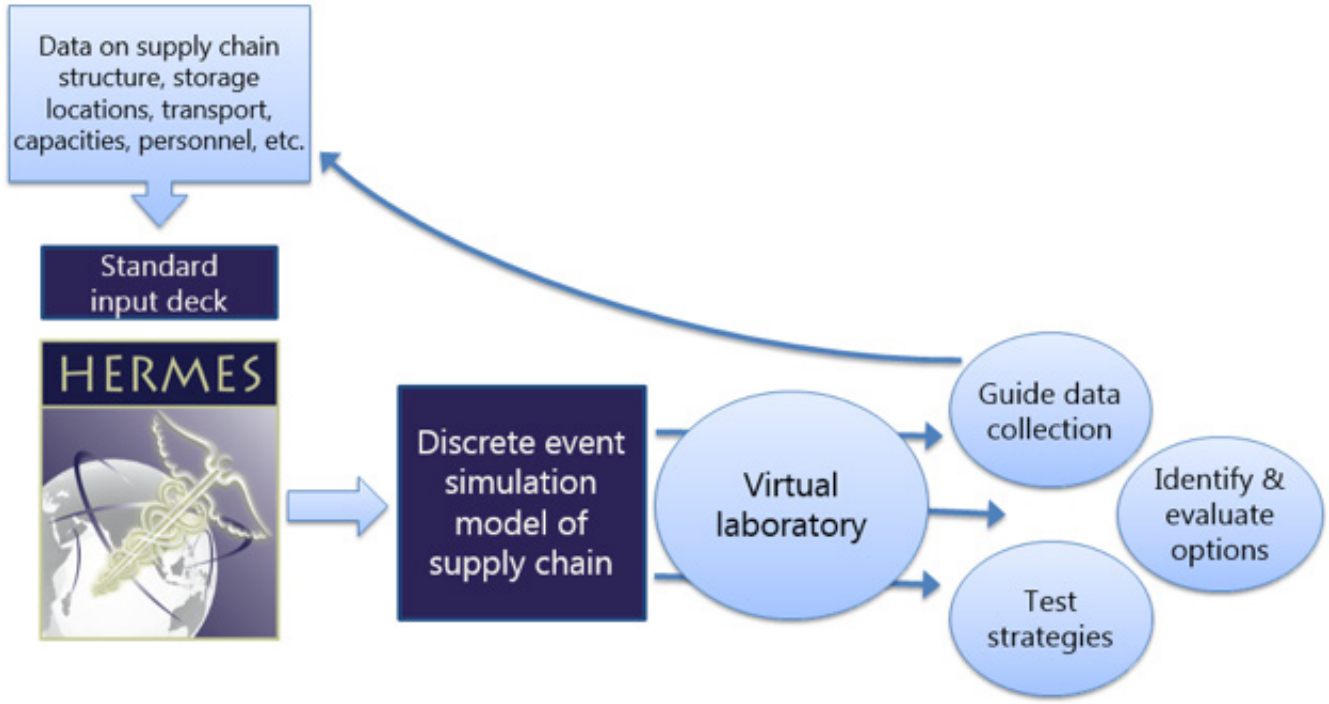


Figure 1 - HERMES Modeling Process & Outputs

What are the learning objectives of the tutorials?

1. Identify each of the components of the vaccine supply chain system

2. Understand the complexities of the supply chain and how each component interacts with each other

3. Describe common vaccine supply chain system issues

4. Identify and assess the critical measures of a vaccine supply chain's "health"

5. Understand the benefit of modeling in assessing the vaccine supply chain system, and testing changes to the system

How are the series of tutorials organized?

The 7 tutorials will walk you through the steps involved in building and using a HERMES model of a vaccine supply chain. This will help you understand the structure and operations of a vaccine supply chain and some key vaccine supply chain principles.

Tutorial 1: Creating a New Vaccine Supply Chain Model

This tutorial will take you through building a vaccine model in HERMES. Through this tutorial you will learn the different components of the vaccine supply chain and how they fit together.

Tutorial 2: Running Your New Model & Viewing Results

This tutorial will teach you how to run your vaccine supply chain model. Through this, you will learn different measures of supply chain performance and operations and how seemingly small changes in the system can lead to significant effects.

Tutorial 3: Introducing or Changing Vaccines

A common question is whether a supply chain can handle the introduction of a new vaccine and what the effects may be. For example, previous studies have shown the challenges countries may face if a new vaccine such as Rotavirus (RV) is introduced.[6] In this tutorial, you will learn how to customize a new vaccine or change the characteristics of a current vaccine in the supply chain model and determine the potential obstacles and effects.

Tutorial 4: Adding, Removing, and Changing Storage Devices

Increasing storage capacity is a useful method for reducing bottlenecks in a supply chain, but achieving the desired outcome means knowing at which level to introduce these devices. In this tutorial, you will learn how to make changes to the available storage devices across a given supply chain level and determine the potential effects.

Tutorial 5: Removing A Level From The Supply Chain

Supply chain redesign, which includes restructuring the number of levels in a supply chain, may help improve efficiencies in vaccine delivery. In this tutorial, you will learn how to make changes to your model by removing a supply chain level and adjusting the policies that determine how vaccines are shipped.

Tutorial 6: Modifying Transport Characteristics by Level

The type of vehicle or mode of transport one uses, the policy that dictates ordering and moving a product and geographic characteristics can all have a significant impact on the performance and efficiency of a supply chain. This tutorial will walk you through making changes to transport routes in your model. The experiment will allow you to choose a collection of routes based on what supply chain level the routes originate at and which supply chain levels the routes run between. You can then specify operations to perform on the routes, such as increasing frequency of trips or changing the vehicle type.

Tutorial 7: Introduce Transport Loops

Transport loops can be more efficient and provide more reliable shipping of products than routes that only make one delivery at a time because they require maintaining a smaller fleet of vehicles that can potentially travel shorter distances and provide a more regular shipping pattern. However, transport loops may also require larger vehicles with additional storage volume which may be more costly to operate and maintain. This experiment will take you through a series of screens that will ask you between which supply chain levels you would like to create transport loops, the number of locations per transport loop and the vehicle that you would like to use for each loop.

INSTALLING HERMES SOFTWARE:

Step 1: If you haven't installed HERMES on your computer yet, please go to the HERMES Installation Instructions to find out how to do so. One you have installed HERMES on to your computer you can proceed to step 2.

Step 2: Find the HERMES application icon on either the desktop or the START menu.

Step 3: Double click the HERMES application icon to launch HERMES.

Step4: If a Registration Screen appears, please complete the information requested.

Step 5: You should then be taken to the Welcome Screen for HERMES.

[1] Lee BY, and Haidari LA. “The importance of vaccine supply chains to everyone in the vaccine world.” Vaccine (2017).

[2] Lee BY. “A New Hope: Vaccine Supply Chains Get More Attention.” Forbes (2017). https://www.forbes.com/sites/brucelee/2017/05/01/a-new-hope-vaccine-supply-chains-get-more-attention

[3] Lee BY, Connor DL, Wateska AR, Norman BA, Rajgopal J, Cakouros BE, Chen S-I, Claypool EG, Haidari LA, Karir V, Leonard J, Mueller LE, Paul P, Schmitz MM, Welling JS, Weng YT, Brown ST.

[4] Landscaping the structures of GAVI country vaccine supply chains and testing the effects of radical redesign

[5] World Health Organization. Immunization supply chain and logistics: a neglected but essential system for national immunization programmes; 2014. Available at: http://www.who.int/immunization/call-to-action_ipac-iscl.pdf.

[6] Lee BY, Bartsch SM, Mui Y, Haidari LA, Spiker ML, Gittelsohn J. A systems approach to obesity. Nutrition Reviews, Volume 75, Issue suppl_1, 1 January 2017, Pages 94–106

[7] Lee BY, Assi TM, Rajgopal J, Norman BA, Chen S-I, Brown ST, Slayton RB, Kone S, Kenea H, Welling JS. “Impact of introducing the pneumococcal and rotavirus vaccines into the routine immunization program in Niger.” American journal of public health 102.2 (2012): 269-276.

Tutorial 1 | Creating a New Vaccine Supply Chain Model

This is the first tutorial for the **"Introduction to Vaccine Supply Chains: Using a Systems Approach & Systems Modeling"** tutorial series. This tutorial will provide an overview of the vaccine supply chain system and introduce you to simulation modeling as a tool to visualize, evaluate and experiment with vaccine supply chains.

Through our HERMES model, this module will walk you through the construction of a virtual supply chain. HERMES is based on real-world data from the expanded program on immunization (EPI) vaccine supply chain in Gaza Province, Mozambique. This tutorial explores each of the components of a vaccine supply chain through a hands-on approach. You will build a model of your own in order to conduct baseline and experimental simulation runs.

This example model will include the Gaza provincial vaccine store, two district stores in Cidade de Xai-Xai and Massinger, and 11 health centers in these districts. You will be able to build a model with detailed representations of the storage devices, personnel, vehicles and associated operating costs at each location, as well as the transport routes and shipping policies between locations, and the vaccine vials flowing through the supply chain. Additional tutorials alter this wexample model to produce and run experimental scenarios to assess the impact of changes such as introducing new vaccines, removing a supply chain level, adding storage capacity, modifying shipping policies and introducing shipping loops.

HERMES MODEL CREATION GUIDED WORKFLOW

Part 1: Getting Started

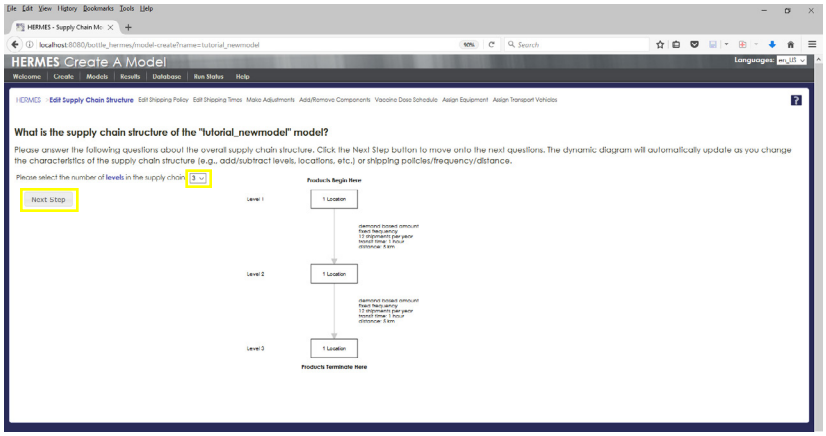
Note: You should already have HERMES downloaded and opened. Please see here if you still need to download and open prior to starting step #1.

1. On the Welcome Page, click **"Create or Upload a New Model"**
2. Click on **"Create a New Model"** in the dialogue box
3. Enter **"tutorial_newmodel"** when prompted for model name then click the **"Create"** button.

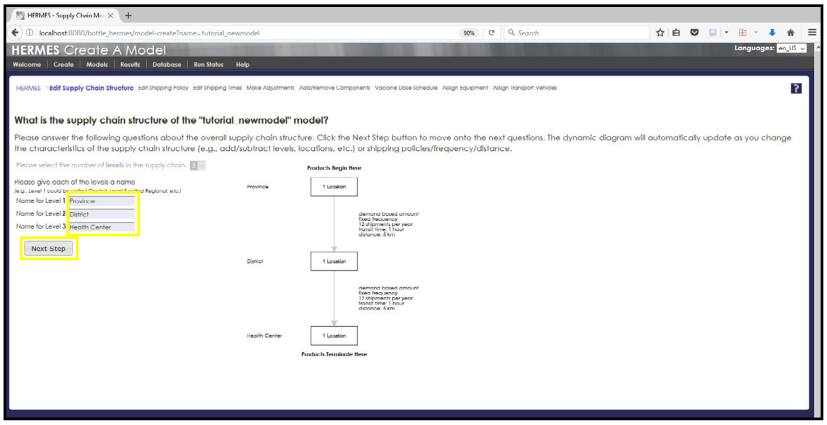
Part 2: Supply Chain Structure

The structure of a supply chain is the hierarchy of locations between which products travel to reach the population. The structure of a national vaccine supply chain often starts with a central store that receives vaccines from the manufacturer. Beyond the central store, a supply chain may contain regional or provincial hubs, state stores, district stores and local stores such as health posts to optimize outreach. The structure of a supply chain can have various effects on the function of the supply chain.

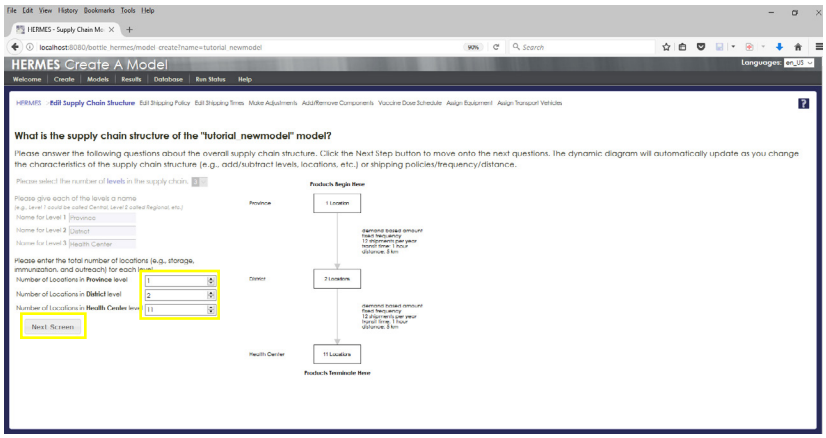
To begin:



1. Select **3** from the "Please select the number of **levels** in the supply chain" dropdown
2. Click the "**Next Step**" button



3. Rename:
   Level 1 to "Province" – this is where vaccines will enter the model
   Level 2 to "District" – this level both receives and distributes vaccines
   Level 3 to "Health Center" – this is where vaccines will be administered
4. Click the "**Next Step**" button

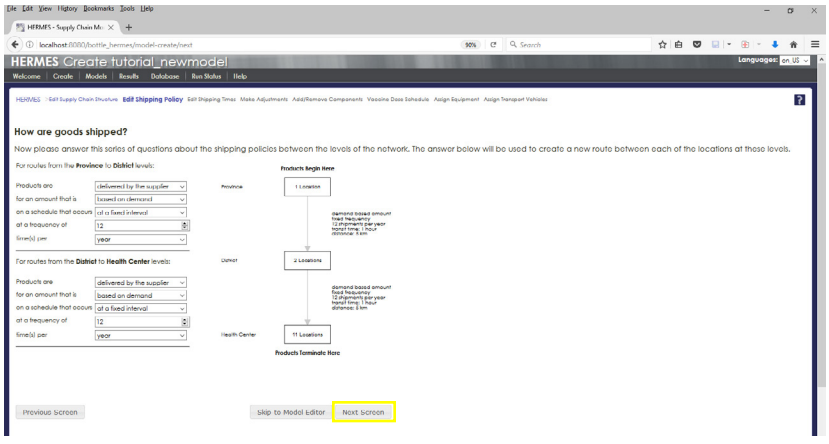


5. For the number of locations:
   Set Province Level to **1**
   Set District Level to **2**
   Set Health Center Level to **11**
6. Click the "**Next Step**" button

Part 3: Shipping Details

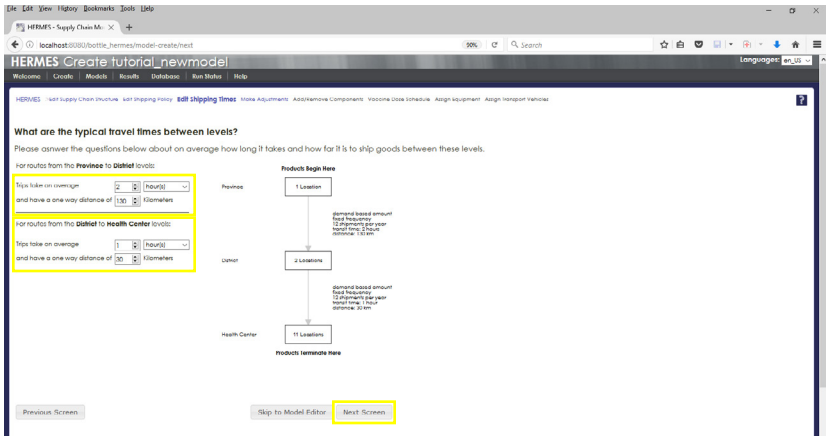
The shipment policies between each level can differ based on transport availability and other factors. In our example, most or all locations at each level (Provincial, District and Health Center) receive the vaccines via delivery instead of traveling to a higher level to manually pick up the vaccines. The shipment sizes for each delivery is based on demand rather than a fixed quantity. These shipments are delivered at a fixed monthly interval, rather than allowing extra shipments as needed.

Each of these shipping details can be changed in the model with direct and indirect effects. The HERMES model allows the user to set the policy not just between each level, but between each store, based on available data or interest.



7. The policies described above are preset for this example model.
   Please select **"Next Screen"**

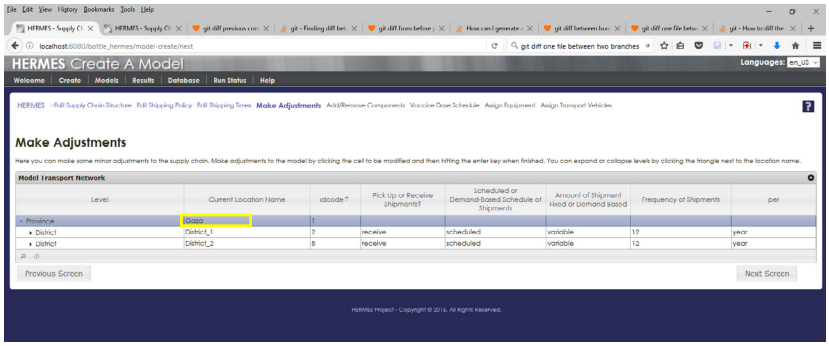
NOTE: In addition to shipping policies (direction, quantity, frequency), shipping time is an important consideration when considering the effectiveness of a supply chain. The time to ship between places can be effected by geographical distance as well as road and weather conditions. Simulation modeling via HERMES allows the user to set the time between each level and store based on available data or assumptions.



8. What is entered in the **"Edit Shipping Times"** page will be modified later because shipping times and distances vary for individual routes, but for now input the following approximate averages for this model then click the **"Next Screen"** button.

Parameters	Province to District	District to Health Center
Average Time	2 hours	1 hour
Average Distance	130 km	30 km

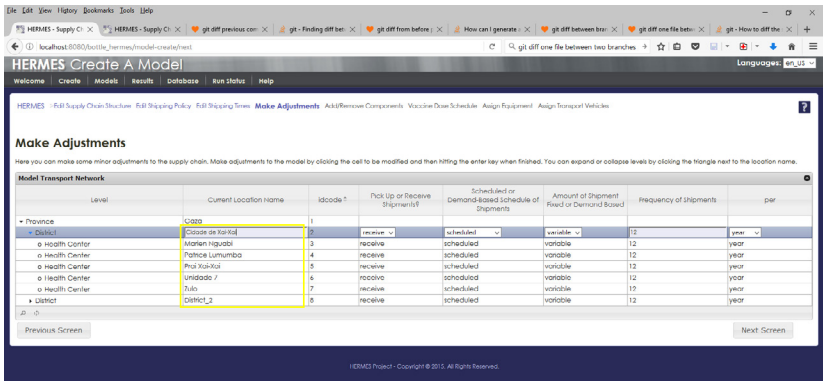
Part 4: Location Names



9. The **"Make Adjustments"** page allows details to be entered for individual locations, including location names. Location names can also be entered and edited at any time using the Advanced Model Editor. Entering the names now will facilitate further location-specific data entry in future steps.

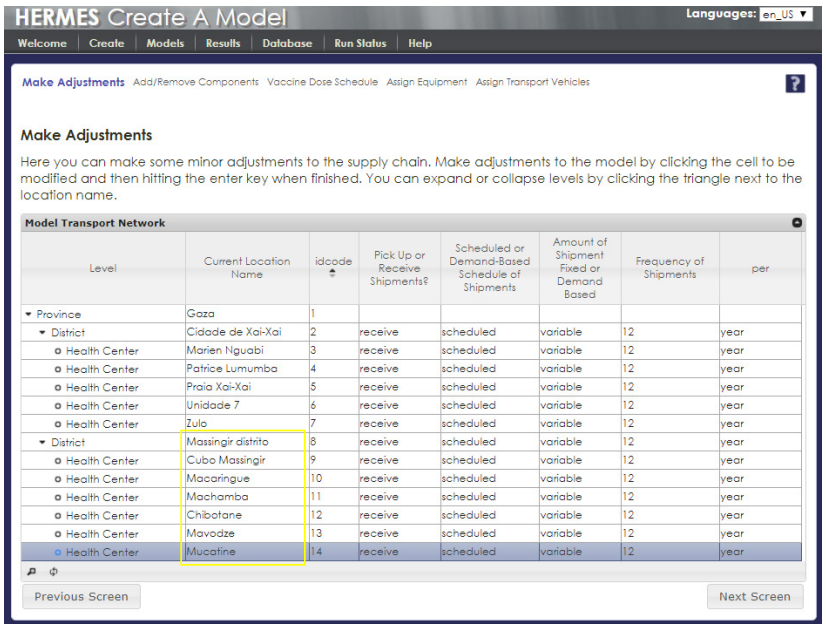
   Change the Current Location Name for the Province Level to **"Gaza."**

10. In the first column, titled **"Level"**, click the triangle next to Province (if you haven't already) and then click the triangle next to District in the row with Current Location Name **"District_1"** to open all levels served by that district.



11. Change **"Current Location Names":**
District_1 to "Cidade de Xai-Xai"
Health Center_1 to "Marien Nguabi"
Health Center_2 to "Patrice Lumumba"
Health Center_3 to "Praia Xai-Xai"
Health Center_4 to "Unidade 7"
Health Center_5 to "Zulo"

NOTE: (Zulo actually belongs to the second district, but we will move it later using the Advanced Model Editor).



12. Now click the triangle next to District in the row with Current Location Name "District_2" to open all levels served by that district.

13. Change **"Current Location Names"** then click the **"Next Screen"** button:
District_2 to "Massingir distrito"
Health Center_6 to "Cubo Massingir"
Health Center_7 to "Macaringue"
Health Center_8 to "Machamba"
Health Center_9 to "Chibotane"
Health Center_10 to "Mavodze"
Health Center_11 to "Mucatine"

NOTE: It is recommended that you continue to build your model without exiting the workflow. If you do exit the Model Creation workflow at this point (by exiting the program or clicking on a link to a different page), you will be able to access the new model from your available models table (which can be accessed by clicking "Models" in the main menu, located at the top left of every page).

Part 5: Adding Supply Chain Components

In this section, we will begin adding in each of the components that make up the system of a vaccine supply chain (e.g. vaccines, storage devices, vehicles, personnel and the population served). Each component is defined by a set of characteristics that effect the overall function of the supply chain. We will describe each of these characteristics as we incorporate each component into the model.

The “Edit Components” page allows you to add or create all components needed in your model, including: vaccines, storage devices, transport vehicles, target populations, supply chain personnel and per diem policies. These components will be assigned to locations and routes later in the Model Creation workflow. Clicking the “Info” button next to any component will display detailed information about its characteristics. Components can be copied from your other available models as well as the HERMES database, which includes examples from World Health Organization (WHO) prequalified catalogs.

Vaccines

Vaccines are the basic element of the vaccine supply chain. Vaccines manufactured at one location need to be procured and delivered to a population at another location. When determining which vaccines to procure, decision-makers will consider the demand for the vaccine, the physical characteristics of a vaccine and the storage needs of a vaccine.

Vaccine demand:

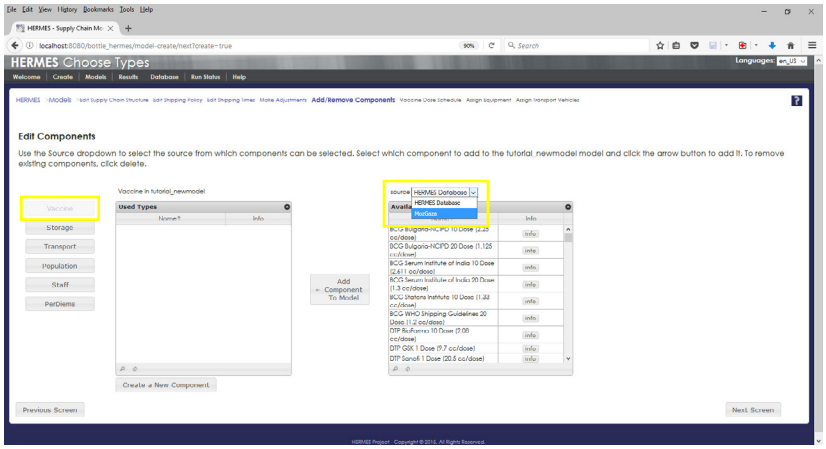
The demand for vaccines can be influenced by which diseases pose the highest risk to a country, which diseases are common for routine vaccination and which diseases are prioritized by international and national organizations through vertical programs.

Physical characteristics of a vaccine and vaccine components:

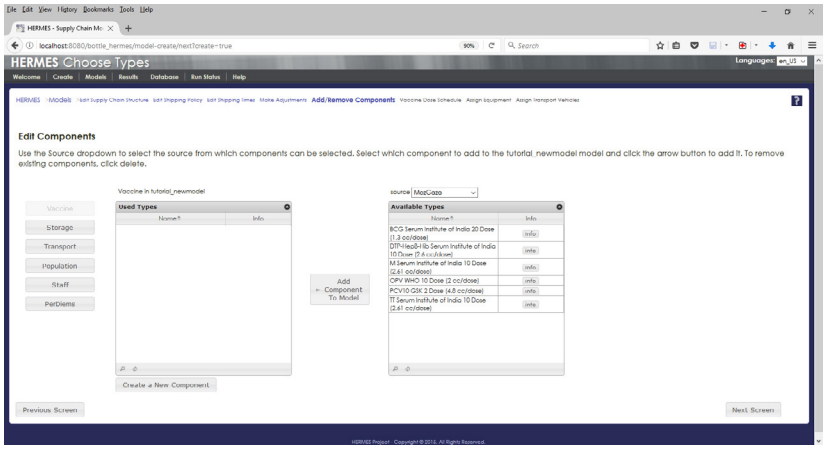
The size, shape and packaging of a vaccine and its components can have unexpected effects on the supply chain function. Previous findings from simulation modeling of the Benin vaccine supply chain show that reducing the number of doses per vial (and subsequently increasing the number of vials flowing through the system) can lead to a decrease in overall vaccine availability and an increase in logistical costs per dose administered.1 Another study looking at the vaccine vial presentation size (10-dose, 5-dose, 1-dose) found that decreasing the doses per container led to a decrease in overall vaccine availability, an increase in transport utilization and an increase in costs per immunized patient.[2]

Storage needs of a vaccine and vaccine components:

Whether or not a vaccine needs to be kept in thermostable conditions can affect the function of the supply chain and the final costs of immunization. In many parts of the world, scarce cool and cold storage availability and frequent power outages can lead to bottlenecks, vaccine wastage and reduced vaccine availability. Modeling studies have shown that removing one or more vaccines from cold storage, even at increased price points, can save operational costs by reducing bottlenecks, as well as clinical costs by increasing vaccine availability.[3,4]



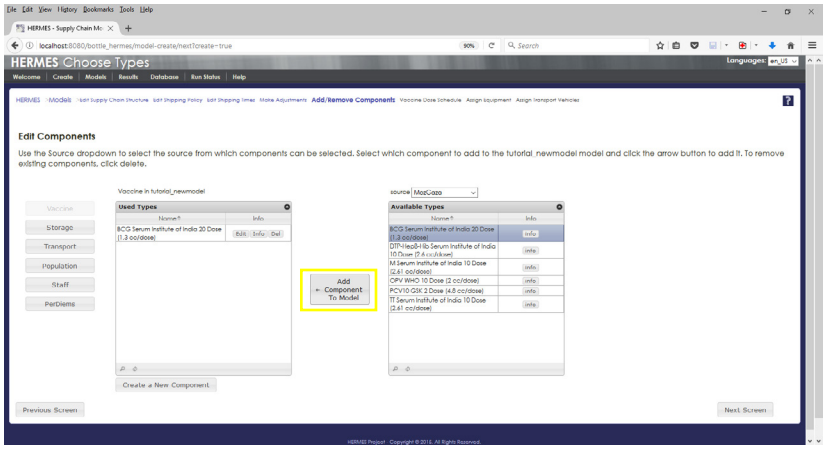
14. The Vaccine category is initially selected (shown by the grayed-out Vaccine box). Choose **"MozGaza"** from the source dropdown menu to get the list of vaccines associated with the MozGaza model.



This is how your screen should look after selecting MozGaza from the dropdown menu.

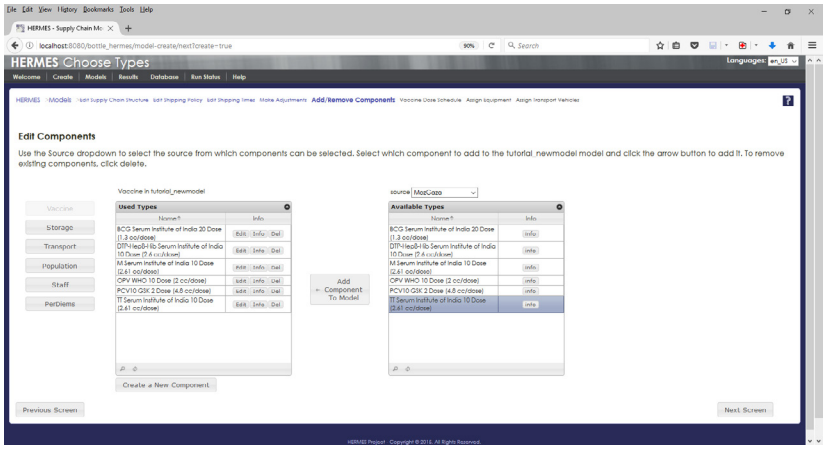
15. All of the vaccines shown in the MozGaza model will be used in the new model you are creating.

These represent the 2014 EPI vaccines in Mozambique, which include Bacille Calmette-Guérin (BCG), diphtheria-tetanus-pertussis-haemophilus influenza type B-hepatitis B (DTP-HepB-Hib), measles (M), oral polio (OPV), pneumococcal conjugate (PCV) and tetanus toxoid (TT) vaccines. Move the first vaccine from the MozGaza model to your new model:



a. Select a vaccine by clicking on its row (right table).

b. Click "**Add Component to Model"** button between the two tables to add the vaccine to the current model.

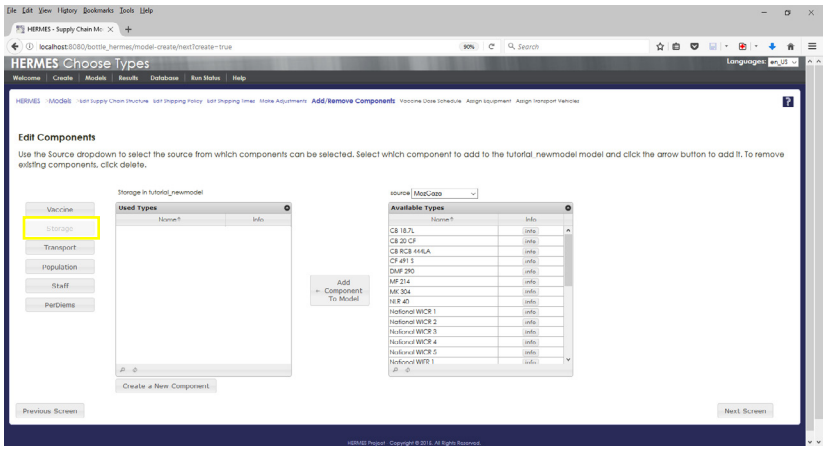


16. Continue to add the rest of the vaccines from the MozGaza model (right table) to the new model **"tutorial_newmodel"** (left table) by repeating step 15 for each row.

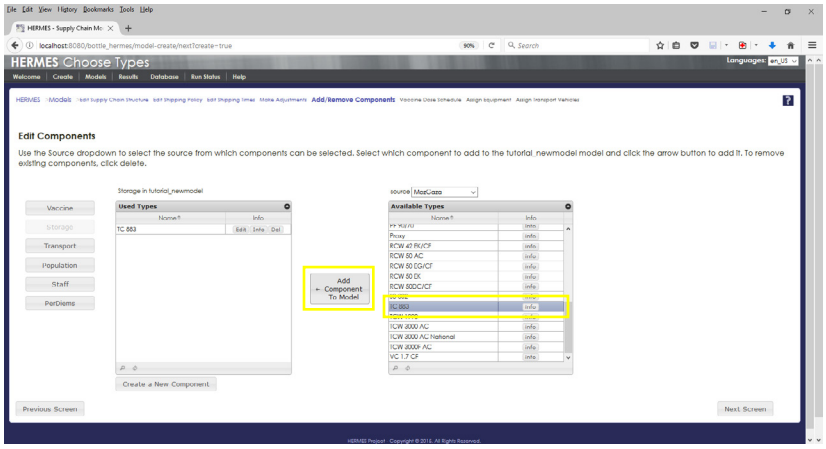
This is how your screen should appear after completion.

Storage

The types of storage in a vaccine supply chain are critical, given that most vaccines in the supply chain require cool or cold storage to remain effective. Storage containers can include freezers, refrigerators and transportable cold boxes. Within these categories, storage containers can be powered differently (via gas, electricity, solar or passively) and store different volumes. All of these components have an effect on the overall function and costs of the supply chain. The HERMES model allows the user to address questions around which types of storage are the best fit for a given location. Previous modeling work has looked at the role of passive cold storage devices[5], using solar-powered refrigeration instead of electrical refrigeration[6,7] and the benefits and costs of adding stationary storage compared to transportable cold boxes[8].

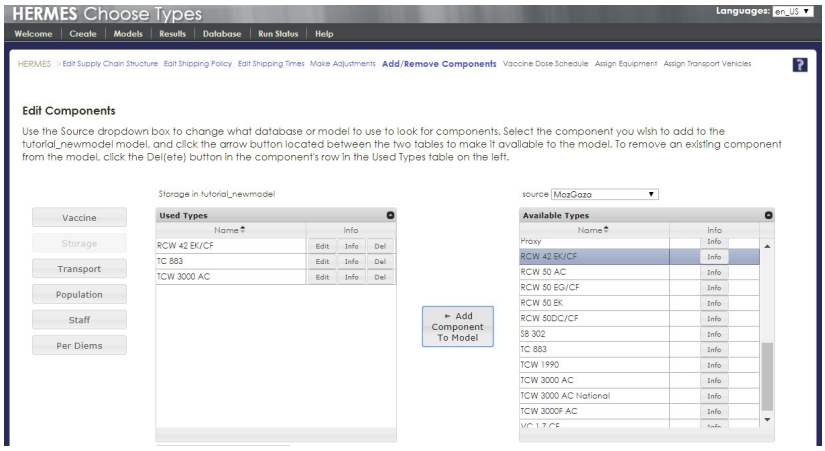


17. Click on the **“Storage”** button on the left hand side of the page (between “Vaccine” and “Transport”) to add the relevant refrigerators and freezers that will be used in your new model. These devices appear in the MozGaza model, so keep this model selected as the source in the dropdown box.



18. Adding the first storage device to the model:

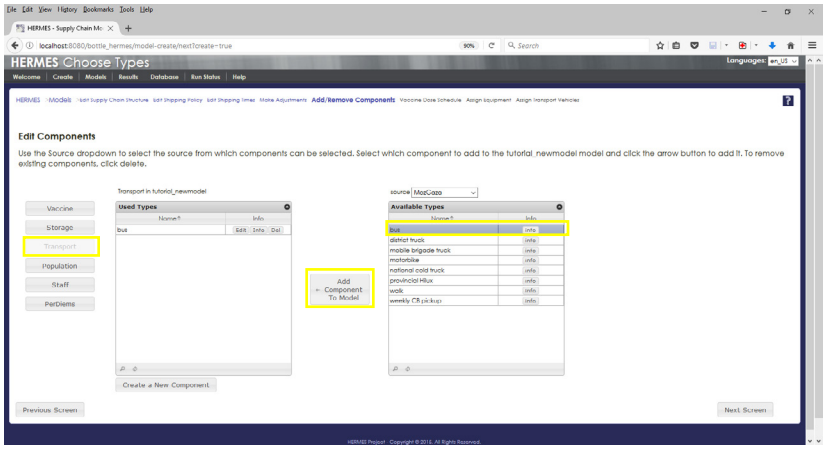
    a. Scroll down to find **“TC 883”** in table on right
    b. Click **“Add Component to Model”** button between the two tables to add the storage type to the current model



19. Repeat steps in 18 to add **"TCW 3000 AC"** and **"RCW 42 EK/CF"** to the storage options for your model.

Transportation

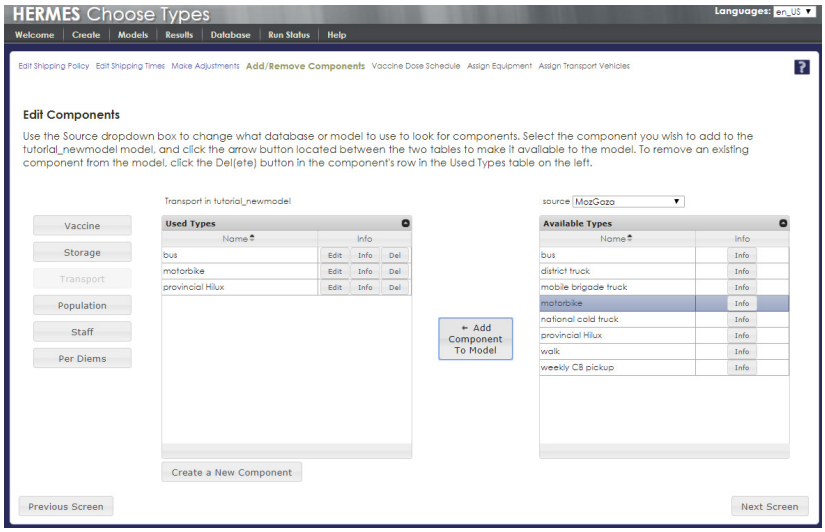
Transportation plays an important role in vaccine supply chains. Transport vehicles can be over-utilized, have a scarcity of storage space or be without cold storage. The HERMES model allows the user to input the volume, cold storage amount and type of each vehicle from a large truck to public transportation. The model considers fuel, capital and depreciation costs for each vehicle.



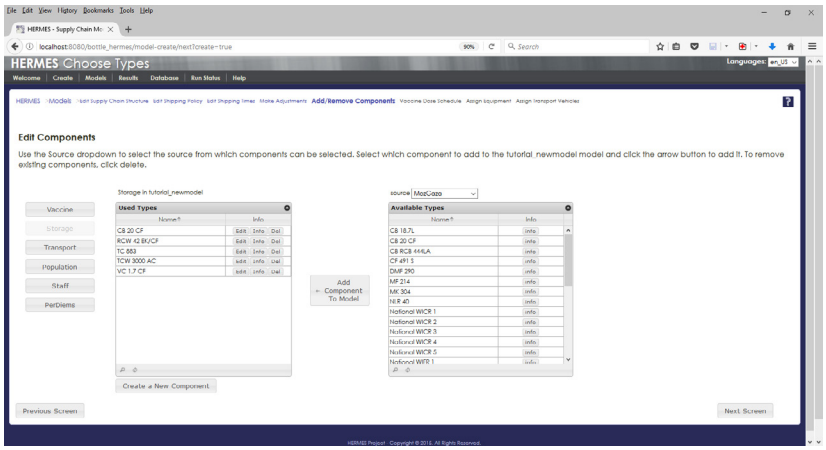
20. Click on the **"Transport"** button on the left hand side of the screen to add modes of transportation used for vaccine distribution. MozGaza should remain as the source selected in the dropdown box.

21. Adding the first transport mode to the model:

a. Public transport will be used for some routes in this model. Scroll down to find **"Bus"** in table on right and click on that row
b. Click **"Add Component to Model"** button between the two tables to add the Bus transport type to the current model

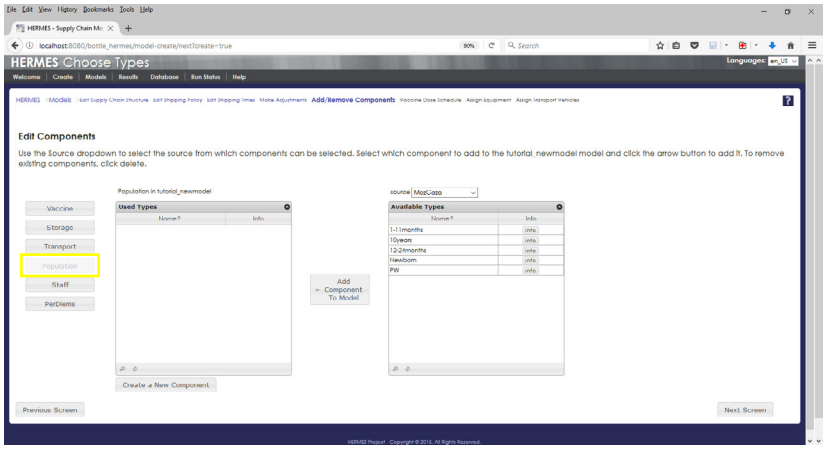


22. Repeat step 21 to add **"provincial Hilux"** and "motorbike" to the transportation types for your model

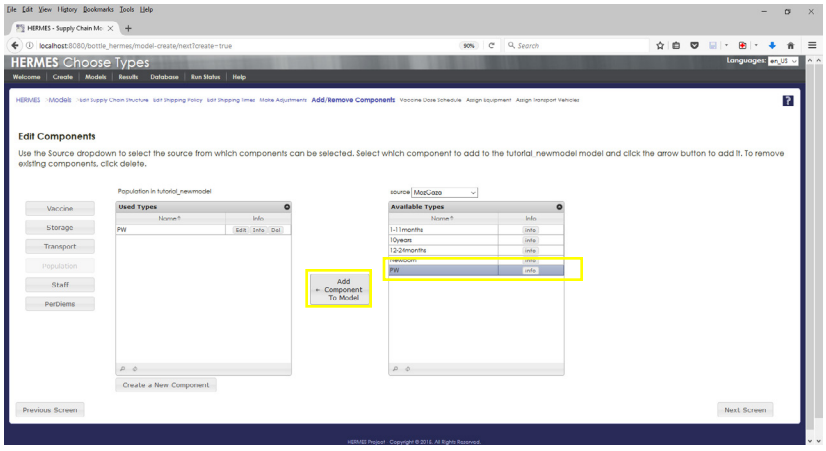


If you return to the Storage page after you have updated the transportation types, you will notice that two more storage types have been added to your used types: **CB 20 CF** and **VC 1.7 CF**. These were automatically added because this list includes not only stationary storage devices but also passively cooled devices for transport, such as cold boxes and vaccine carriers. These new devices represent the cold box and vaccine carrier types that carry vaccines in the transportation vehicles that were added to the model. The type and quantity of devices available in a vehicle can be modified using the **"Edit"** button next to any vehicle in the Transport page.

Population

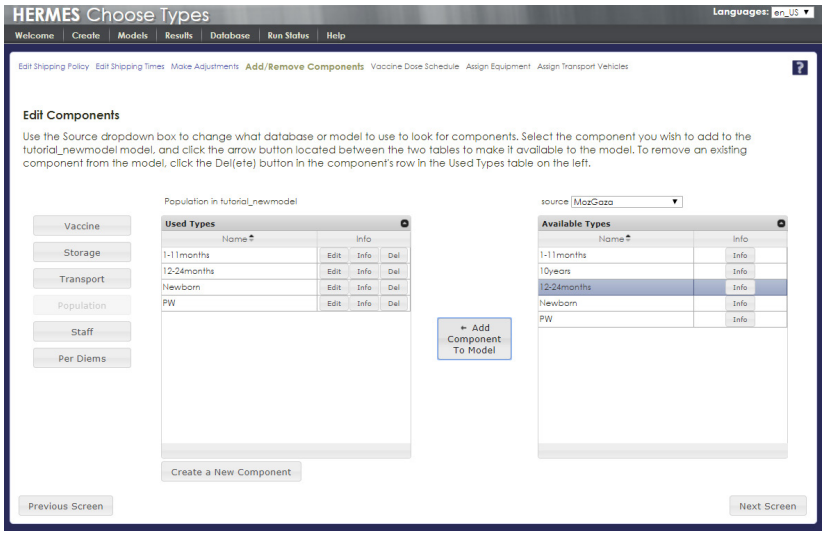


23. Click on the **"Population"** button on the left hand side of the screen to add the population groups who will receive vaccines in the model. The vaccines you added to the model would be given to pregnant women (PW), newborns and infants under one year of age. In this example, you will also add children between 12 and 24 months, to facilitate future vaccine introduction experiments, such as what was described in the Vaccine Introductions tutorial. The population types in your new model are also found in the MozGaza model, which should remain as the source selected in the dropdown box.



24. Add the first population type to the new model:

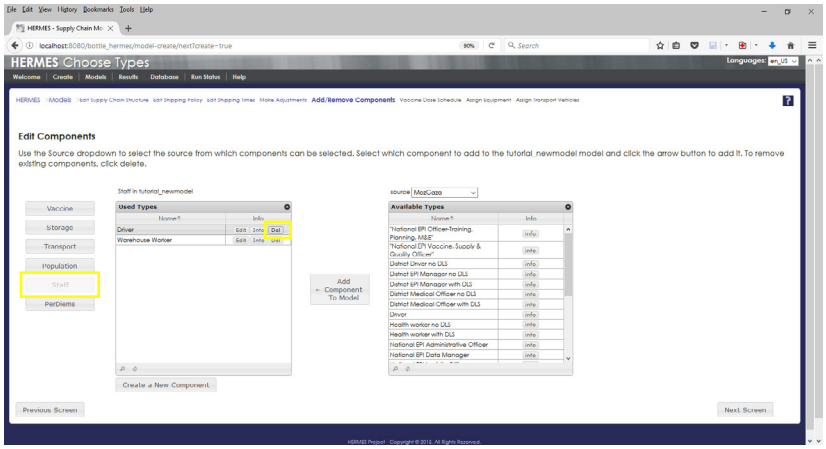
a. Find **"PW"** (pregnant women) in table on right and click on that row
b. Click **"Add Component to Model"** button between the two tables to add that age range to the population types for the current model



25. Repeat step 24 to add **"Newborn"**, **"1-11months"** and **"12-24months"** to the population types for your model

Staff

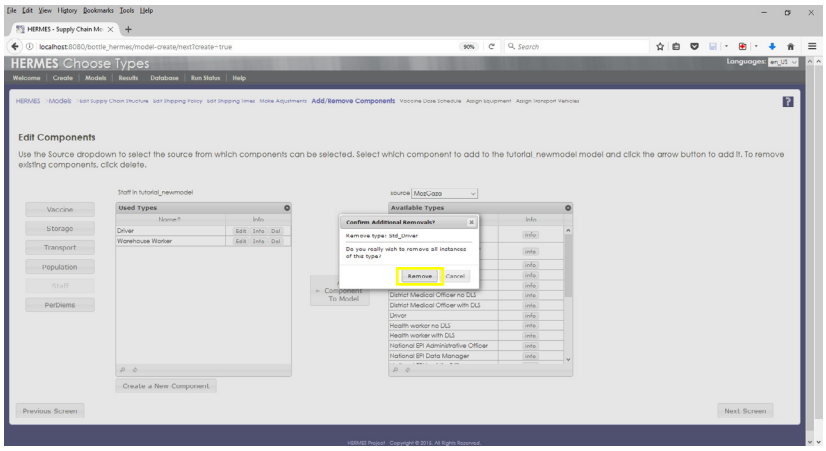
The HERMES model considers the effect of personnel on the supply chain function and costs. Personnel include logisticians, drivers, medical officers, warehouse workers, etc. Each personnel has a certain wage and percentage of time dedicated to the supply chain tasks that factor into the overall cost of the model.



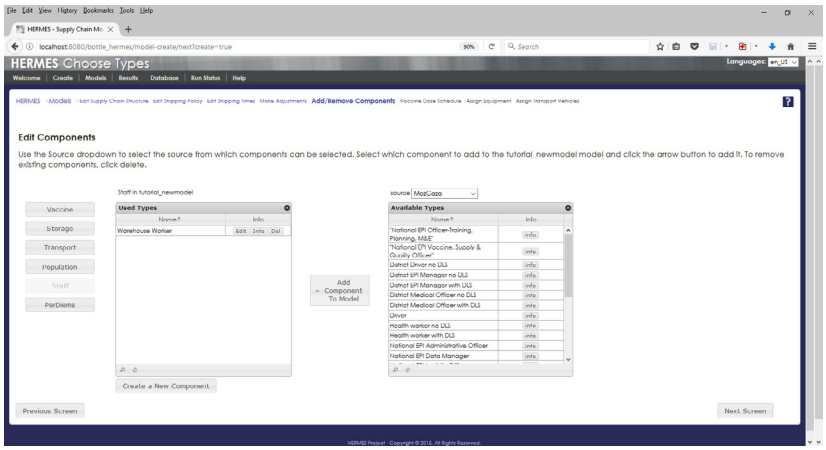
26. Click on the **"Staff"** button on the left hand side of the screen to add the types of personnel working in vaccine supply chain logistics in your new model. The six personnel types in your new model are also found in the MozGaza model, which should remain as the source selected in the dropdown box.

NOTE: You should notice that two example staff types are already listed in the Used Types table on the left. These will not be used in your new model, therefore they need to be removed. To delete the first default:

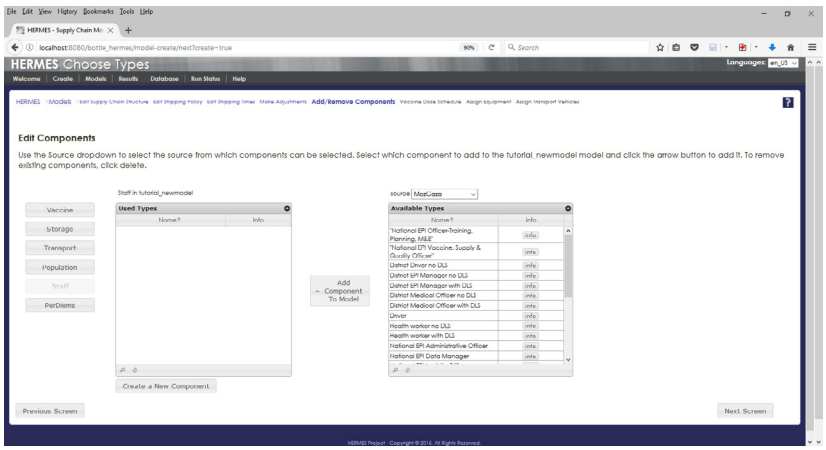
a. Click on the **"Del"** button in the row labeled **"Driver"**



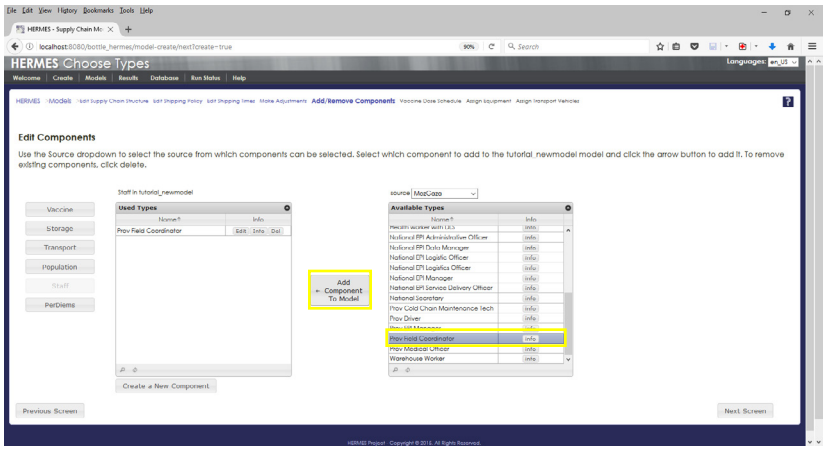
b. Click the **“Remove”** button in the dialogue box that asks you to confirm additional removals



c. Driver is no longer listed in table on right

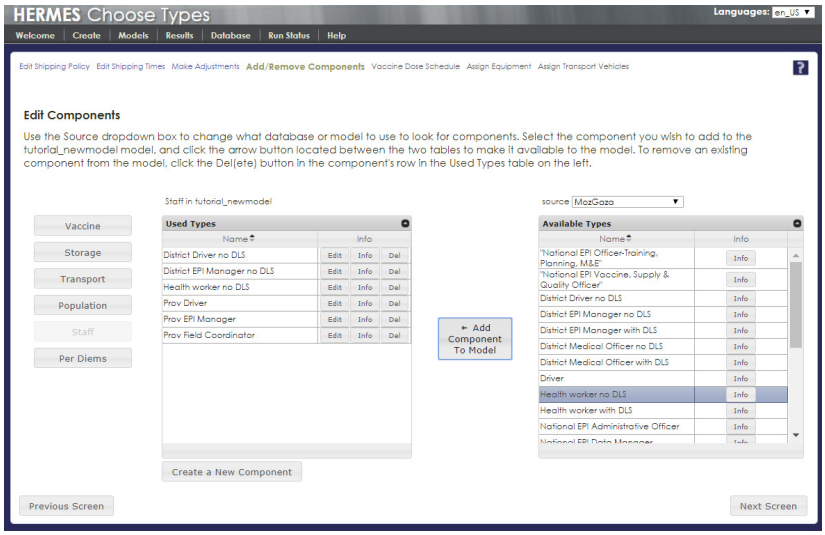


27. Repeat step 27 to remove **“Warehouse Worker”** from Used Types.



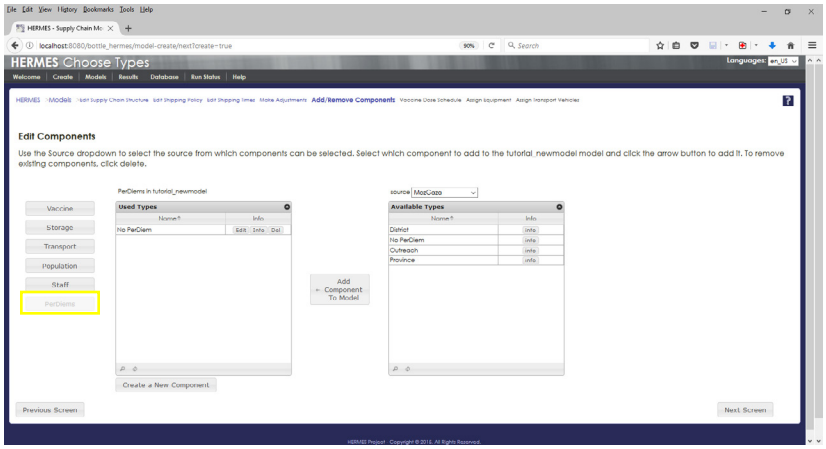
28. Add the first staff type to your new model:

a. Scroll down to find **“Prov Field Coordinator”** in table on right and click on that row
b. Click **“Add Component to Model”** button between the two tables to add the **“Prov Field Coordinator”** staff type to the current model

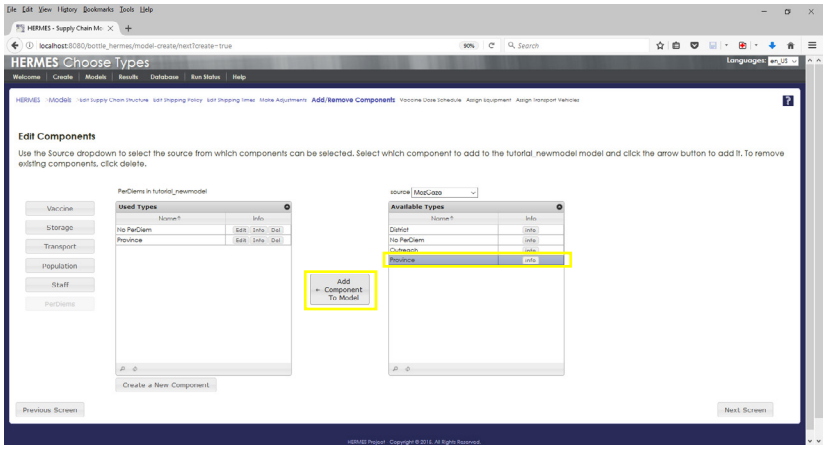


29. Repeat steps in 29 to add **“Prov EPI Manager,” “Prov Driver,” “District EPI Manager no DLS,” “District Driver no DLS”** and **“Health worker no DLS”** to the staff types for your model

Per diems

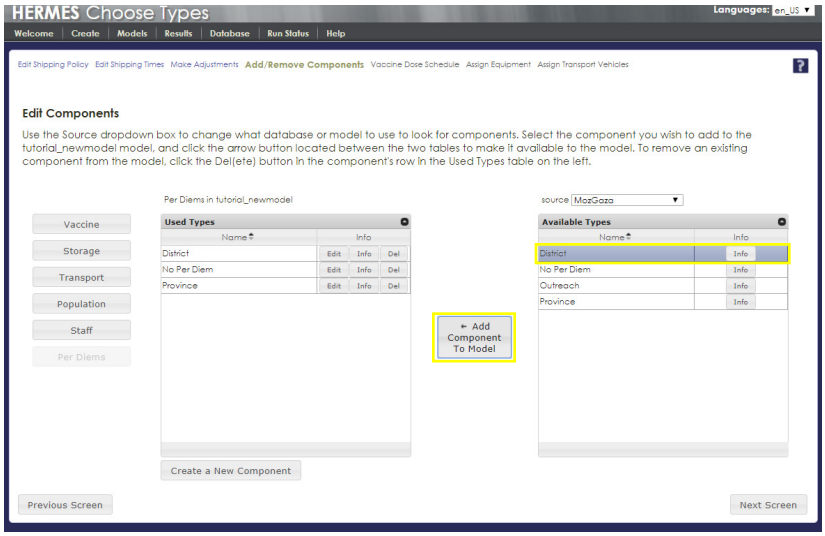


30. “Per diems” are a daily allowance or payment given to an employee or worker for expenses occurred while traveling for work. Click on the **“PerDiems”** button on the left hand side of the screen to specify the policies that will govern when per diems are paid and how much in your model. You will notice that **“No Per Diem”** is included in the table on the left by default. This will be used for some routes in the model. Other per diem policies in your model vary by supply chain level and are found in the MozGaza model, which should remain as the source selected in the dropdown box.



31. Add a per diem type to the new model:

a. Find **“Province”** in the table on right and click on that row. This represents the per diem policies for trips that originate at the provincial store, and will be assigned to deliveries from the provincial store to district stores in a future step.
b. Click **“Add Component to Model”** button between the two tables to add the Province per diem type to the current model



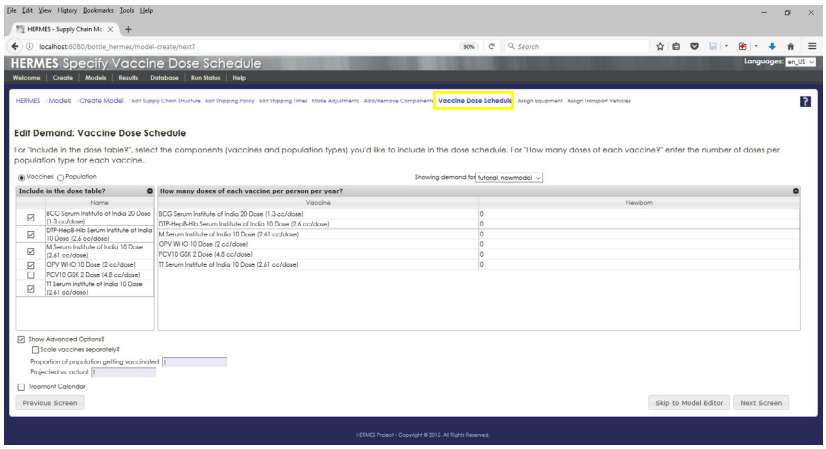
32. Repeat step 32 to add **"District"** per diem to the per diem policies for your model. This represents the per diem policy used to pay drivers at the district level, who will deliver vaccines to health centers in this model.

Check your work:

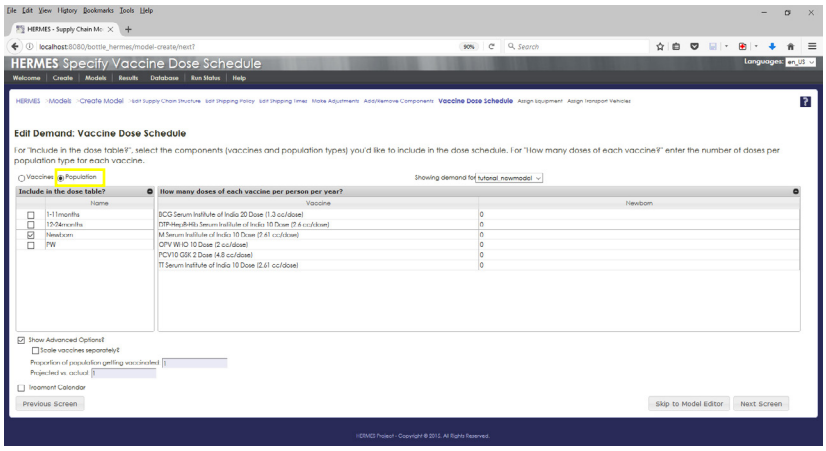
33. Click through the component category buttons on the left (Vaccine, Storage, Transport, etc.) to check that the **"Used Types"** table that contains the correct components for your model. When you are satisfied that you have the correct components, click the **"Next Screen"** button.

Part 6: Specify vaccine schedule

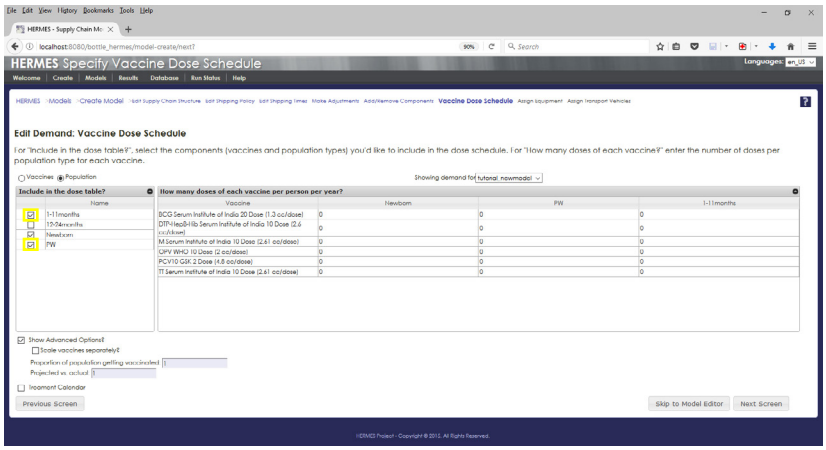
The Vaccine Dose Schedule page specifies the doses needed to fully immunize the target population.



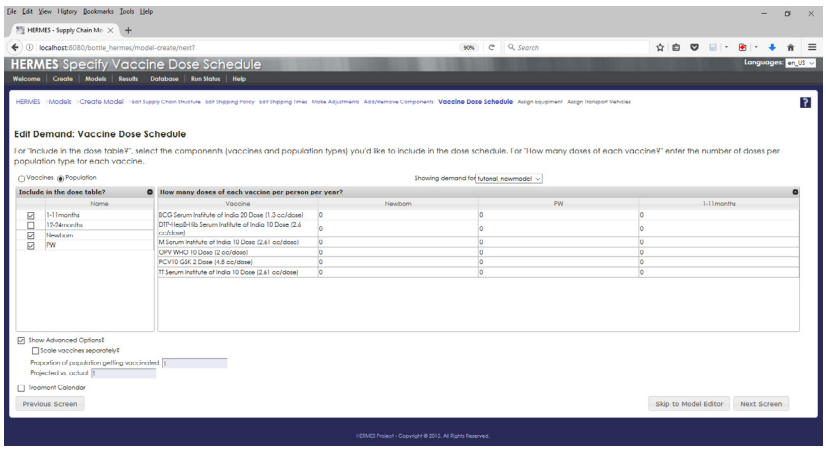
34. If the Next Screen button does not take you there automatically, click on the **"Vaccine Dose Schedule"** at the top of the screen.



35. Click on the **“Population”** button that is above the tables to the left to display the populations you added to your model. Checking the box next to a population will add it to the table on the right.



36. **“Newborn”** is checked by default. Check **“1-11months”** and **“PW”**. The table on the right will update each time you check another population.

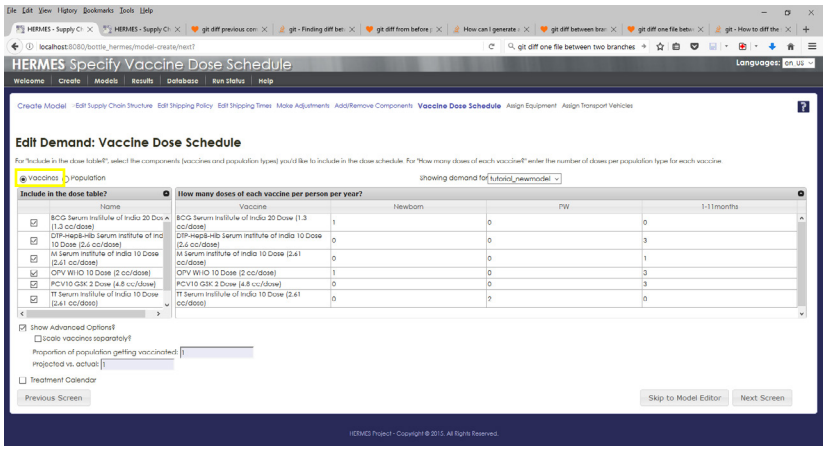


37. Update the table on the right by clicking in the appropriate cells and changing the numbers:

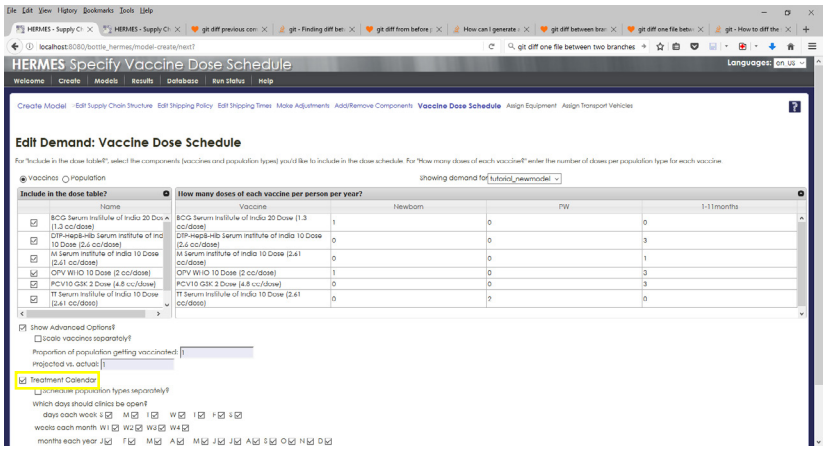
Pregnant women (PW) get **2** doses of **“TT Serum”**

Newborns get **1** dose of **“BCG”** and **1** of **“OPV”**

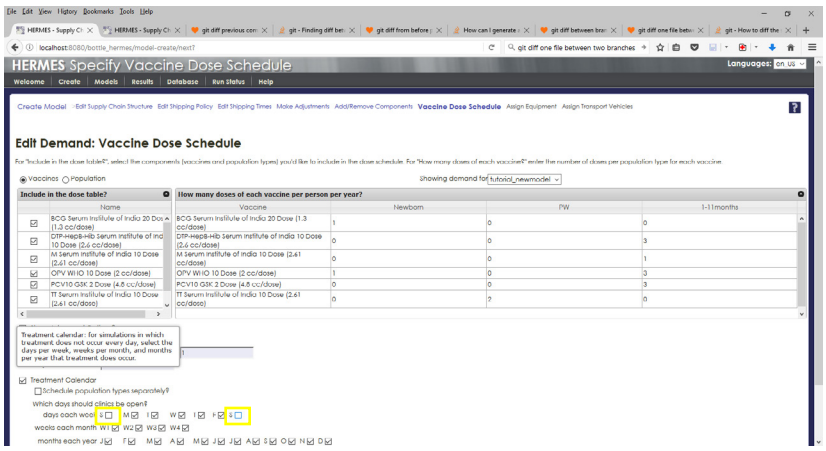
1-11 months get **3** doses of **“DTP-HepB-Hib”**, **3** of **“OPV”**, **3** of **“PCV”**, and **1** of **“M Serum”**



When this is complete, click back on the **"Vaccines"** button shown to the left.

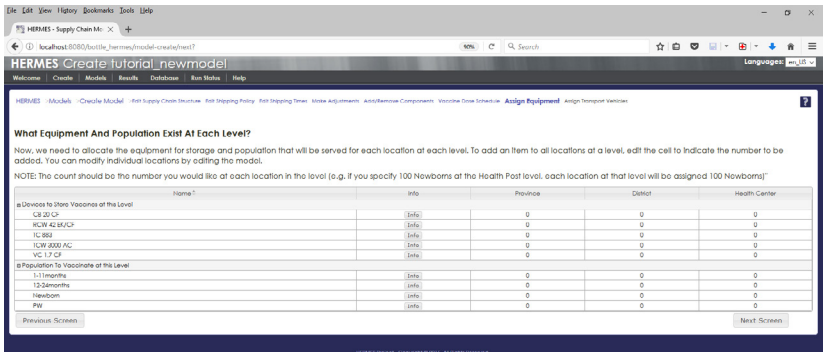


38. Click **"Treatment Calendar"** box in lower left corner to show options.

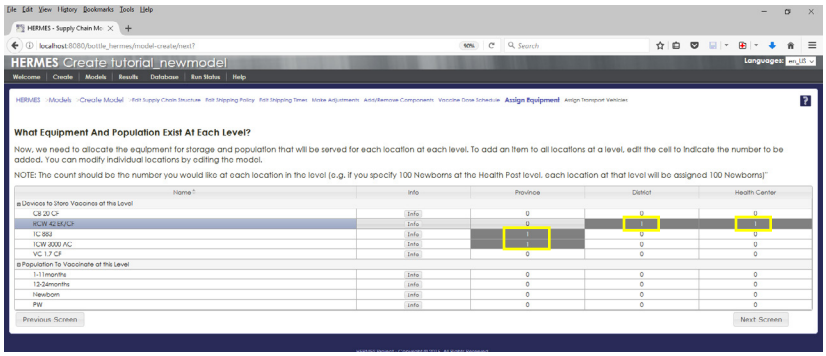


39. Uncheck first and last **"S"** next to **"days each week"** then click **"Next Screen"** button.

Part 7: Assign storage devices and populations



The Assign Equipment page allows you to specify the number of storage devices available and the size of the population served at each location, entered by supply chain level.



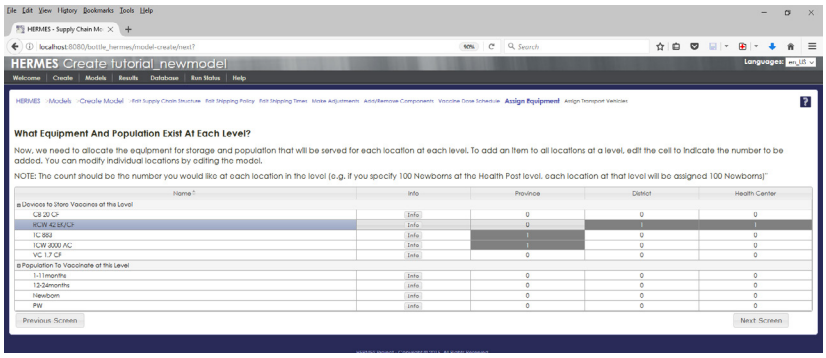
*Devices may not be listed in same order as shown in image above

40. Click on the **"Assign Equipment"** tab at the top of the screen if not already there. Assign storage devices by clicking on the appropriate cells and entering the number available at a typical location in the selected level.

    For **"Province"** enter **1 "TC 883"** and **1 "TCW 3000 AC"**

    For **"District"** and **"Health Center"** enter **1 "RCW 42 EK/CF".**

NOTE: Cold boxes and vaccine carriers should only be assigned here if they are used for stationary cold storage. The passively cooled devices in our example model are only used on vehicles, so the quantities on this page should remain zero.

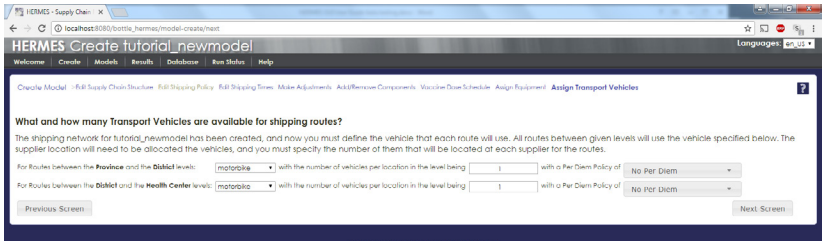


41. Similarly, populations entered here represent the number of people who would arrive for vaccinations at a typical location over a period of a year. Only enter population numbers for levels that administer vaccinations; the province level should have zero population here. Enter the average annual number of people in each target population group seeking vaccines at a district or health center location, as shown in the table below then click the **"Next Screen"** button:

Target Population	District	Health Center
1-11months	520	280
12-24months	500	270
Newborn	530	290
PW	660	360

Part 8: Assign transport vehicles

This step assigns transport vehicles to routes and locations by level, as well as per diem policies by level. Specifying the type of vehicle and per diem policy typically used between a pair of supply chain levels will assign that vehicle type and per diem policy to all routes between those levels. The number of vehicles specified will be added to each location at the appropriate supply chain level.



42. Click on the "**Assign Transport Vehicles"** tab at the top of the screen.

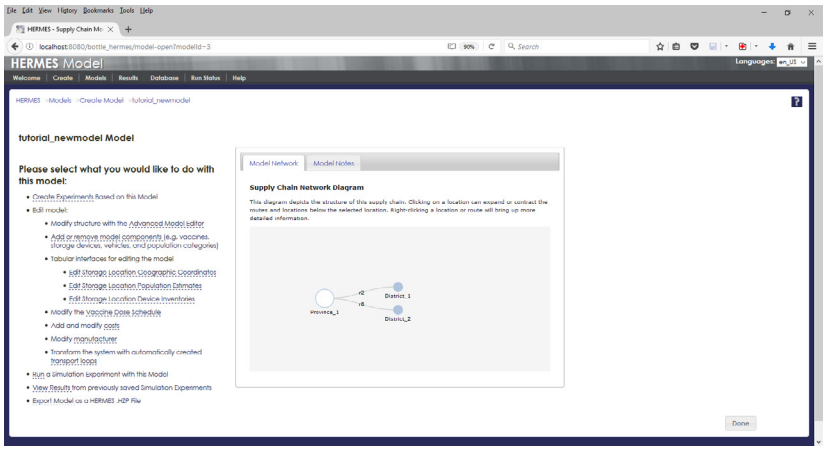
"For Routes between the **Province and District** levels", select **"provincial Hilux"** of dropdown menu (this is the truck used at the province level to deliver to district locations), enter 1 (so the province store will have 1 truck in its inventory), and select the **"Province"** per diem policy.

"For Routes between the **District** and **Health Center** levels" select a **"motorbike"** and the **"District"** per diem policy (each district location should then be assigned 1 motorbike).

Then Click **"Next Screen"** button, which will return you to the home page.

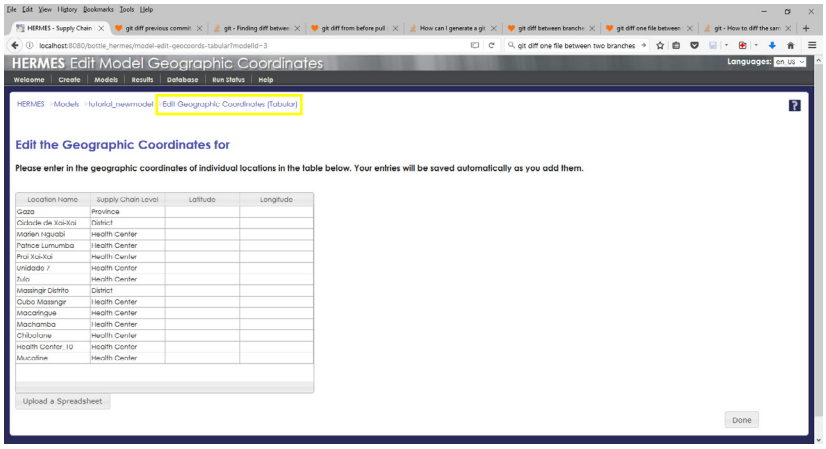
Part 9: Enter data by location

Congratulations! You have finished the initial steps in creating a model! This model can be run, with the simplifying assumptions that each location at a level has the same characteristics, such as equipment inventory and population demand.

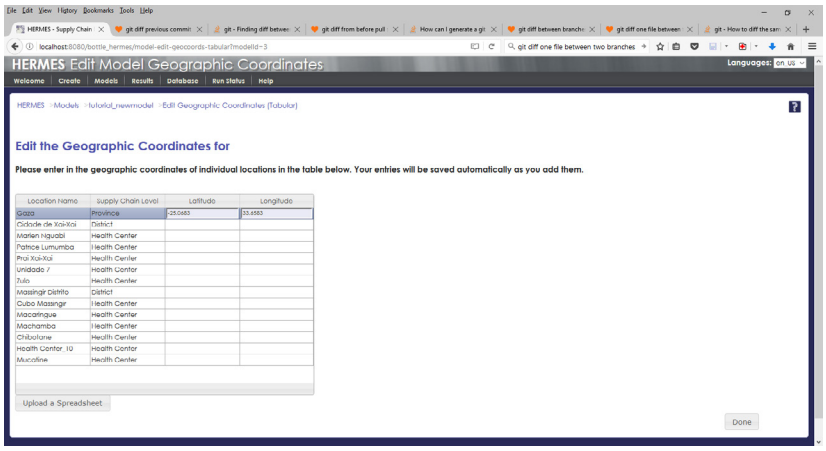


The following steps will allow you to fine tune your model, starting from the model open page shown here.

Geographic coordinates

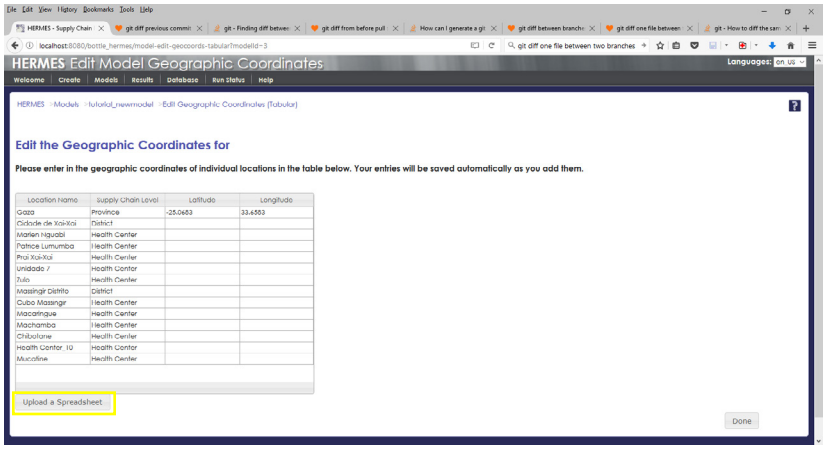


43. First select **"Edit Storage Location Geographic Coordinates"**

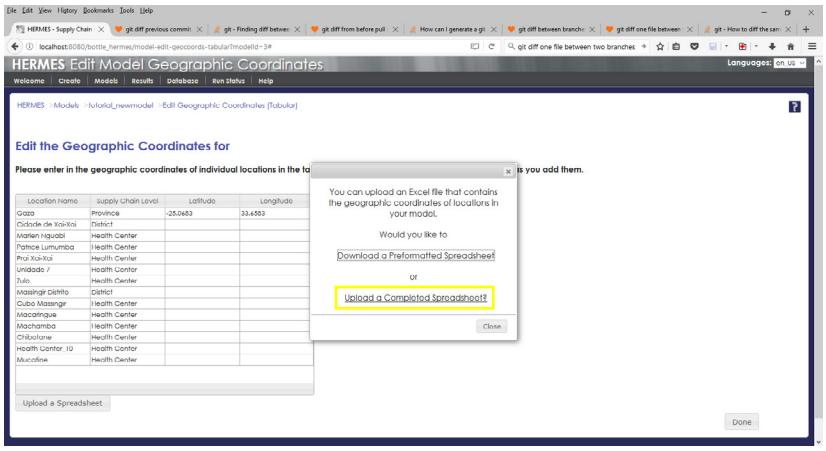


44. Coordinates can be entered manually or by uploading a spreadsheet. To enter manually, click on the first row (Location Name "Gaza") and enter a **latitude** of **-25.0683** and **longitude** of **33.6583**.

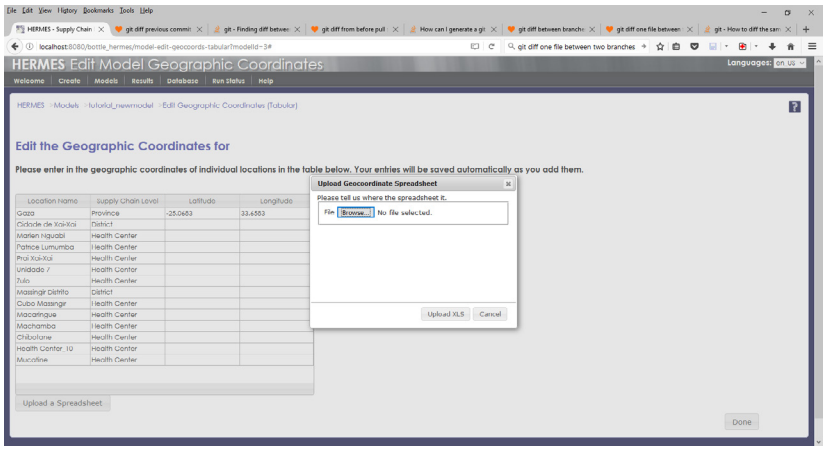
NOTE: the cells remained outlined for data entry. The changes are not recorded **until you press the Enter key** while in that row, at which point the cells return to a white background.



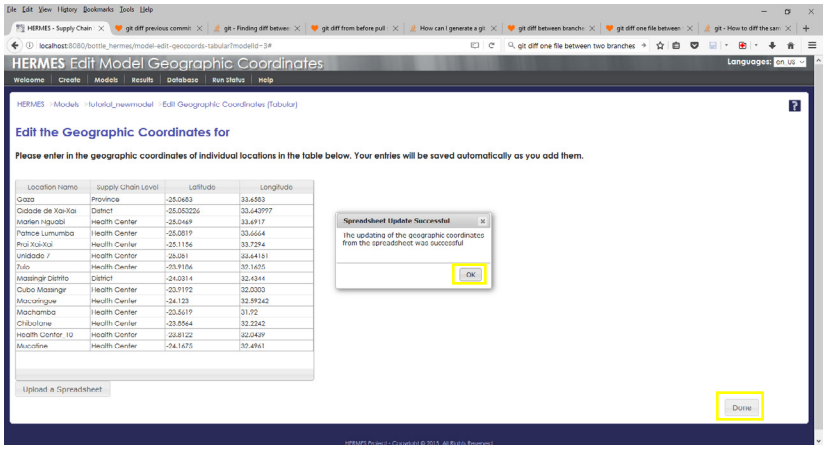
45. You can also upload the coordinates from a spreadsheet. To do this, click the **"Upload a Spreadsheet"** button.



46. Then click **"Upload a Completed Spreadsheet"**

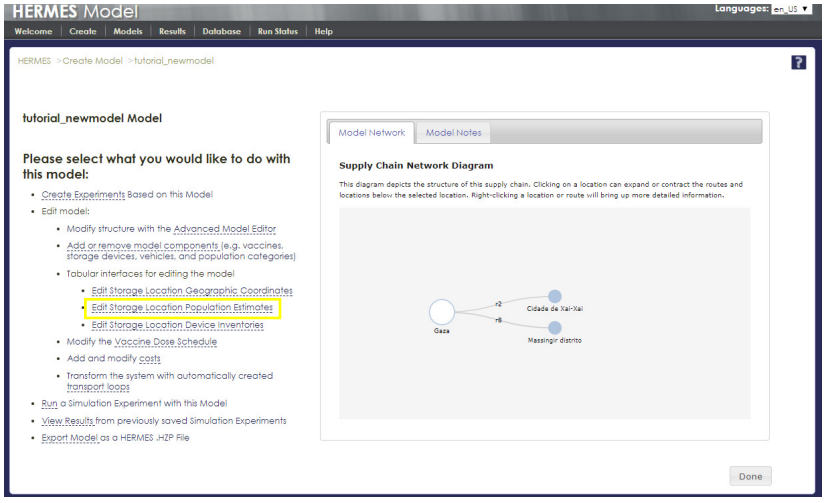


47. A completed spreadsheet is provided in the file **tutmodel_ geocoord.xlsx**. Use the Browse button to select that file and then click on **"Upload XLS"**

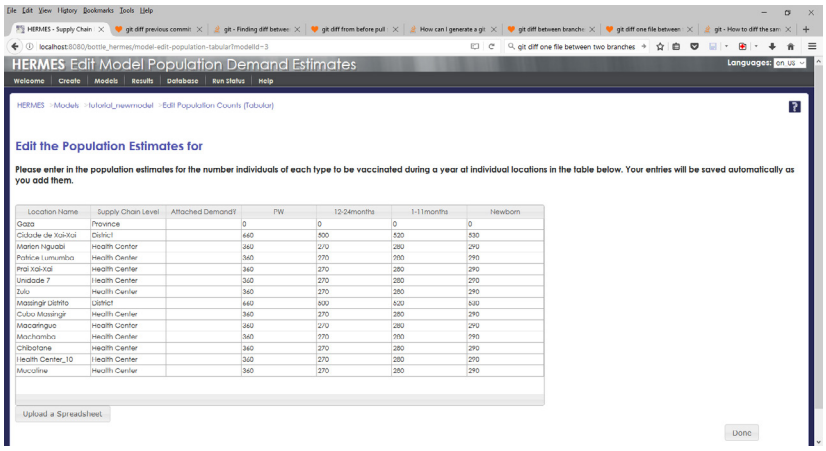


48. Click **"OK"** in the Spreadsheet Update Successful dialog box and then click **"Done"** to return to the main model page.

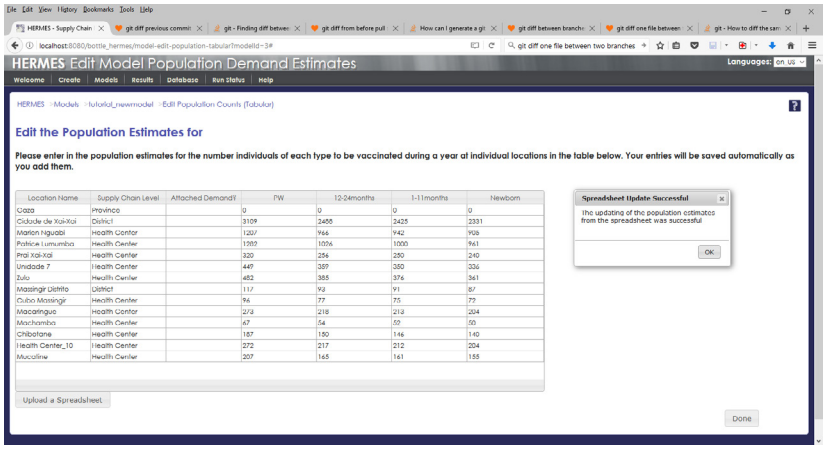
Population Estimates



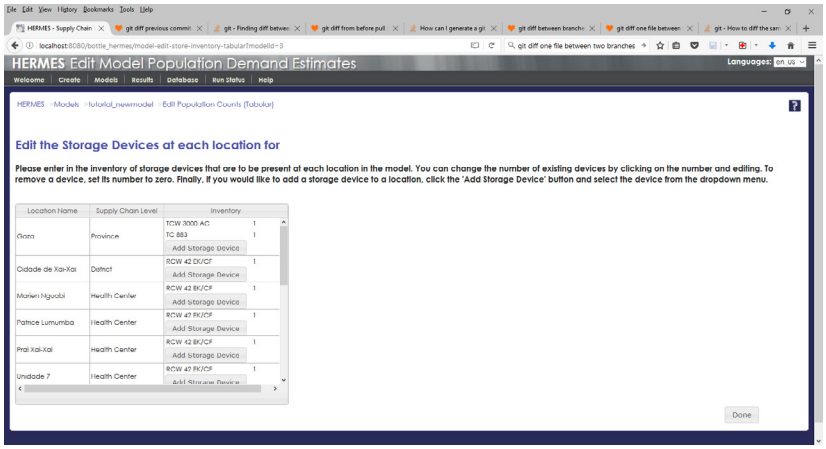
49. Now select **"Edit Storage Location Population Estimates"** It shows the populations we assigned by level back in step 41



50. Similar to the Storage Location Geographical Coordinates, these numbers can be uploaded from a spreadsheet. The actual population totals for this model have been saved as **tutmodel_pop.xlsx**. Follow steps 45-47 to update the population totals.



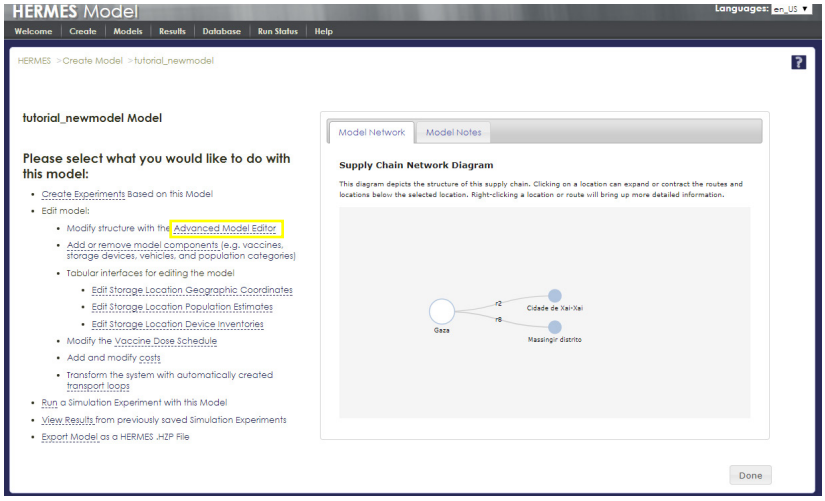
Storage Devices



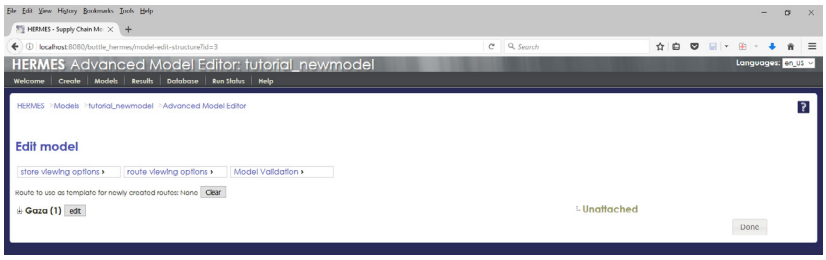
51. The other tabular edit available from the main model page allows you to **"Edit Storage Location Device Inventories"** at individual locations. You can select this option to view the devices currently assigned at each location in the model. For this exercise, no changes to the device inventories are needed.

Advanced Editing

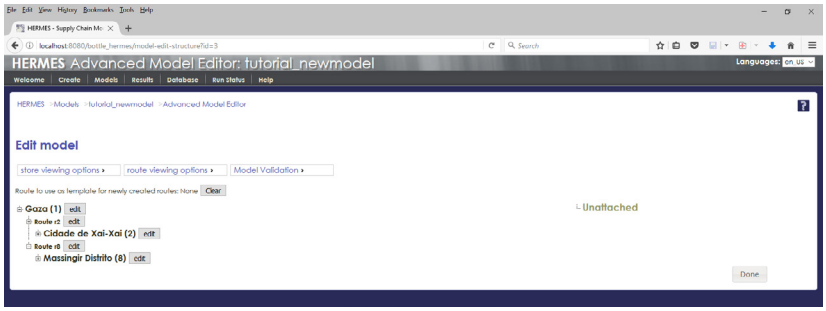
Some changes to add further detail and heterogeneity to the model can be most easily done using the Advanced Editor. The following steps demonstrate how to change the supplier of a location, enter shipping times and distances for each route, alter shipping policies and modes of transport for individual routes, add modes of transport to individual locations and assign building costs by level.



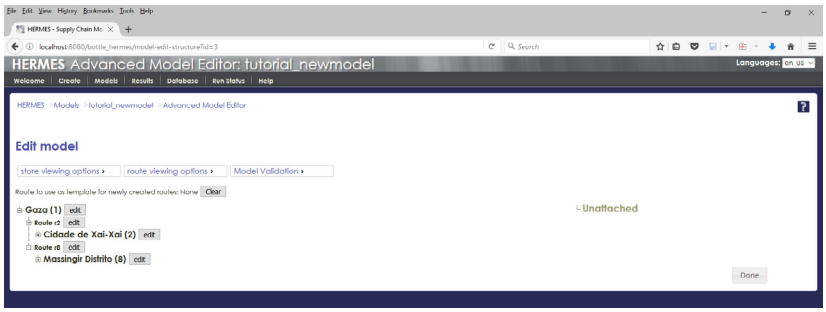
52. Choose **"Modify structure with Advanced Model Editor"** from the main model page to open the advanced interface.



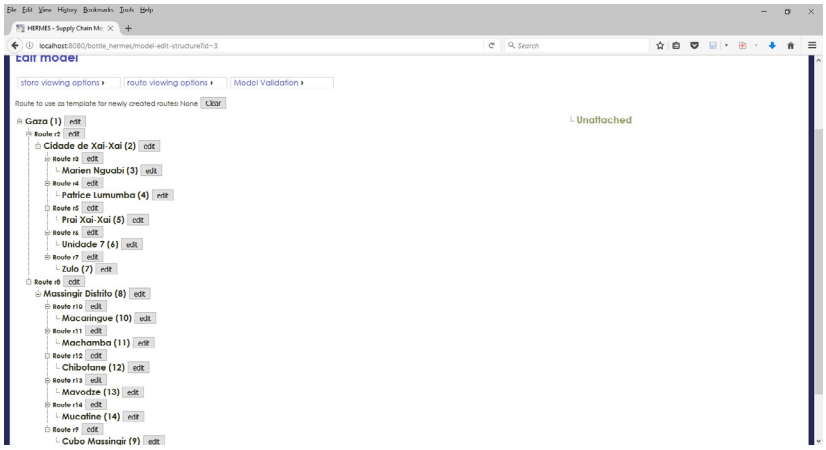
53. Click the plus sign next to **"Gaza"** to expand the locations below



54. Then do the same next to the two district locations to open the health centers below them. All locations and routes in the model are now displayed.

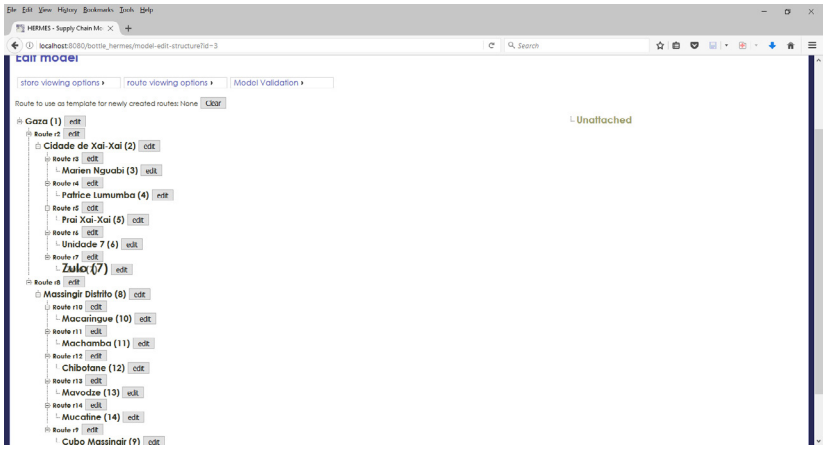


54. Then do the same next to the two district locations to open the health centers below them. All locations and routes in the model are now displayed.

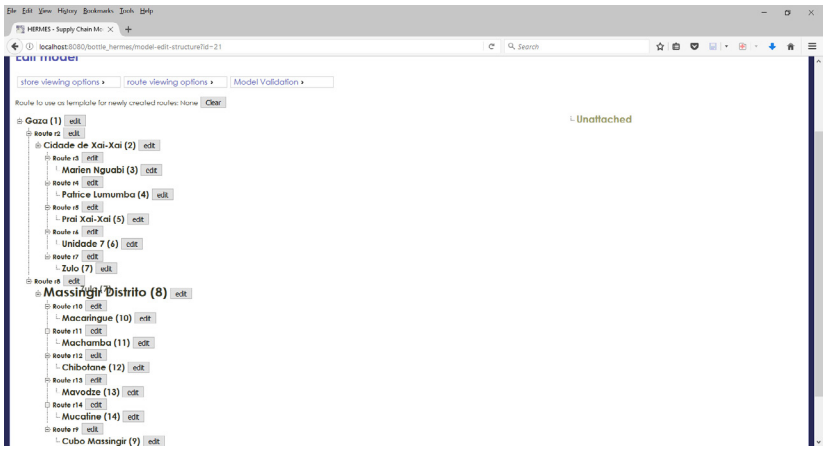


Moving a Location

In this first example, we will move the location Zulo, currently located in the Cidade de Xai-Xai district, to the Massingir district where it is actually found.

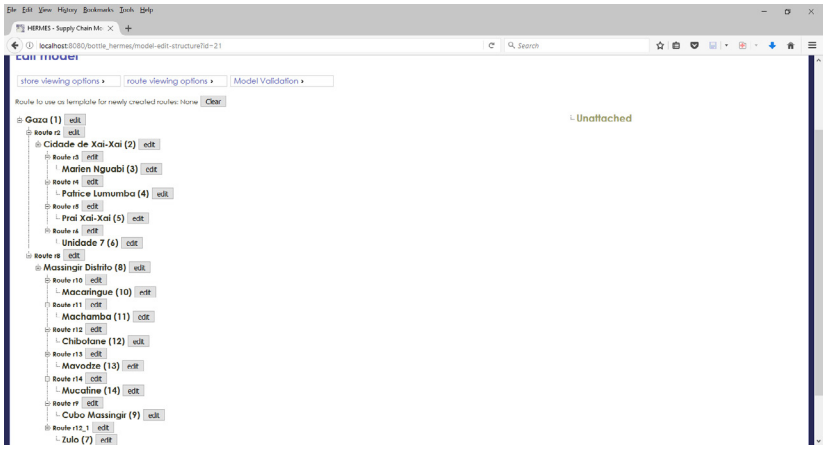


55. Click on the label **"Zulo"** and start dragging it toward the Massingir Distrito label. You should notice it enlarge slightly as you move it.



56. Drag it over the label **“Massingir Distrito”** until it enlarges then release.

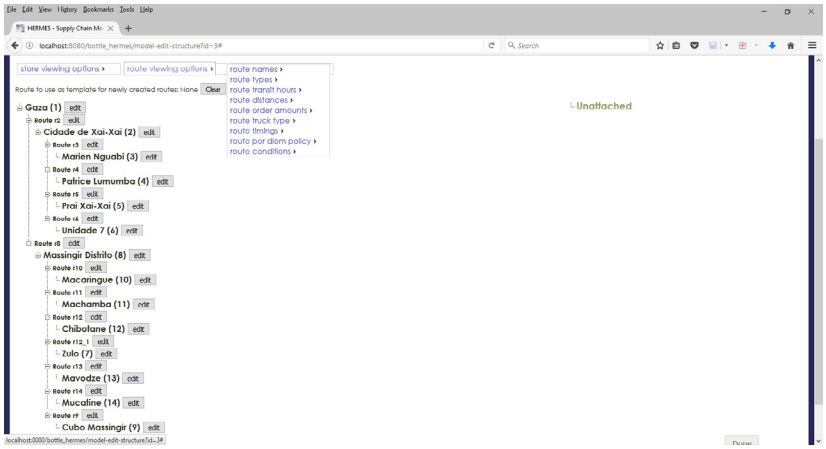
Zulo is now part of the Massingir Distrito district. You will notice that the route name for Zulo has changed.



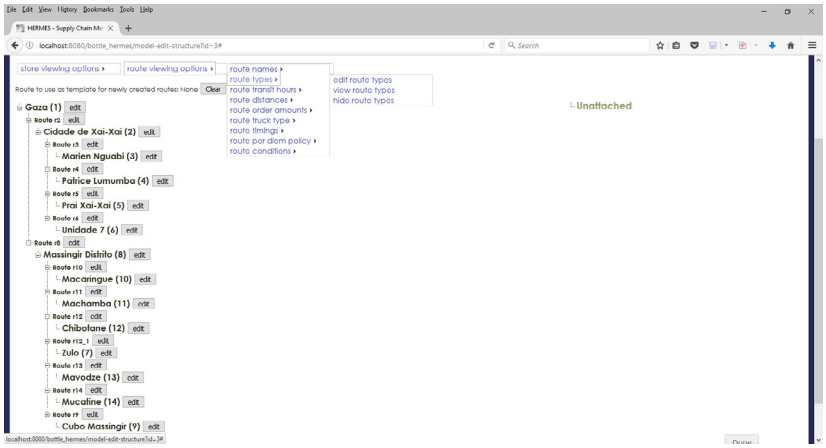
57. You can see these changes reflected in the supply chain network diagram if you exit the Advanced Editor by clicking on the model name breadcrumb at the top of the page, **“tutorial_ newmodel”**, then clicking on the **Cidade de Xai-Xai** circle in the supply chain network diagram to see that there are now only 4 health center locations in this district.

Viewing Information

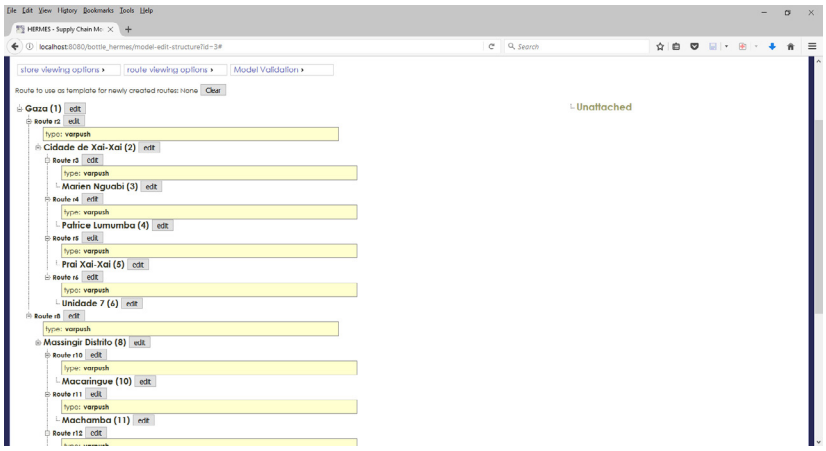
Before we do any editing of locations or routes, we'll use the editor to view some of the information we're going to change.



58. From the middle dropdown box near the top of the page, click on **"route viewing options"**



Then click on **"route types"**

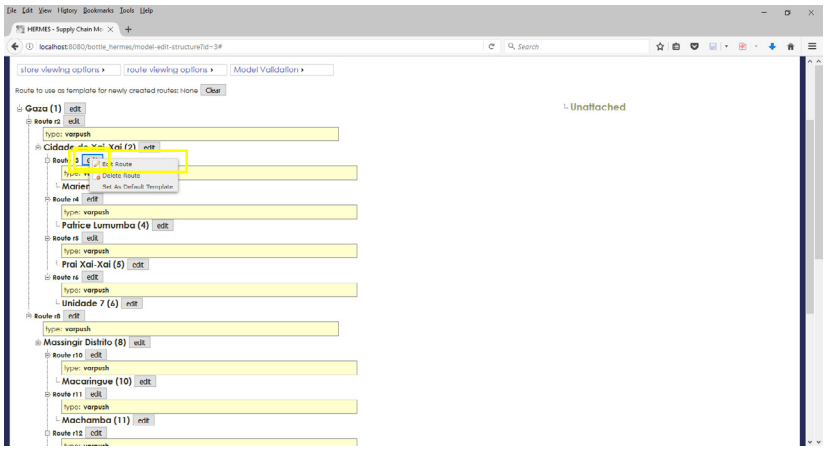


Then finally click on **"view route types."** Notice that you can now see the type of each route in a colored box.

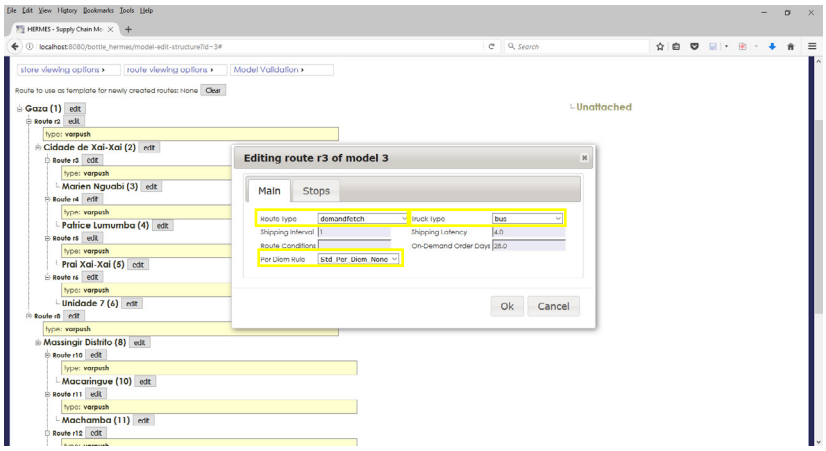
NOTE: You will be editing more than the route type in the next section, but you will see the type change reflected in the colored text boxes once the change is saved.

Editing specific routes

In this example, you will edit routes to 3 health centers (Marien Nguabi, Patrice Lumumba, and Unidade 7) that are very close to the Cidade de Xai-Xai district store and therefore can travel to pick up vaccines frequently via public transport, rather than receiving shipments from the provincial store.



59. Click on the **"edit"** button next to the route between Cidade de Xai-Xai and Marien Nguabi and then Click on "Edit Route".

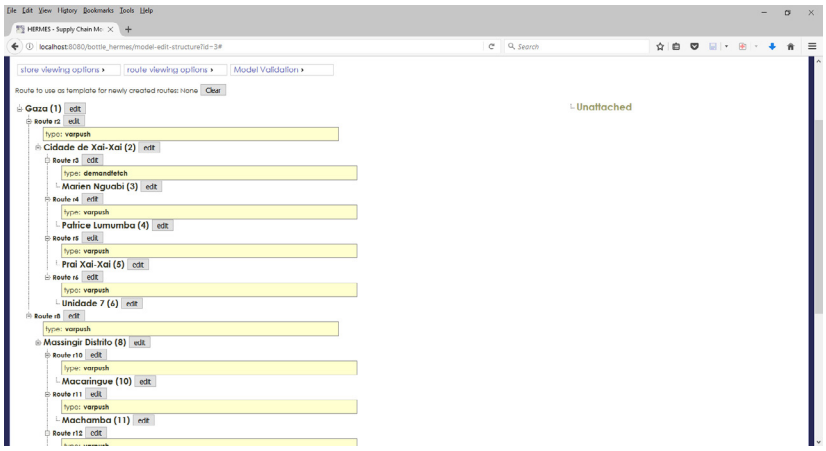


60. Update:

a. Route type to **“demandfetch”**, which specifies that the receiving location (in our example, Marien Nguabi) travels to pick up vaccines from its supplier (Cidade de Xai-Xai) and allows extra trips as needed. An extra trip is needed when stock levels for any vaccine at the receiving location fall below the level of buffer stock prescribed by program policies (this model will use a policy of 25% buffer stock, as specified in a later step).

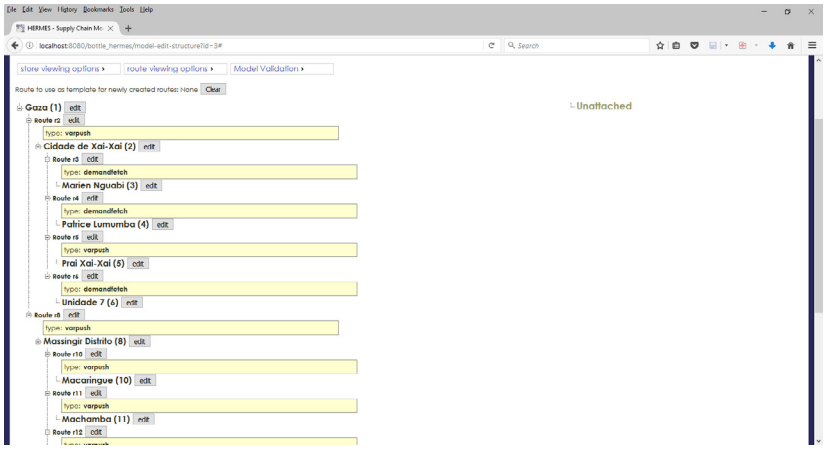
b. Change the truck type to **“bus”**, to indicate public transit is used. Enter **28** for on-demand order days, which specifies a policy of monthly trips, and enter **1** for shipping interval, which will allow extra trips as needed up to once per day.

c. Change the per diem rule to **“STD_Per_Diem_None”**, as health workers will not be paid per diems for traveling to pick up vaccines.

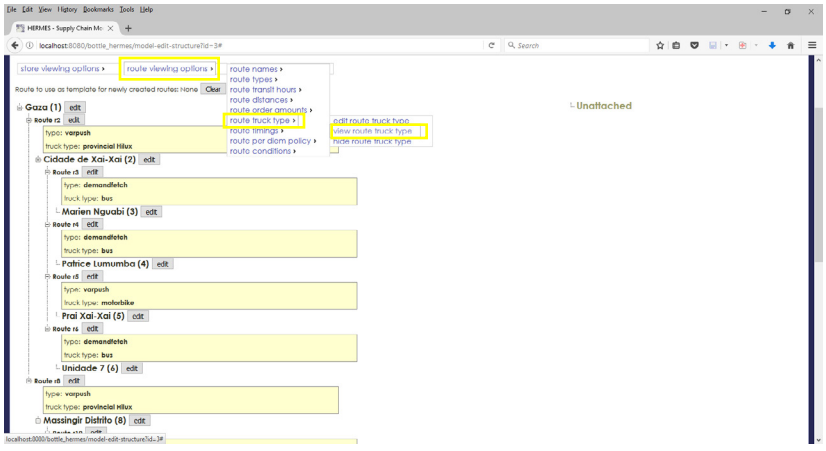


61. Then click **“Ok.”** Notice the change in type to demandfetch for the route supplying Marien Nguabi.

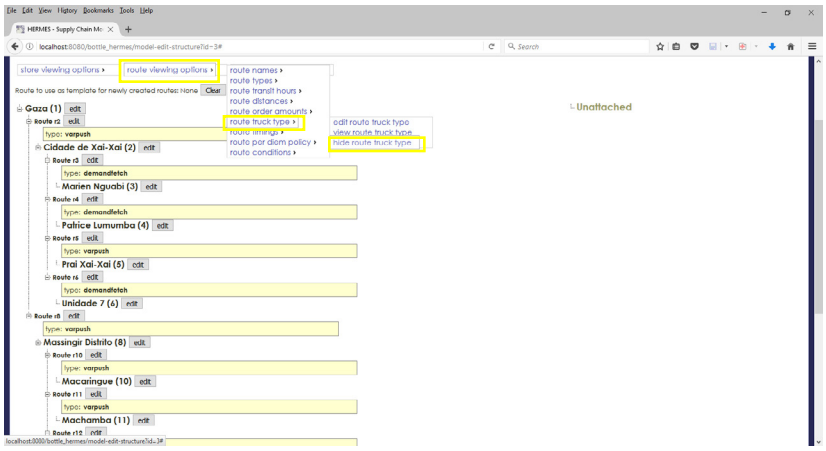
NOTE: Values for shipping latency in your model may differ from the screenshots in this tutorial but do not need to be changed. These are assigned automatically for model calibration purposes.



62. Repeat steps 59-61 for the routes serving Patrice Lumumba and Unidade 7 to have the same parameters as the route for Marien Nguabi.

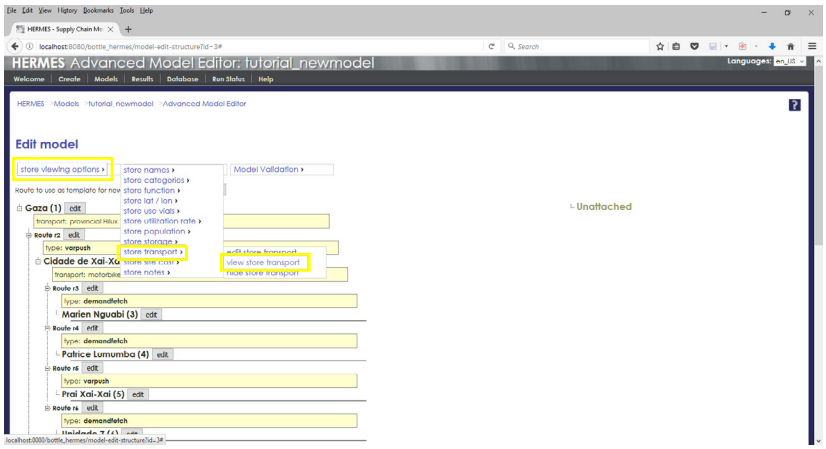


63. From the **“route viewing options”** dropdown box choose **“route truck type”**, then **“view route truck type”**. You’ll notice that Prai Xai-Xai is the only location in the Cidade de Xai-Xai district with the original/default route parameters.

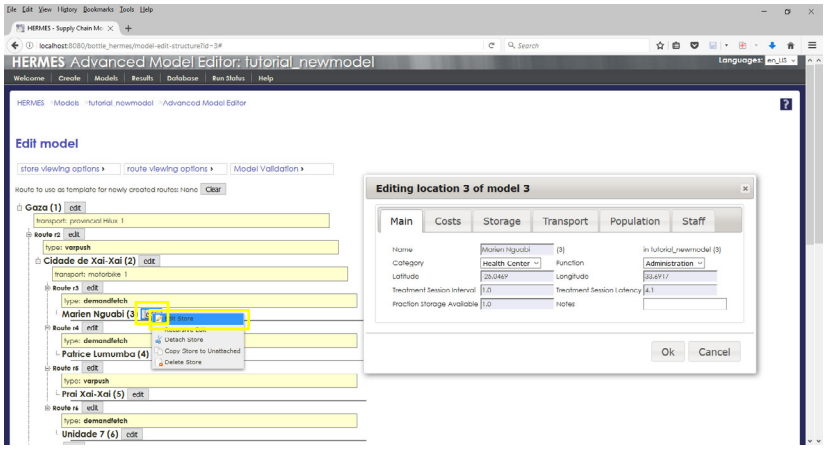


64. To avoid clutter, click on **“route viewing options,” “route truck type,”** and **“hide route truck type”** to hide the information about truck types.

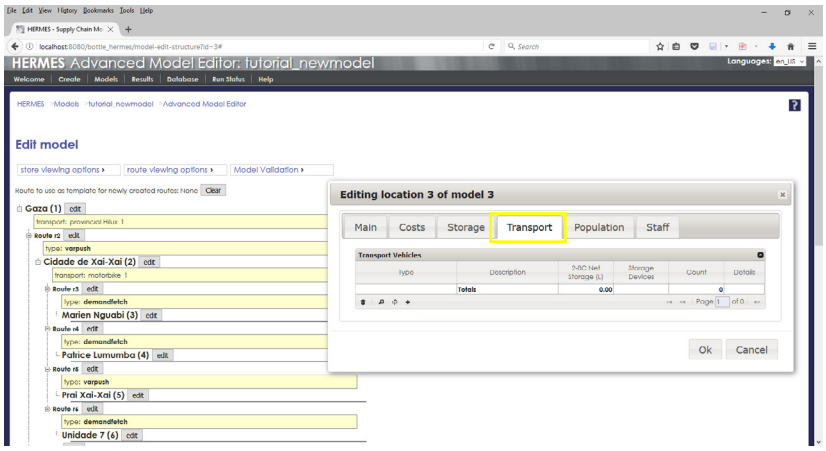
Editing specific routes



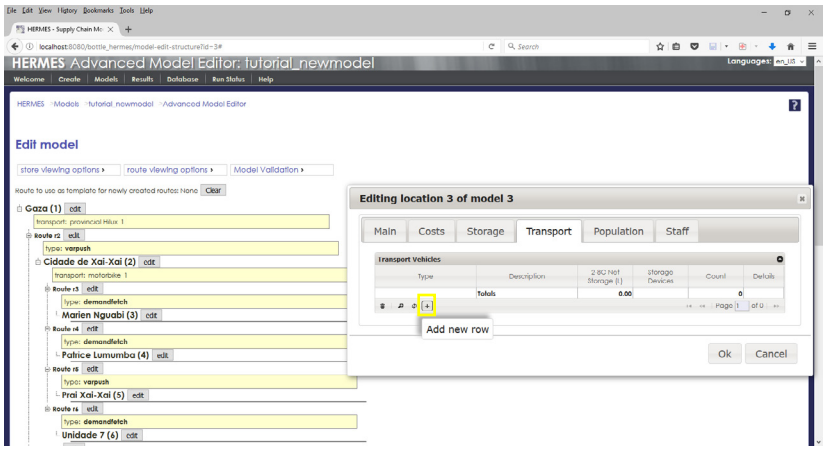
65. First, view the store transport types by clicking on the **“store viewing options”** dropdown box in the upper left corner, then **“store transport”**, then **“view store transport.”** Notice that you can stack the different types of views that you find useful.



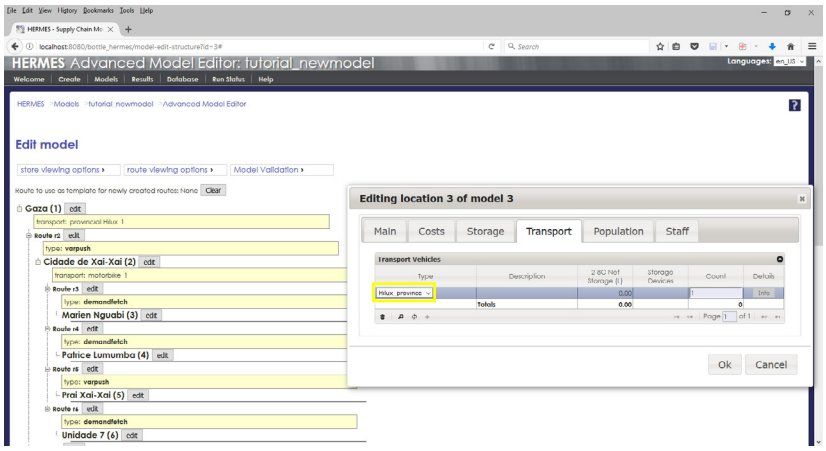
66. You are only adding transport types to the locations whose route types were just changed. Because routes to the other health centers remain varpush, meaning these locations receive deliveries and do not need transport vehicles, the 3 health centers that pick up their vaccines will need a mode of transport in their inventories. Click the **“edit”** button next to Marien Nguabi, then click **“Edit Store.”**



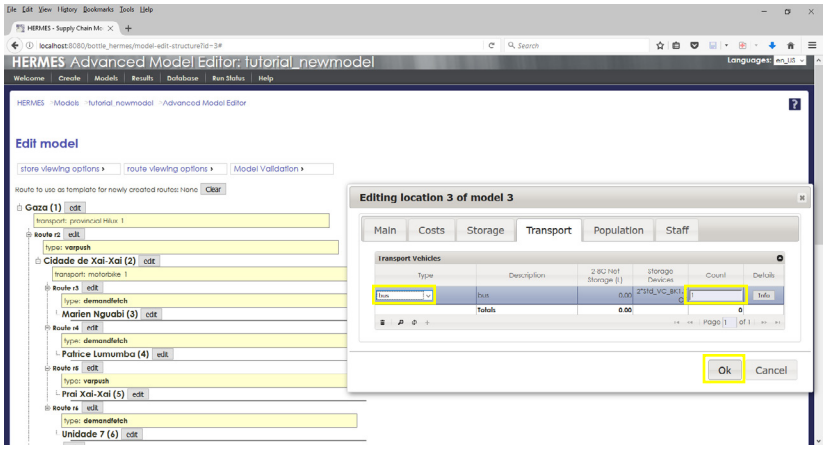
67. Click on the **"Transport"** tab.

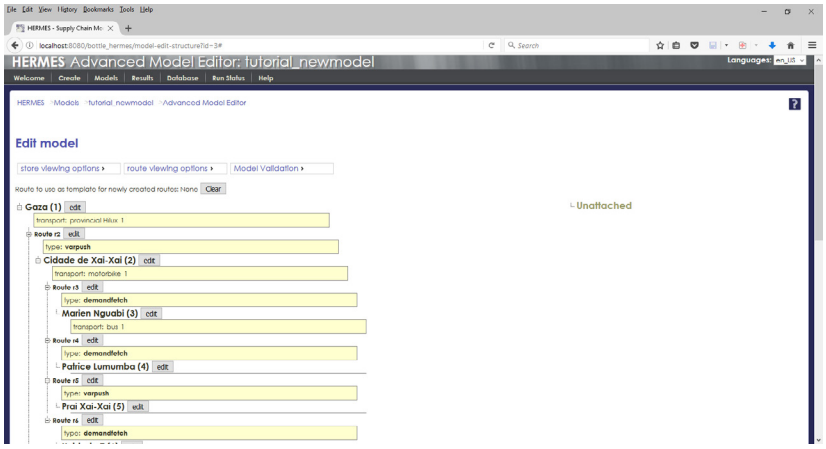


68. Click on the plus sign in the lower left corner of the table to add a new row.

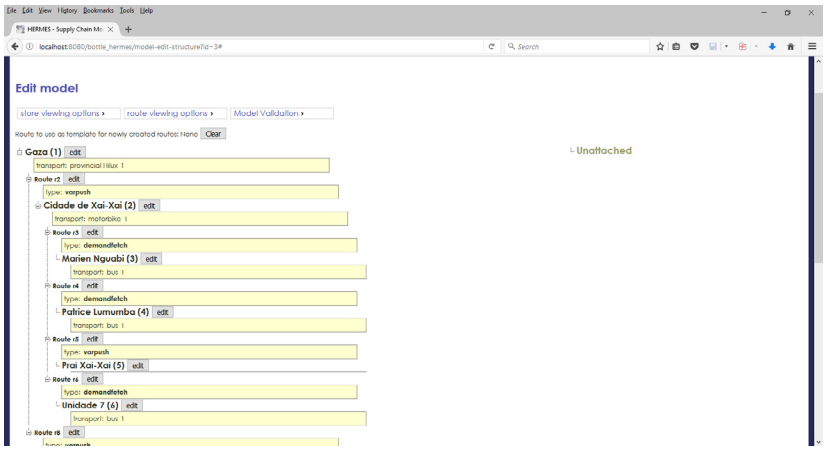


69. Change the type to **“bus”** and leave the count at 1. As shown in the storage devices column, a health worker can carry up to 2 vaccine carriers on each bus ride in this model then click **“Ok.”**

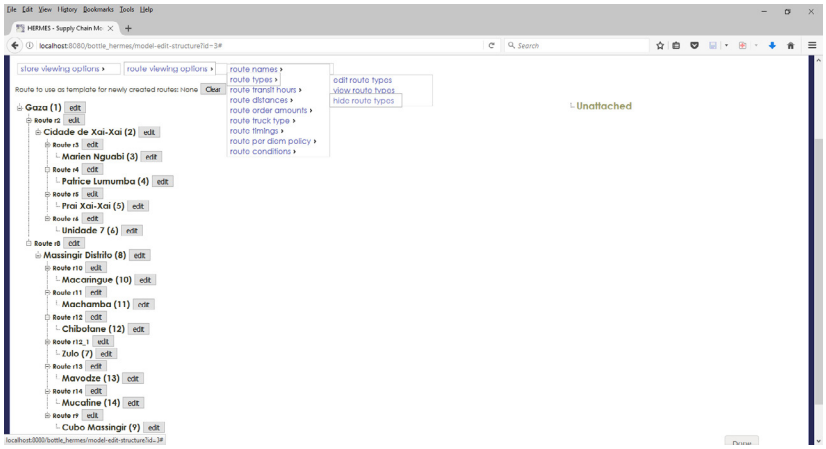




NOTE: Marien Nguabi now has a bus listed underneath it.



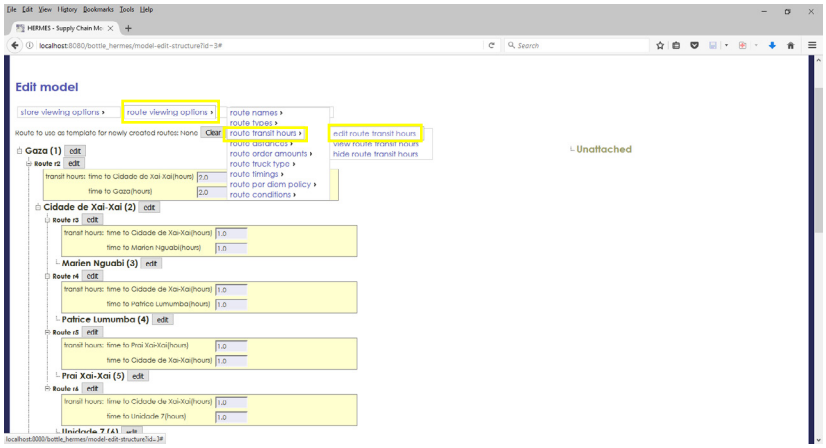
70. Repeat steps 66-69 to add a bus to the other 2 health centers in this district with **"demand-fetch"** route types.



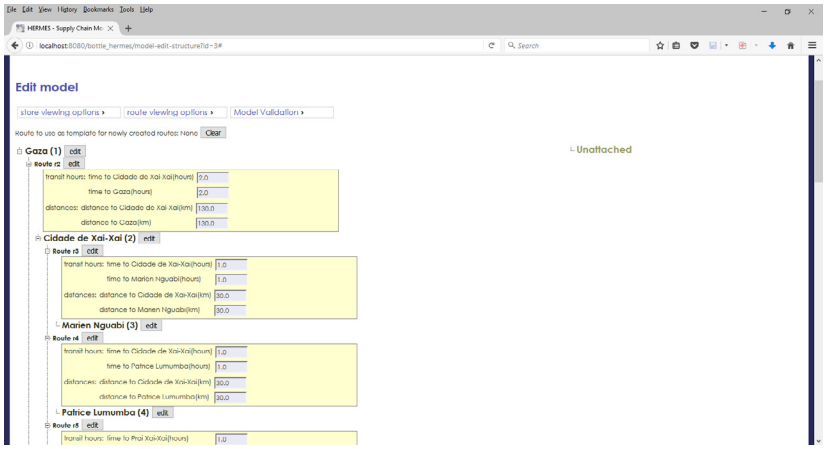
71. Finally, **hide** the store transport view and the route type view (see step 64).

Editing details for all routes

The Advanced Editor allows you to select specific parameters to view and edit for all locations or routes displayed that are displayed. You can stack combinations of view and edit boxes.



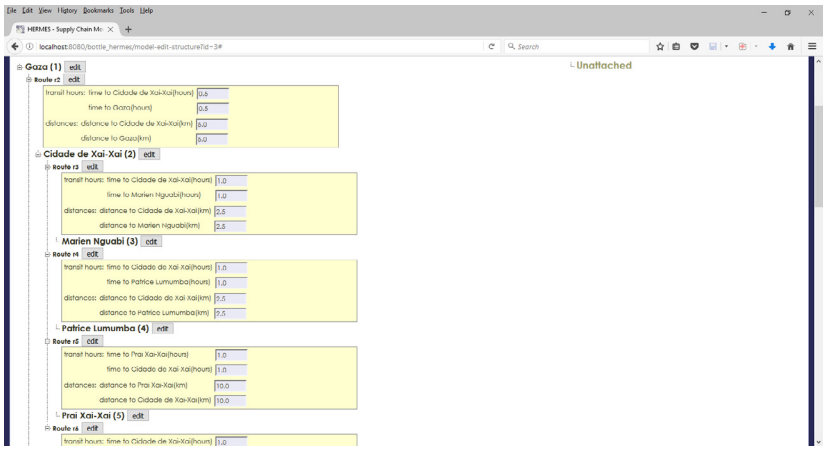
72. Open **“route viewing options,”** click on **“route transit hours”** and then **“edit route transit hours.”**

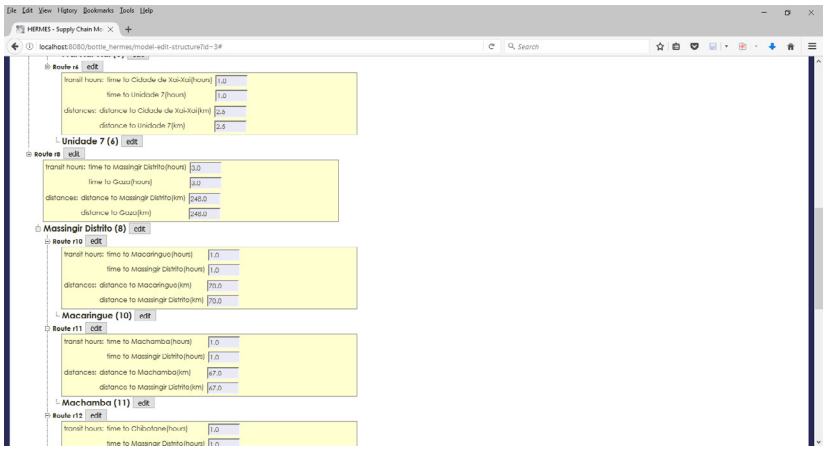


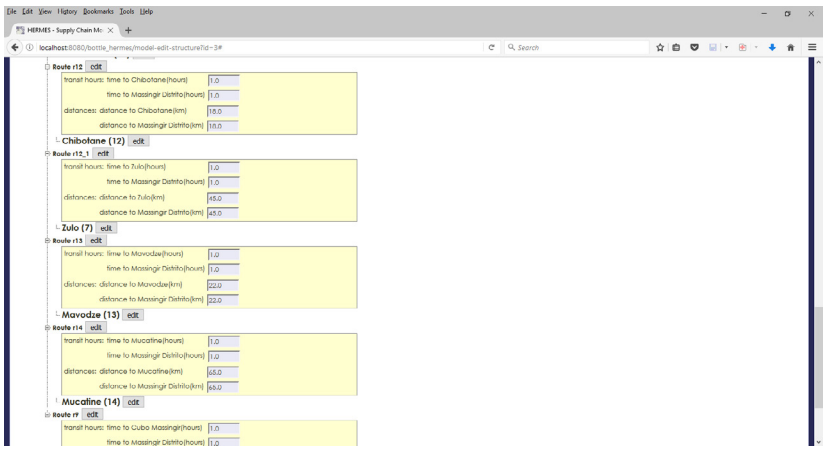
73. Also, open route viewing options, route distances, edit route distances.

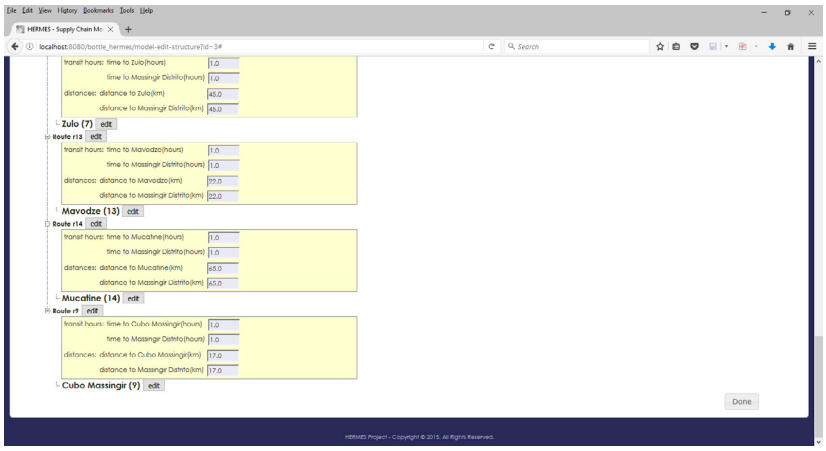
74. The values shown reflect the average one-way distances and transit times you entered in step 8. You can optionally edit these for each individual route to add heterogeneity to the model, using the information in the table below:

Supplier Location	Recipient Location	Leg of trip	Transit time (hours)	Distance (km)
Gaza	**Cidade de Xai-Xai**	to Cidade de Xai-Xai	0.5	5.0
	Return	to Gaza	0.5	5.0
Cidade de Xai-Xai	**Marien Nguabi**	to Cidade de Xai-Xai	1.0	2.5
	Return	to marien Nguabi	1.0	2.5
Cidade de Xai-Xai	**Patrice Lumumba**	to Cidade de Xai-Xai	1.0	2.5
	Return	to Patrice Lumumba	1.0	2.5
Cidade de Xai-Xai	**Prai Xai-Xai**	to Prai Xai-Xai	1.0	10.0
	Return	to Cidade de Xai-Xai	1.0	10.0
Cidade de Xai-Xai	**Unidade 7**	to Cidade de Xai-Xai	1.0	2.5
	Return	to Unidade 7	1.0	2.5
Gaza	**Massingir Distrito**	to Massingir Distrito	3.0	248.0
	Return	to Gaza	3.0	248.0
Massingir Distrito	**Macaringue**	to Macaringue	1.0	70.0
	Return	to Massingir Distrito	1.0	70.0
Massingir Distrito	**Machamba**	to Machamba	1.0	67.0
	Return	to Massingir Distrito	1.0	67.0
Massingir Distrito	**Chibotane**	to Chibotane	1.0	18.0
	Return	to Massingir Distrito	1.0	18.0
Massingir Distrito	**Zulo**	to Zulo	1.0	45.0
	Return	to Massingir Distrito	1.0	45.0
Massingir Distrito	**Mavodze**	to Mavodze	1.0	22.0
	Return	to Massingir Distrito	1.0	22.0
Massingir Distrito	**Mucatine**	to Mucatine	1.0	65.0
	Return	to Massingir Distrito	1.0	65.0
Massingir Distrito	**Cubo Massingir**	to Cubo Massingir	1.0	17.0
	Return	to Massingir Distrito	1.0	17.0


HERMES - Supply Chain Mc
localhost:8080/bottle_hermes/model-edit-structureTid=3#
Unattached
Gaza (1) edit
Route r2 edit
transit hours: time to Cidade de Xai-Xai(hours) 0.5
time to Gaza(hours) 0.5
distances: distance to Cidade de Xai-Xai(km) 5.0
distance to Gaza(km) 5.0
Cidade de Xai-Xai (2) edit
Route r3 edit
transit hours: time to Cidade de Xai-Xai(hours) 1.0
time to Marien Nguabi(hours) 1.0
distances: distance to Cidade de Xai-Xai(km) 2.5
distance to Marien Nguabi(km) 2.5
Marien Nguabi (3) edit
Route r4 edit
transit hours: time to Cidade de Xai-Xai(hours) 1.0
time to Patrice Lumumba(hours) 1.0
distances: distance to Cidade de Xai-Xai(km) 7.5
distance to Patrice Lumumba(km) 7.5
Patrice Lumumba (4) edit
Route r5 edit
transit hours: time to Prai Xai-Xai(hours) 1.0
time to Cidade de Xai-Xai(hours) 1.0
distances: distance to Prai Xai-Xai(km) 10.0
distance to Cidade de Xai-Xai(km) 10.0
Prai Xai-Xai (5) edit
Route r6 edit
transit hours: time to Cidade de Xai-Xai(hours) 1.0


HERMES - Supply Chain Mc
localhost:8080/bottle_hermes/model-edit-structureTid=3#
Route r6 edit
transit hours: time to Cidade de Xai-Xai(hours) 1.0
time to Unidade 7(hours) 1.0
distances: distance to Cidade de Xai-Xai(km) 2.5
distance to Unidade 7(km) 2.5
Unidade 7 (6) edit
Route r8 edit
transit hours: time to Massingir Distrito(hours) 3.0
time to Gaza(hours) 4.0
distances: distance to Massingir Distrito(km) 248.0
distance to Gaza(km) 248.0
Massingir Distrito (8) edit
Route r10 edit
transit hours: time to Macaringue(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Macaringue(km) 70.0
distance to Massingir Distrito(km) 70.0
Macaringue (10) edit
Route r11 edit
transit hours: time to Machamba(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Machamba(km) 67.0
distance to Massingir Distrito(km) 67.0
Machamba (11) edit
Route r12 edit
transit hours: time to Chibotane(hours) 1.0

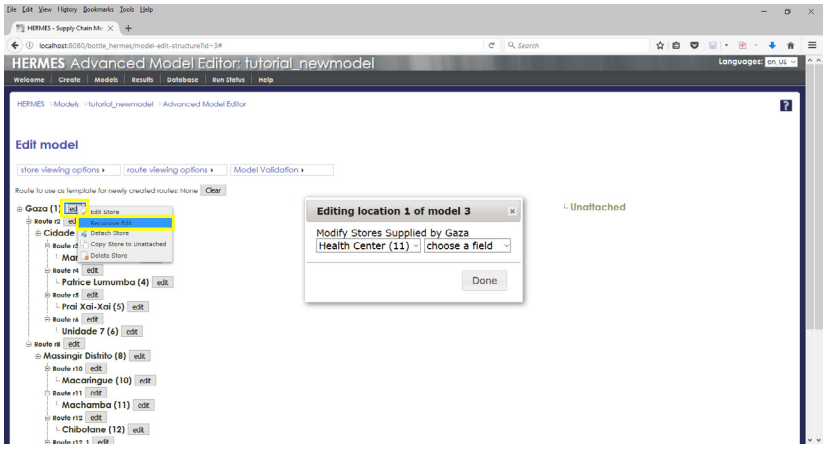

HERMES - Supply Chain Mc
localhost:8080/bottle_hermes/model-edit-structureTid=3#
Route r12 edit
transit hours: time to Chibotane(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Chibotane(km) 18.0
distance to Massingir Distrito(km) 18.0
Chibotane (12) edit
Route r12_1 edit
transit hours: time to Zulo(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Zulo(km) 45.0
distance to Massingir Distrito(km) 45.0
Zulo (7) edit
Route r13 edit
transit hours: time to Mavodze(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Mavodze(km) 22.0
distance to Massingir Distrito(km) 22.0
Mavodze (13) edit
Route r14 edit
transit hours: time to Mucatine(hours) 1.0
time to Massingir Distrito(hours) 1.0
distances: distance to Mucatine(km) 68.0
distance to Massingir Distrito(km) 68.0
Mucatine (14) edit
Route r7 edit
transit hours: time to Cubo Massingir(hours) 1.0



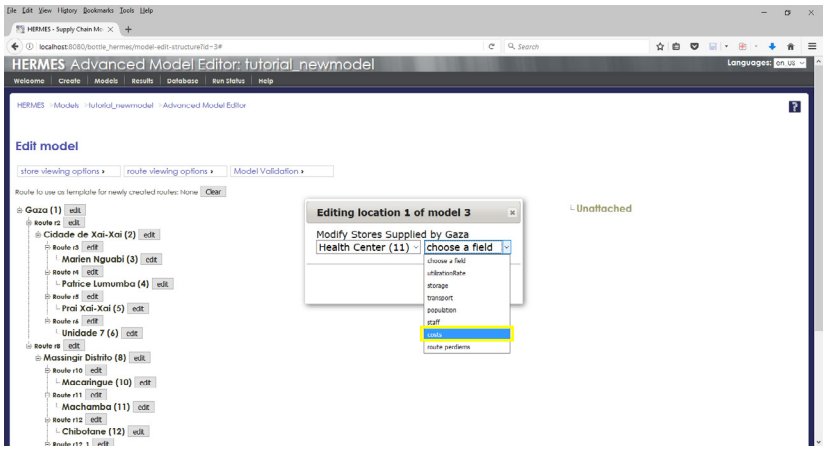
75. Finish by hiding (-) both types of route edit views, transit hours and distances.

Recursive editing

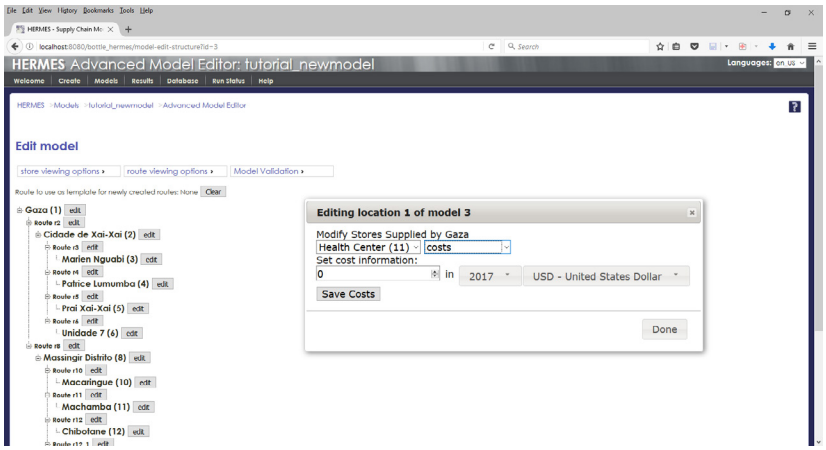
In the last advanced editing option for this tutorial, you will use recursive editing to make a similar change quickly on a large number of locations at a time. Locations are selected by hierarchy, so you can recursively edit the locations at any supply chain level located below a given location in the supply chain (e.g. selecting all health centers under Cidade de Xai-Xai). The cost for all annual building overhead will be changed in this section to reflect the electricity tariffs of **103 USD per year**.

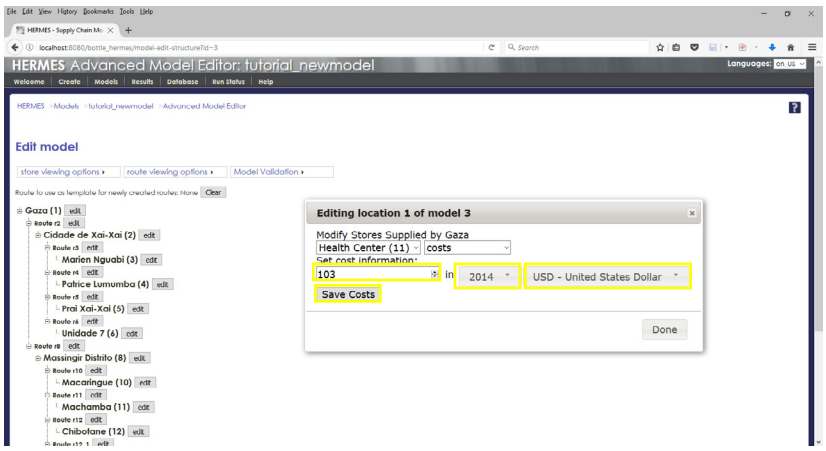


76. Click on the **“edit”** button next to the top location, “Gaza”, and then **“Recursive Edit.”**



77. In this case, you will need to adjust the health center levels and the district levels. You can leave the level selector on Health Center **"Health Center (11)"** for now. Choose **"costs"** for field type from the dropdown menu.





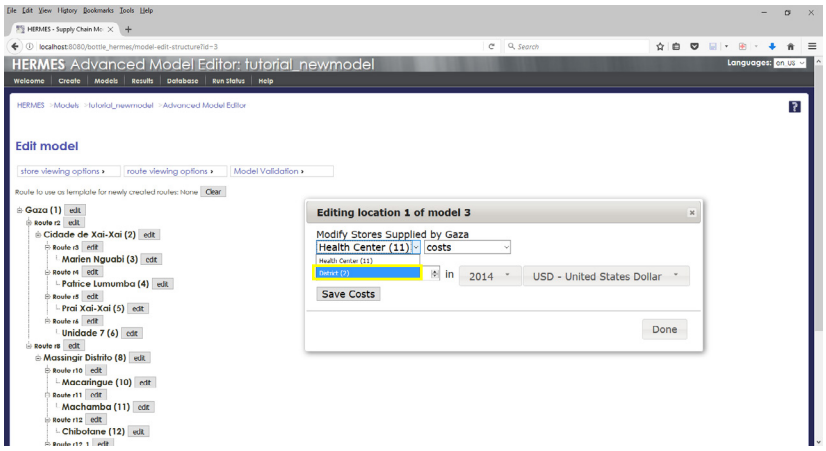
78.

a. Enter 103.00 in **"set cost information"**

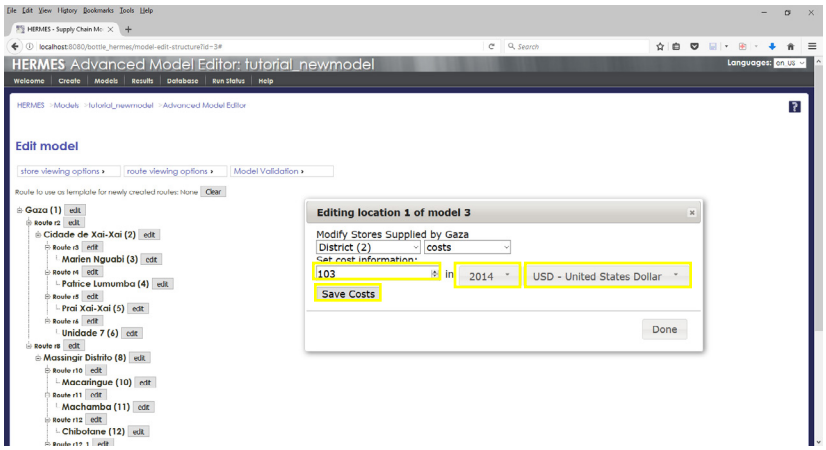
b. Choose year **2014**

c. Choose **USD** – United States Dollar (if not selected by default)

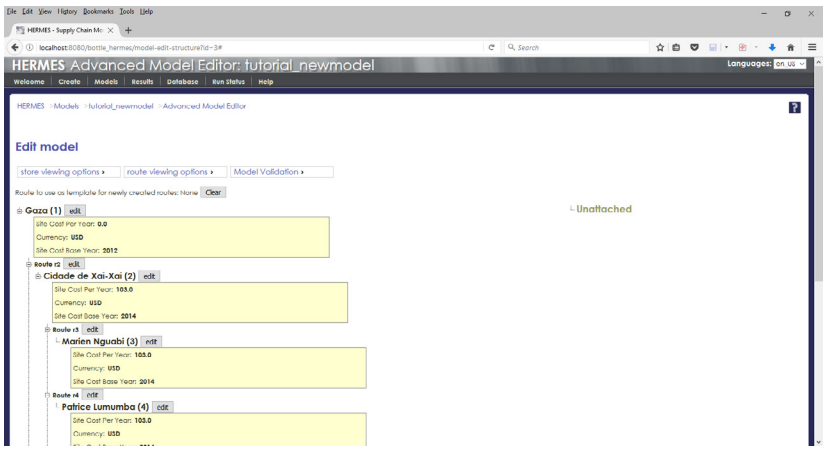
d. Then click **"Save Costs."** You may see a window pop up saying information is being saved, after which the dialog box will revert to the second picture in the previous step.



79. Click on Health Center to activate the dropdown box and select the District level **"District (2)".**



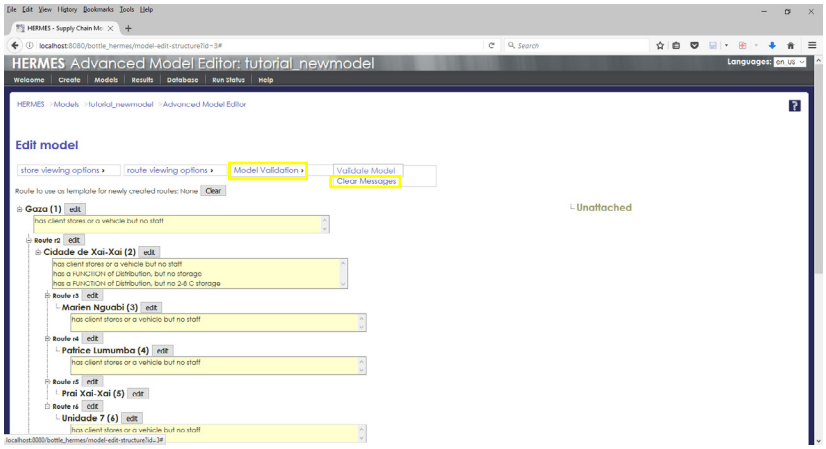
80. Make the same cost changes to the district level as you did for the health center level (**$103, 2014, USD**) then press **"Save Costs."**



81. View the results by choosing **"store viewing options," "store site costs"** and "**view store site costs."** You can see that the costs have been changed at all the locations except the topmost level. You will be making that edit in a later section.

Model validation

The Advanced Model Editor allows you to manually trigger a check of the validity of the model you have created to make sure you have included all necessary information. The validator will list all issues under the relevant locations and routes or in a scrollable window if supply chain network is not fully expanded. See Section 6 for more information on model validation.

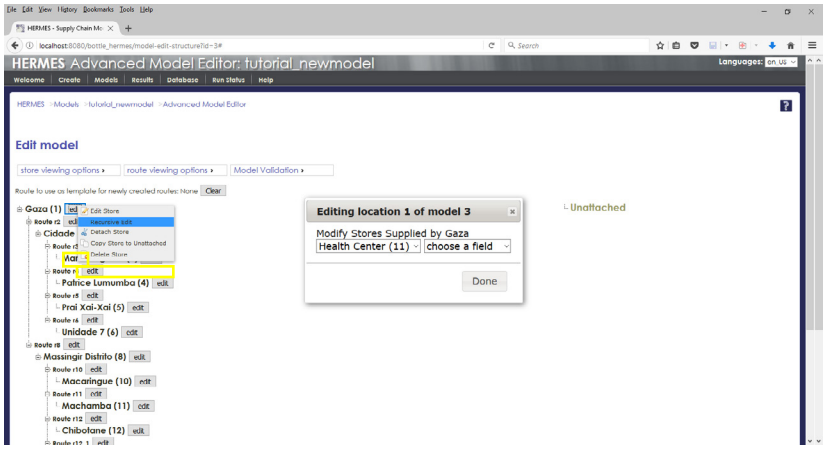


82. Click on the "**Model Validation"** dropdown box near the top middle of the page box and choose **"Clear Messages"** to remove the messages from the screen, so you can begin to address these errors. In future use, it may be helpful to copy these errors to a separate document for reference.

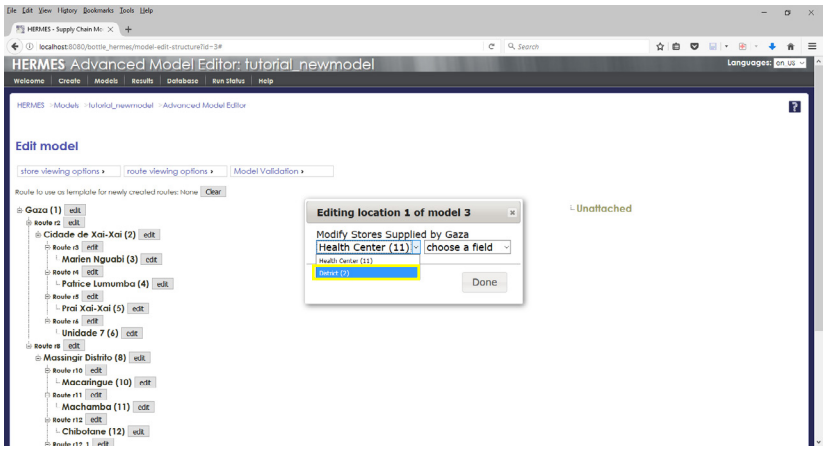
NOTE: Many of the locations have a complaint that they are missing staff.

Recursive and other editing, take 2

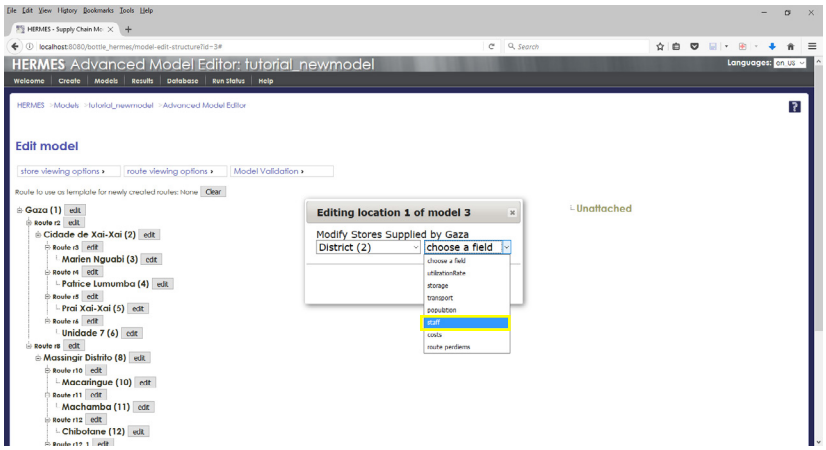
Since no staff has been added to the model, you will use a combination of recursive editing and specific store editing to update the staff at the different locations. In this model, we will assume that different locations at a given supply chain level have the same number and types of staff.



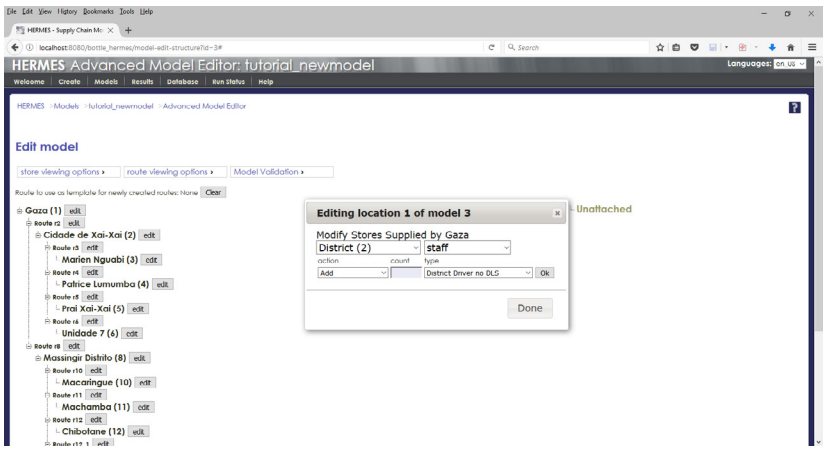
83. Click the **"edit"** button next to the Gaza store and then **"Recursive Edit."**



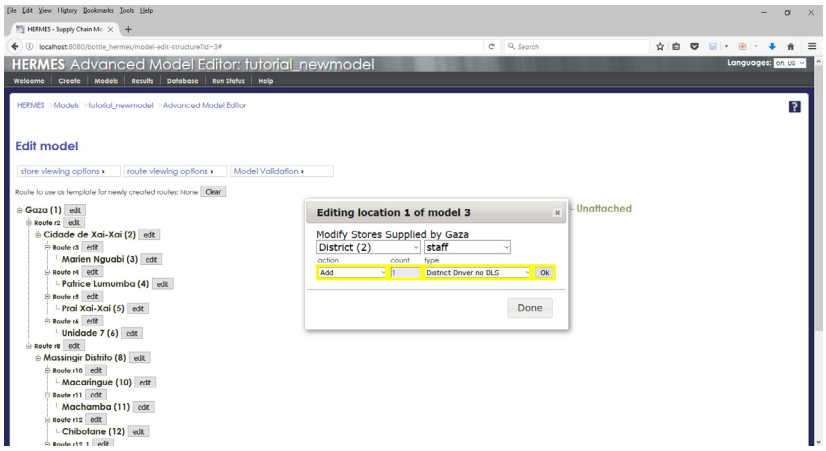
84. Then select **“District (2)”** from the dropdown menu.



85. Next, choose **“staff”** from the **“choose a field”** dropdown menu.

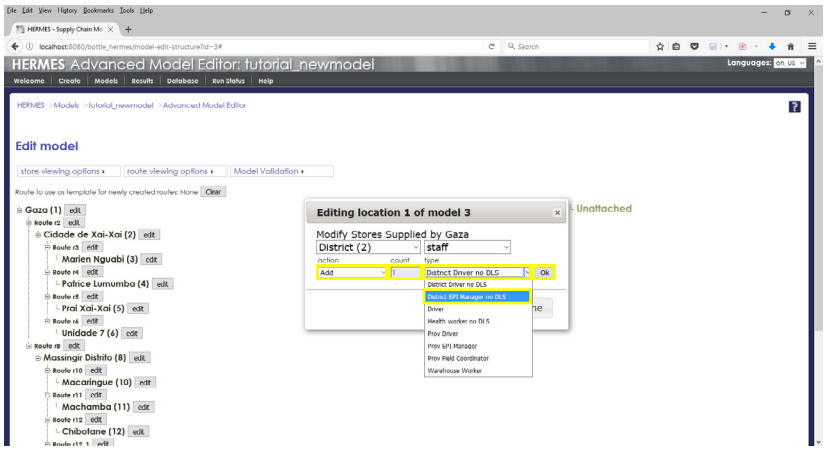


This dialogue box will then open.

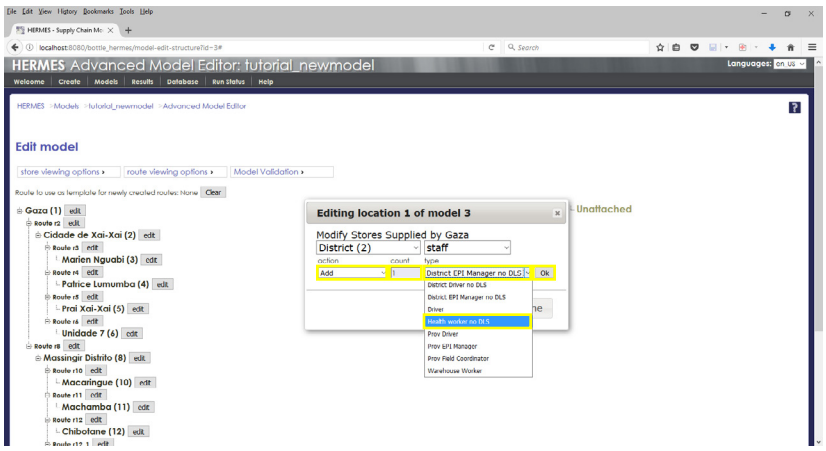


86. Leave the action as **“Add”** and type **1** into the count box and leave type as **“District Driver no DLS”** then click **“Ok.”** There might be a message box that flashes as the update is made and then the count box will be empty.

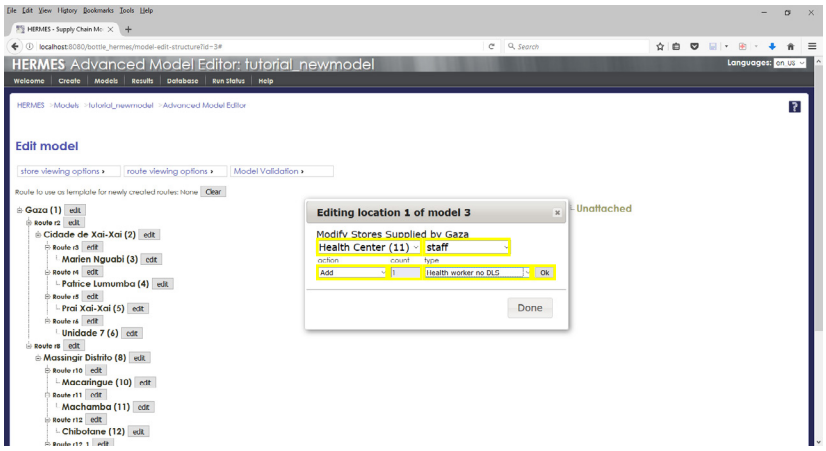
NOTE: Do not click on **“Done”** until step 90.



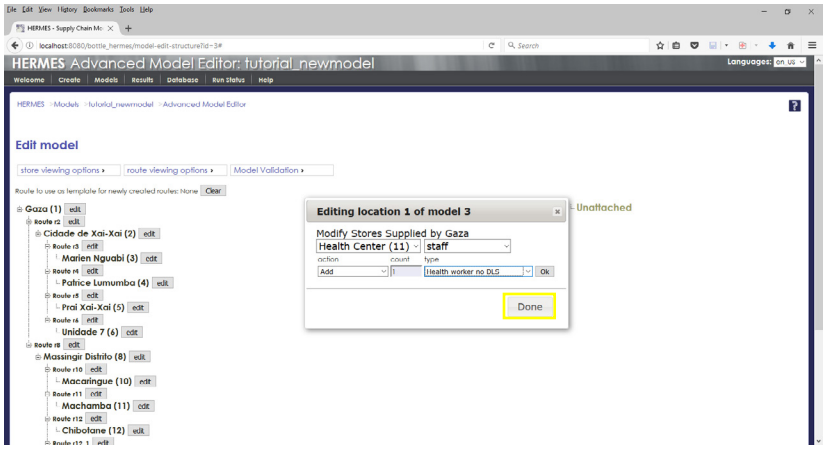
87. Leave **“Add”** for action, type **1** into count, change type to **“District_EPI_Manager_no_DLS”** from the dropdown menu and click **“Ok.”**



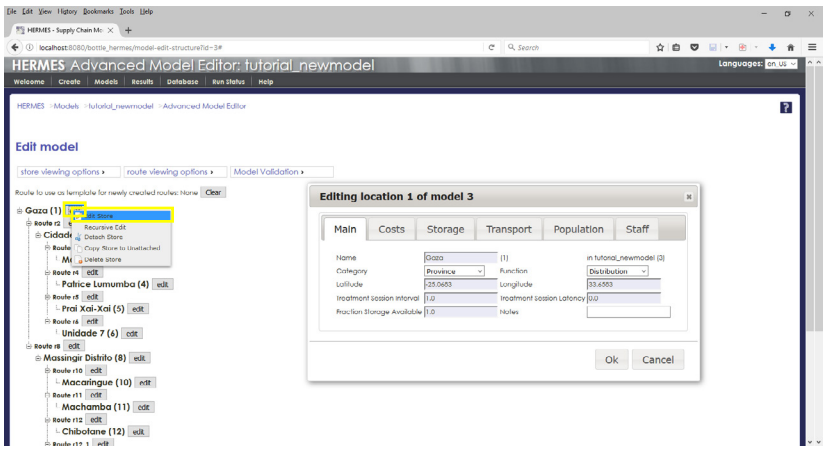
88. Similarly, leave **“Add”** for action, add **1** into count, change type to **“Health Worker no DLS”** from the dropdown menu and click **“Ok.”**



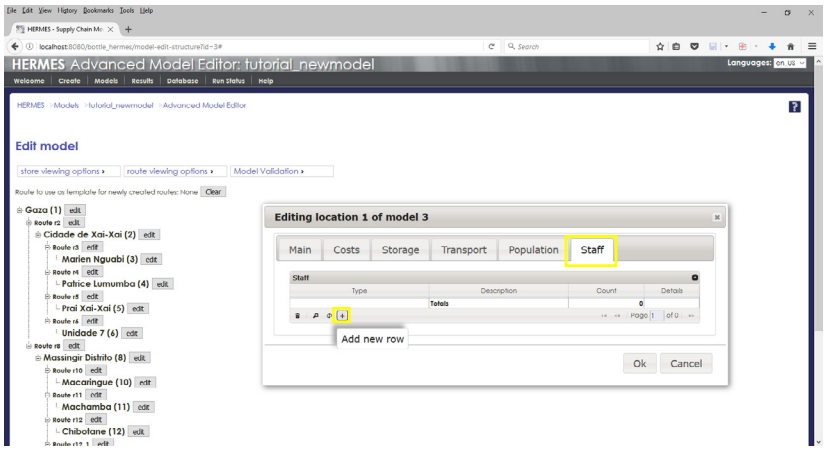
89. Change the level to **"Health Center"**, leave the field as **"staff,"** leave **"Add"** for action, add 1 to count, change type to **"Health worker no DLS"** from dropdown menu and press **"Ok."**



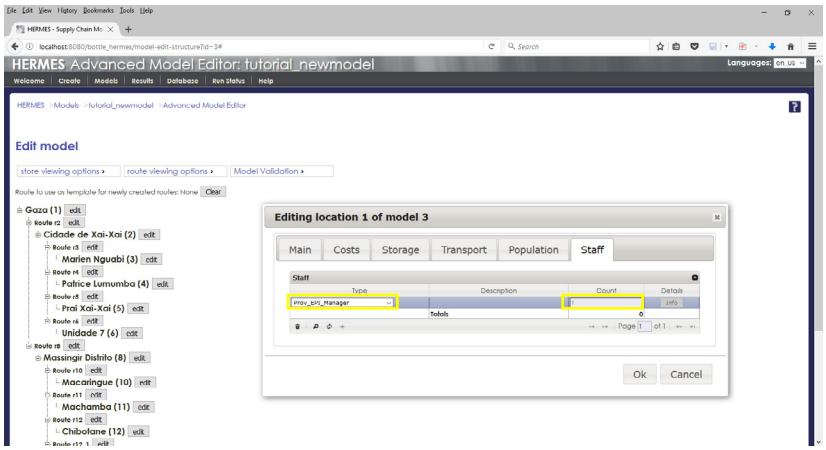
90. Click the **"Done"** button to finish recursively editing.



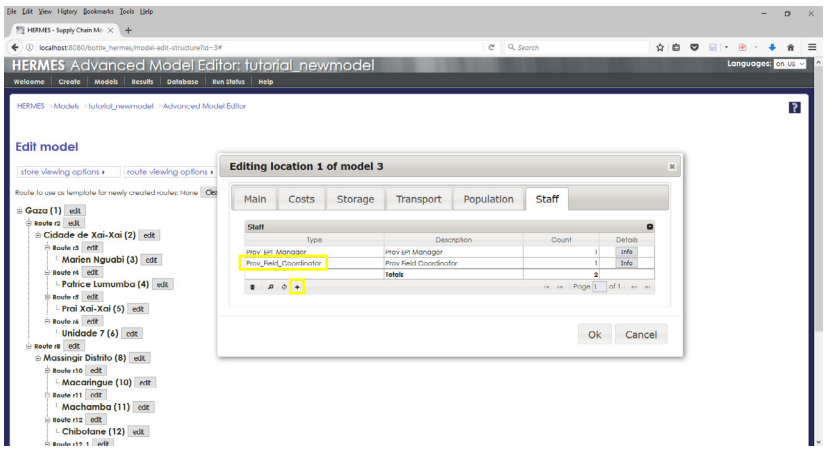
91. Now click the **"edit"** button next to the Gaza location and choose **"Edit Store."**



92. Click the **“Staff”** tab and click the **“+”** symbol in the lower left of the table to add a row.



93. You need to add a **“Prov_EPI_ Manager”** so leave the row as is and hit the “enter” or “return” on your keyboard.

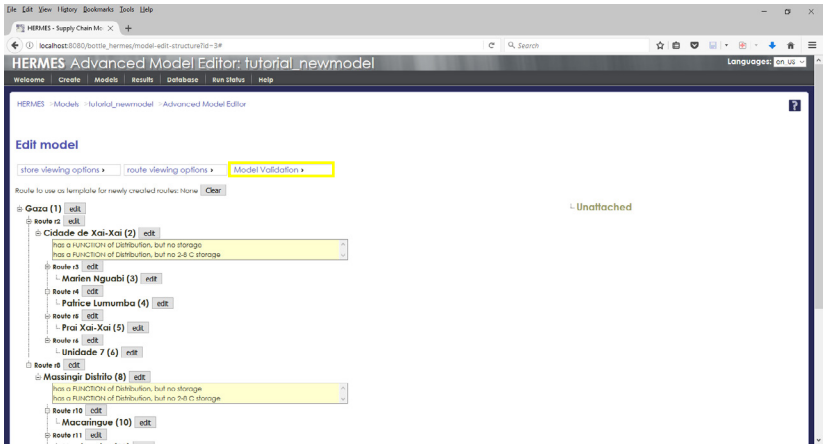


94. Click the **“+”** symbol to add another row, change the Type to **“Prov_Field_Coordinator”** from the dropdown menu and hit enter.

95. Lastly, add a **“Prov Driver”**, then click **“Ok”** to close the edit dialog box.

Model validation, take 2

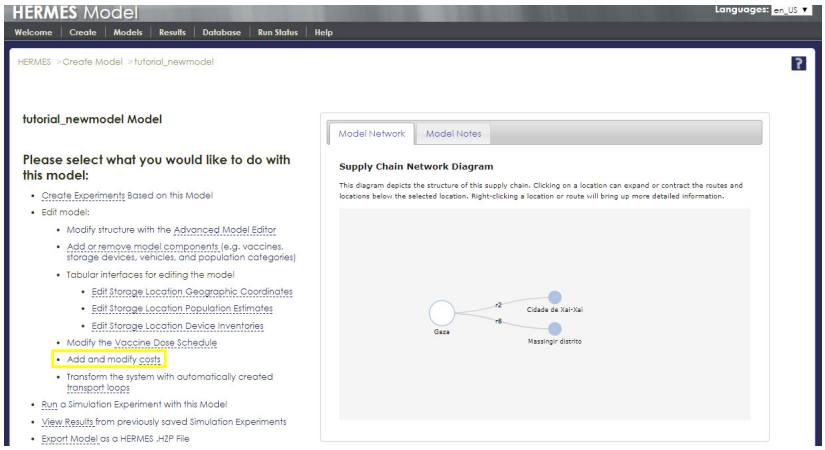
The Advanced Model Editor allows you to manually trigger a check of the validity of the model you have created to make sure you have included all necessary information. The validator will list all issues under the relevant locations and routes or in a scrollable window if supply chain network is not fully expanded. See Section 6 for more information on model validation.



96. Click on the **"Model Validation"** dropdown box near the top middle of the page.

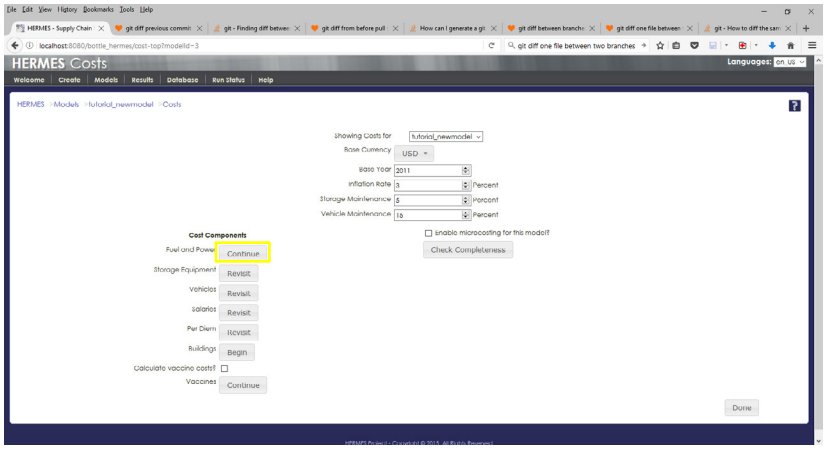
NOTE: there are no more error messages about staff.

Part 10: Enter cost details

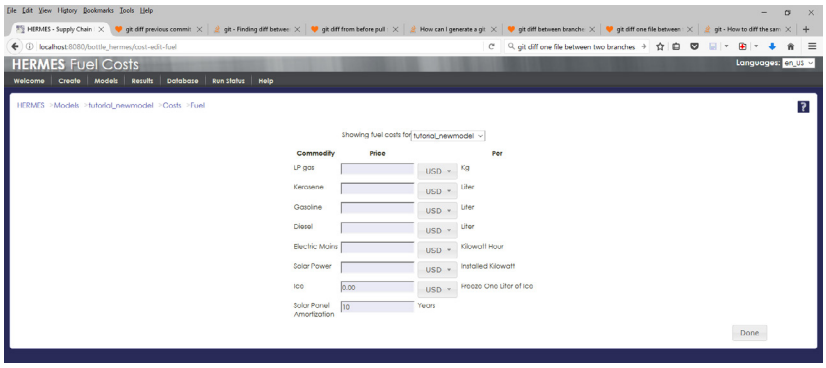


97. Choose **"Add and modify costs"** from the main model page.

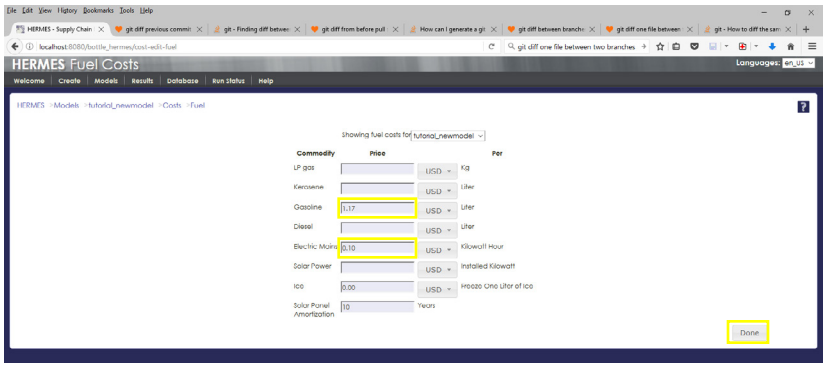
Fuel and power



98. Most of the defaults on this page will be used in your new model. First change the “Base Year” dropdown to **“2014”** instead of 2011. Then, click the **“Continue”** button to the right of the “Fuel and Power” cost component on the left hand side.

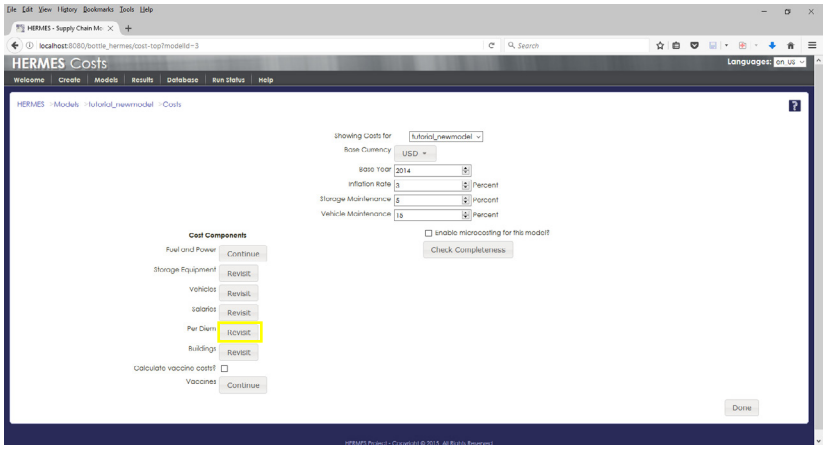


This screen will then appear.

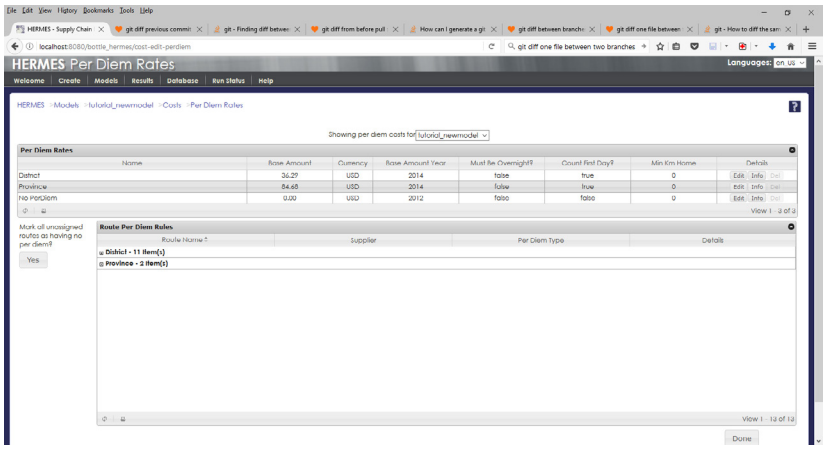


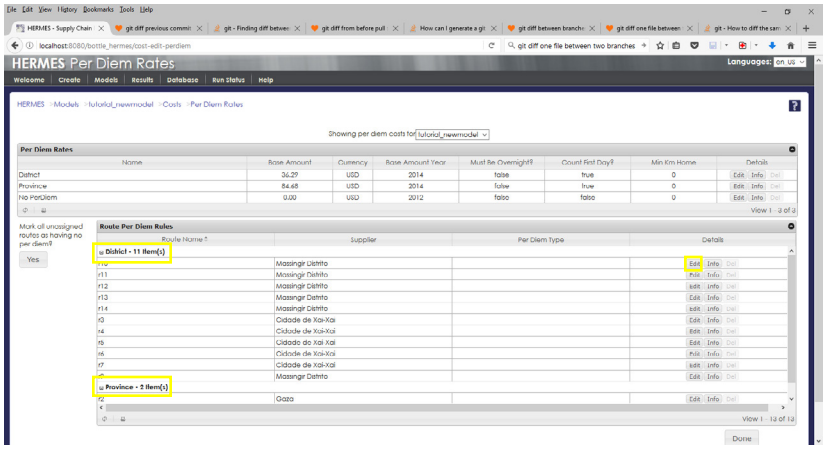
99. Update the prices for **“Gasoline”** to **“1.17 USD per liter”** and “Electric Mains” **“0.10 per kWh”** then press **“Done”** to return to the main costing page.

Per diems

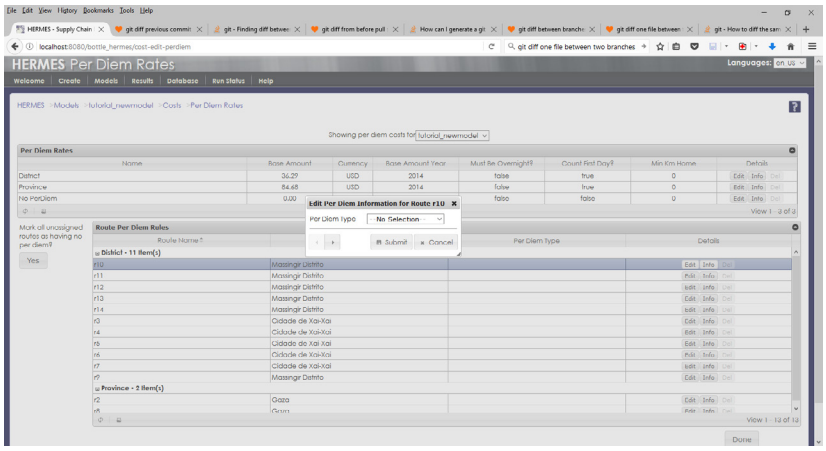


100. Click on the **"Revisit"** button next to the Per Diem cost component.

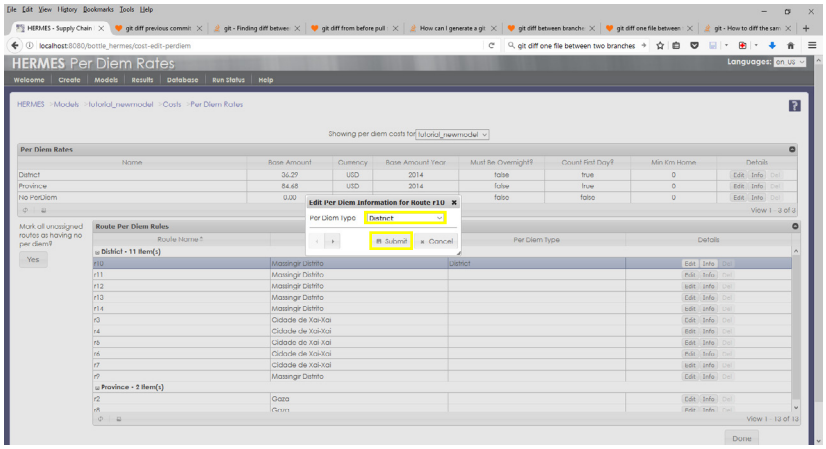




101. In the lower table, "Route Per Diem Rules," click on the "**+**" next to "District" and "Province" to expand the locations below. Then click **"Edit"** next to the first route under District **"r10."**

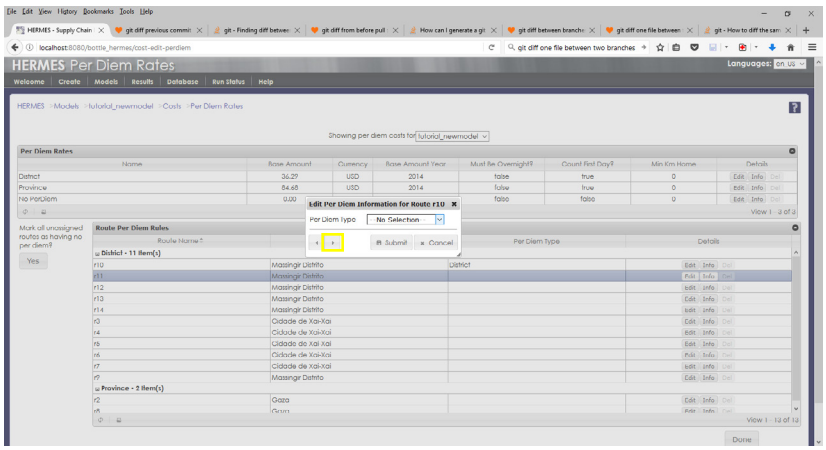


This dialogue box below will then appear.



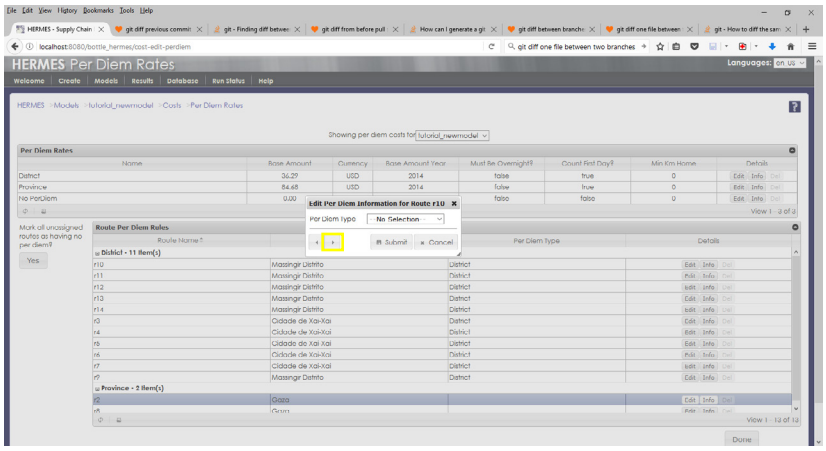
102. Choose **“District”** from the “Per Diem Type” dropdown menu then click the **“Submit”** button.

NOTE: the table has been updated appropriately.

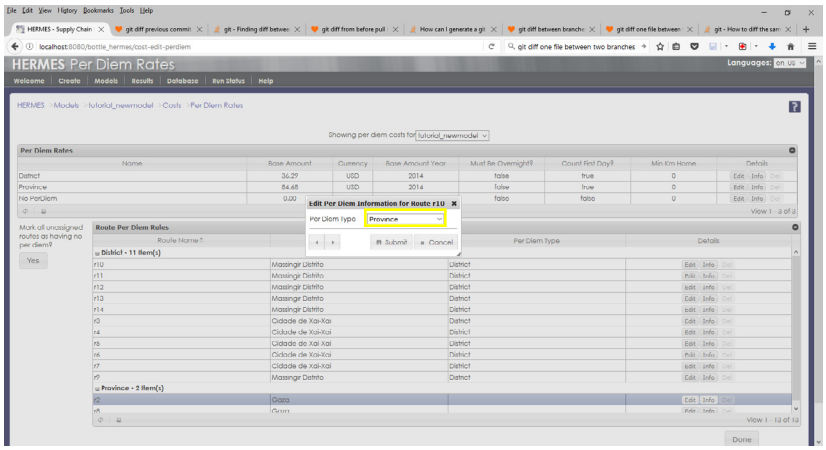


103. Click the right arrow button in the Edit dialog box to advance to the next route.

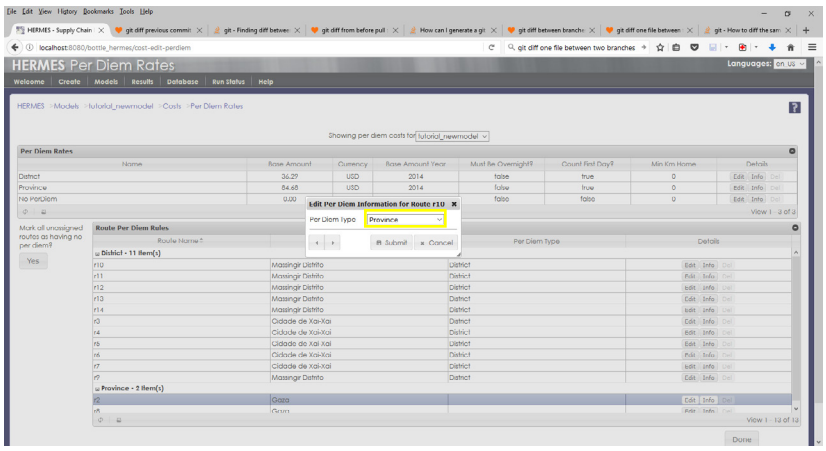
NOTE: You’ll notice that **“r11”** is now highlighted in the table.



104. Repeat step 102 for the rest of the District routes.

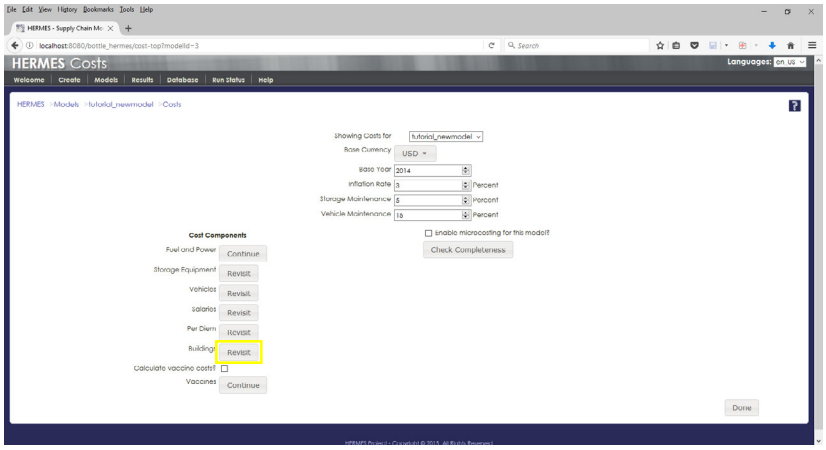


105. You can continue to use the right arrow button to edit the Province routes the same way that you did the District routes, just make sure to choose **"Province"** as the per diem type from the dropdown menu.

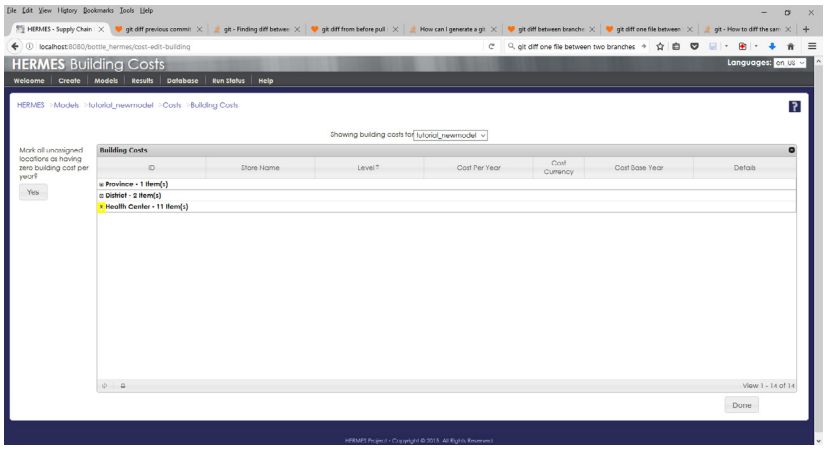


106. Click **"Done"** when finished to return to the main costing page.

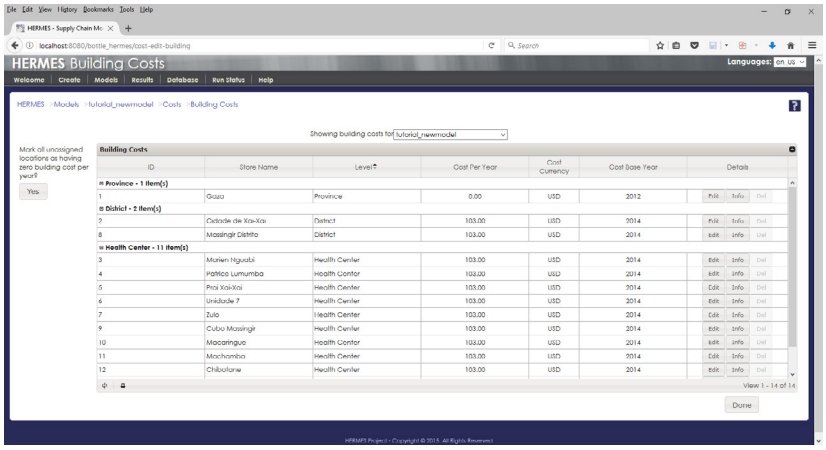
Buildings

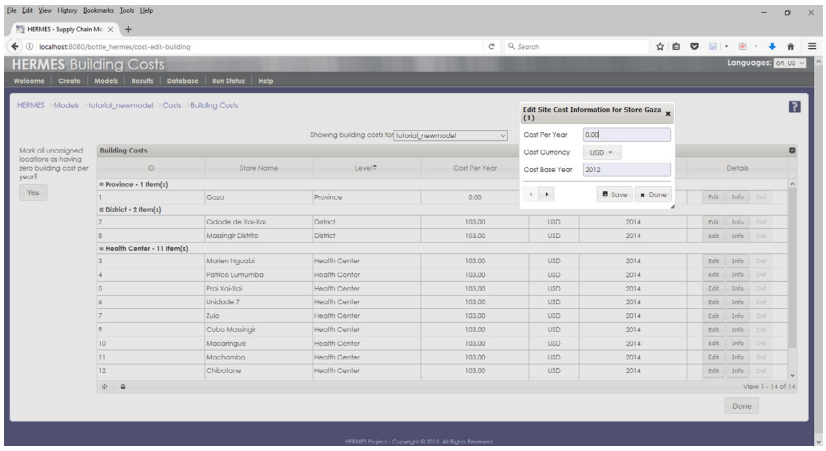


107. Click on the **“Revisit”** button next to the Buildings cost component.

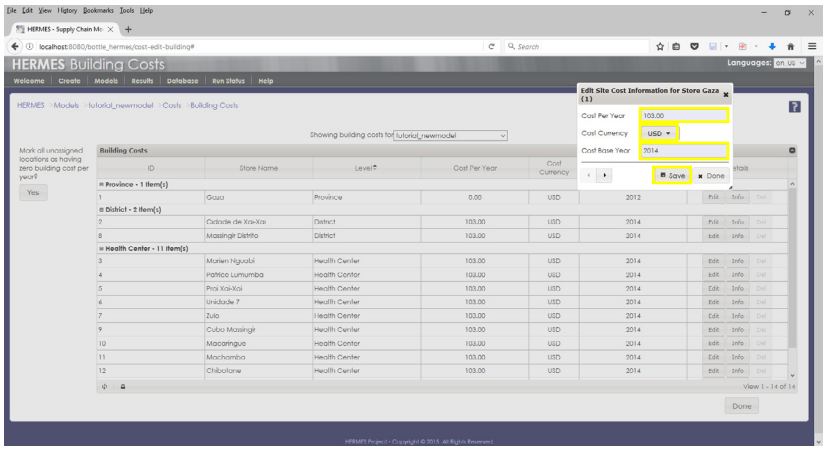


108. Click the **“+”** next to “Province,” “District” and “Health Center” to expand the locations.



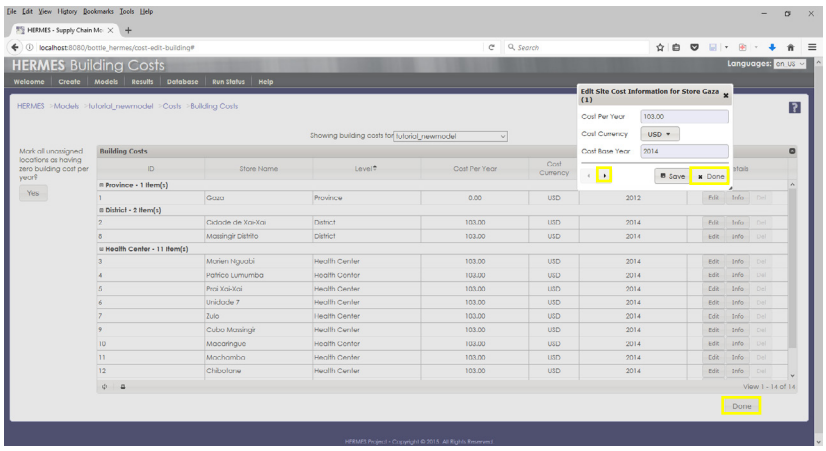


109. This table should be filled out from the recursive editing exercise earlier. However, recursive editing can only change levels below the one which you select, and you did not update Gaza at that time. Click the **"Edit"** button in the first row (Province) to edit the information for the Gaza location.



110. Update "Cost Per Year" to **"103.00"** and "Cost Currency" to **"USD"** with **"2014"** as the "Cost Base Year" then click **"Save."**

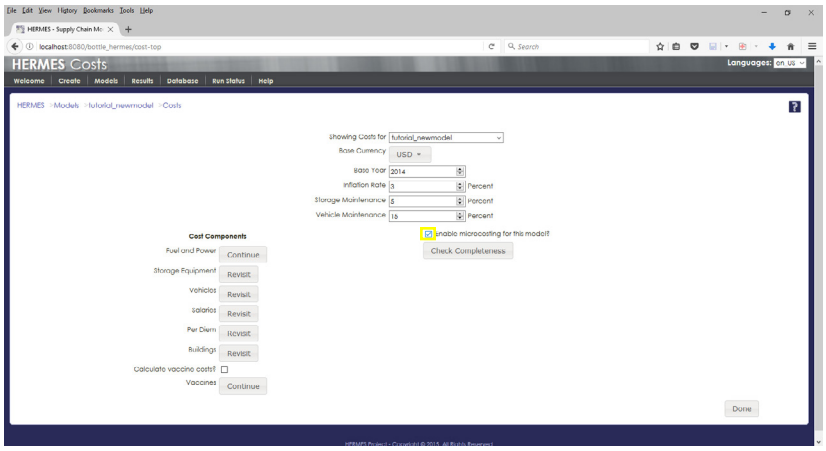
NOTE: You should see that the table has been updated with your input.



a. If you have other edits to make, you can click the right and left arrow buttons in the edit dialog box to move through the table and make adjustments.

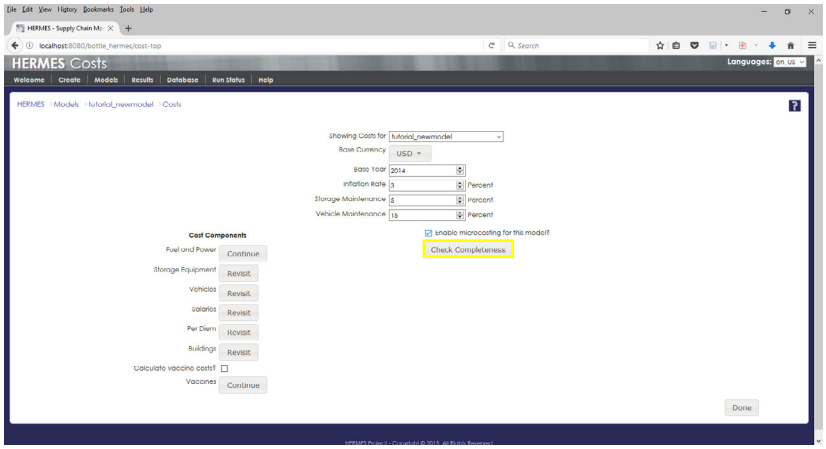
b. For now, click **"Done"** in the edit dialog box.

c. Then click **"Done"** at the bottom corner of the page to return to the costing page.

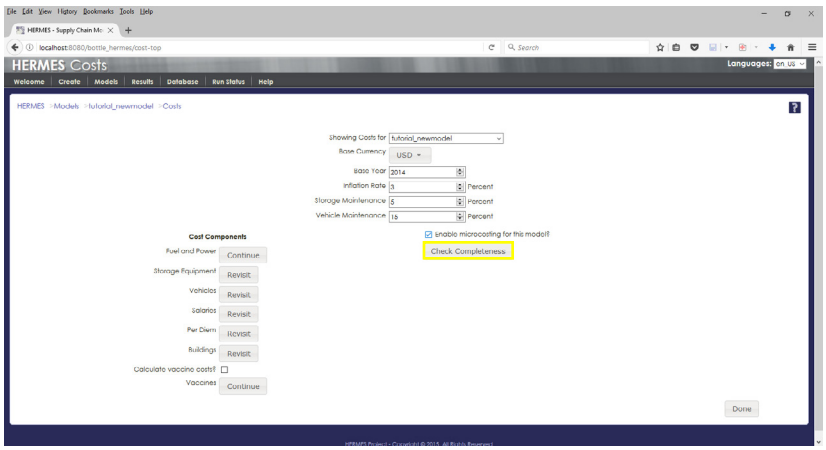


111. Finally, check the **"Enable microcosting for this model?"** box.

NOTE: Without checking this, no costing breakdowns will be performed when you go to run the model.



112. The **"Check Completeness"** button performs validation of the costing parameters. Click on it to see what things might still need to be updated.



After clicking on the **"Check Completeness"** button, the below dialogue box should appear. Then click the **"Done"** button at the bottom of the page to return to the model open page.

NOTE: The next tutorial on running a model and exploring results covers how to address these cost errors.

Next Steps

You have now completed the tutorial “Creating a New Vaccine Supply Chain Model”. Please proceed to the second tutorial “Running Your New Model & Viewing Results” to learn different measures of supply chain performance and operations and how seemingly small changes in the system can have significant effects.

1. Haidari LA, Wahl B, Brown ST, Privor-Dumm L, Wallman-Stokes C, Gorham K, Connor DL, Wateska A, Schreiber B, Dicko H. One size does not fit all: The impact of primary vaccine container size on vaccine distribution and delivery. Vaccine. 2015;33(28):3242-3247.

2. Assi T-M, Brown ST, Djibo A, Norman BA, Rajgopal J, Welling JS, Chen S-I, Bailey R, Kone S, Kenea H. Impact of changing the measles vaccine vial size on Niger’s vaccine supply chain: a computational model. BMC Public Health. 2011;11(1):1.

3. Lee BY, Cakouros BE, Assi TM, Connor DL, Welling JS, Kone S, Djibo A, Wateska AR, Pierre L, Brown ST. The impact of making vaccines thermostable in Niger’s vaccine supply chain. Vaccine. 2012;30(38):5637-5643.

4. Lee BY, Wedlock PT, Haidari LA, Elder K, Potet J, Manring R, Connor DL, Spiker ML, Bonner K, Rangarajan A, Hunyh D, Brown ST. Economic impact of thermostable vaccines. Vaccine. 2017;35(23):3135-3142.

5. Norman BA, Nourollahi S, Chen S-I, Brown ST, Claypool EG, Connor DL, Schmitz MM, Rajgopal J, Wateska AR, Lee BY. A passive cold storage device economic model to evaluate selected immunization location scenarios. Vaccine. 2013;31(45):5232-5238.

6. Haidari LA, Brown ST, Wedlock P, Connor DL, Spiker M, Lee BY. When are solar refrigerators less costly than on-grid refrigerators: A simulation modeling study. Vaccine. 2017;35(17):2224-2228.

7. McCarney S, Robertson J, Arnaud J, Lorenson K, Lloyd J. Using solar-powered refrigeration for vaccine storage where other sources of reliable electricity are inadequate or costly. Vaccine. 2013;31(51):6050-6057.

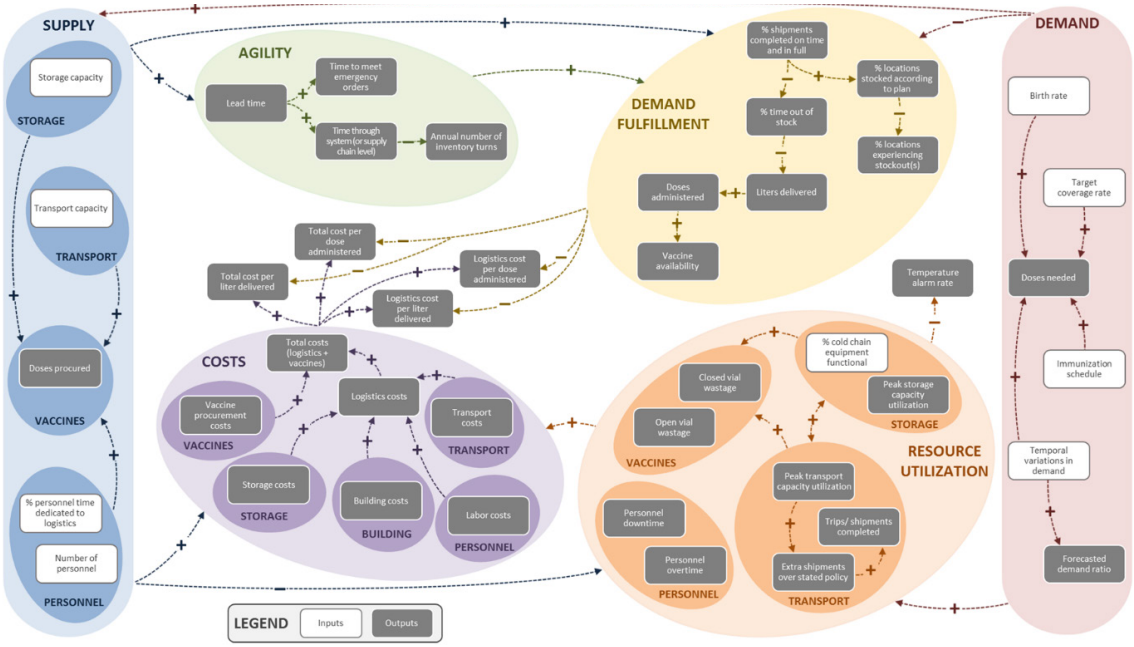
8. Haidari LA, Connor DL, Wateska AR, Brown ST, Mueller LE, Norman BA, Schmitz MM, Paul P, Rajgopal J, Welling JS. Only adding stationary storage to vaccine supply chains may create and worsen transport bottlenecks. Journal of public health management and practice: JPHMP. 2013;19(0 2):S65.

Tutorial 2 | Running Your New Model And Viewing Results

Now that you have a model to run, this tutorial will walk you through the process of fixing any errors, running the model and analyzing the results.

HERMES provides a comprehensive results page including a number of indicators that can help the user analyze the function and cost of a given supply chain. The graphic below illustrates these different measures within a few categories: supply, agility, costs, demand fulfillment, resource utilization and demand.

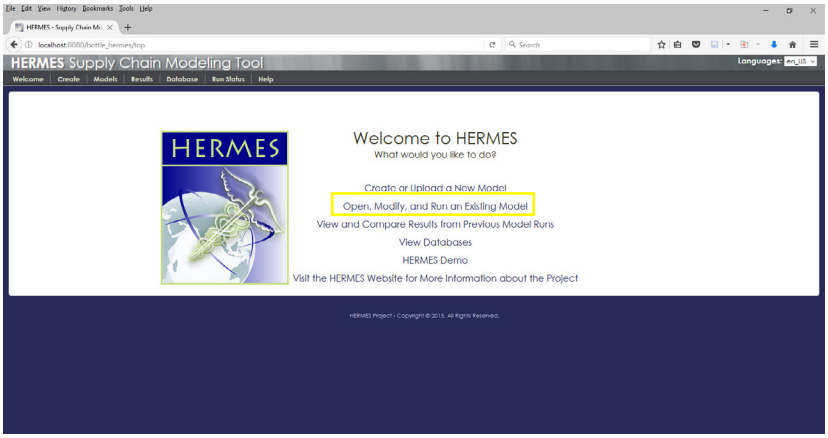
Map of Different Vaccine Supply Chain Efficiency Measures



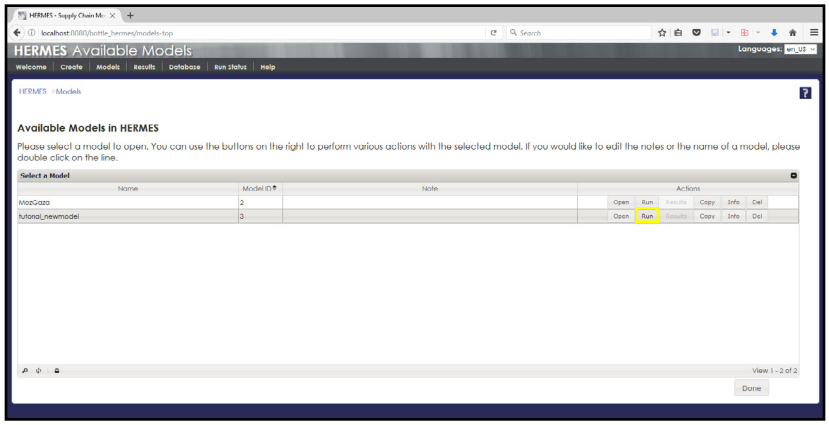
In this tutorial, you will validate, edit and run simulations of your vaccine supply chain model and explore the different types of results that are available in six different visualizations: tabular form, histograms, bar charts, tree maps, geographic conceptions and a downloadable Results Spreadsheet. These results will include outcomes for vaccine availability, doses procured and used, open vial wastage, storage conditions and costs (*including costs for each of storage, transport, personnel and vaccines*).

This tutorial utilizes the model you created in the **"Creating a new model"** tutorial (*Tutorial 1*). You can also find this model in the tutorial materials provided to you.

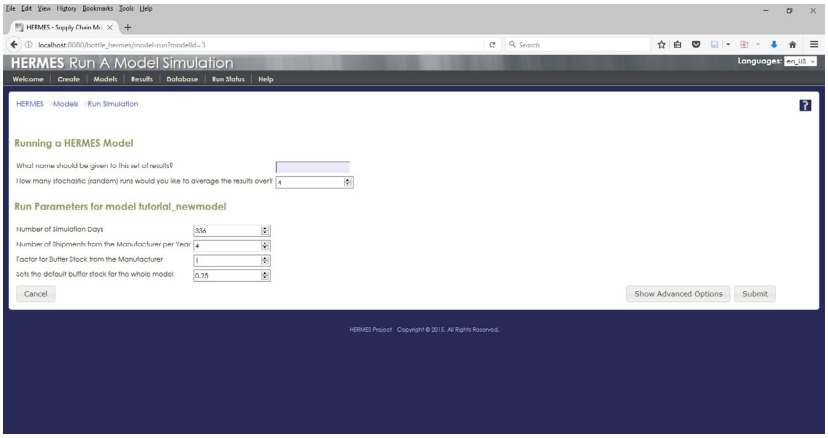
Part 1: Start run



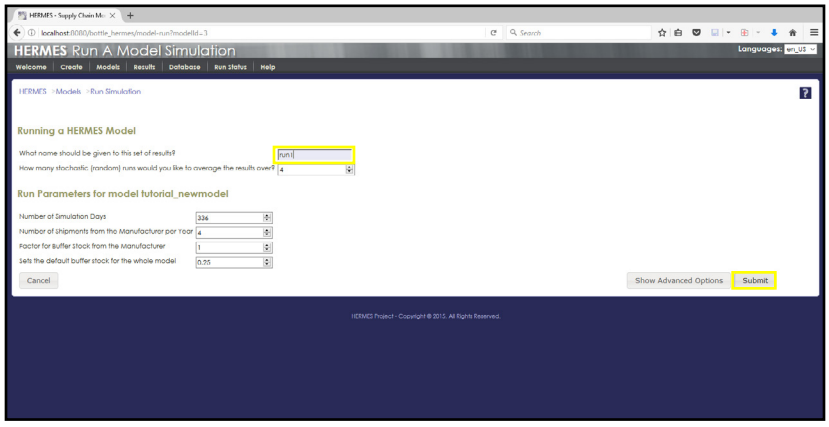
1. On the Welcome Page, click **"Open, Modify and Run and Existing Model"**.



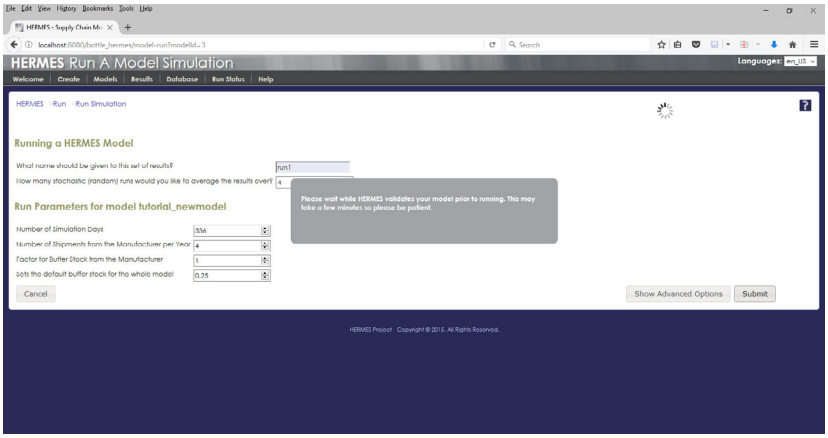
2. Click on the **"Run"** button in the **"tutorial_newmodel"** row.



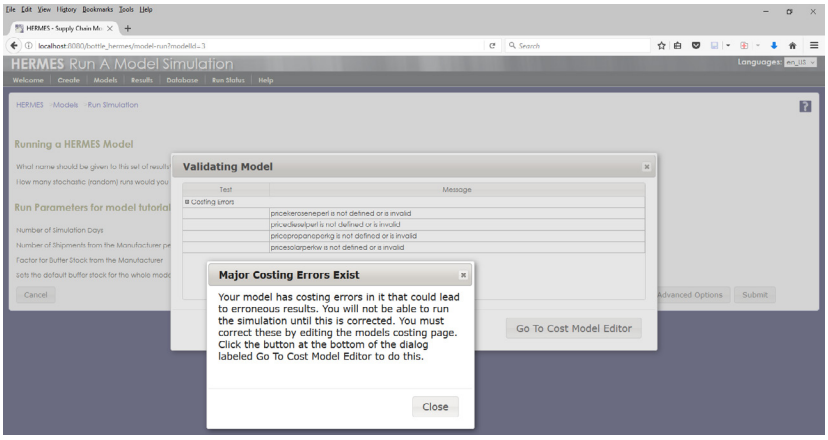
3. This opens the page for running a model simulation. Here you will enter a name for this set of results and specify the number of times you wish to run the model when generating these results. To better capture the day-to-day variation that occurs in the real world, HERMES models are theoretical (*unless otherwise specified in the parameters*). This means each run of the model will generate somewhat different results. For example, the daily demand at an immunizing location is not going to be the same every day-- some days will have more patients than others at any given location. Thus, HERMES generates a flux of daily demand.



4. In the text box, enter run1 for this set of results. Leave the rest of the parameters with their default settings. Then click the **"Submit"** button.



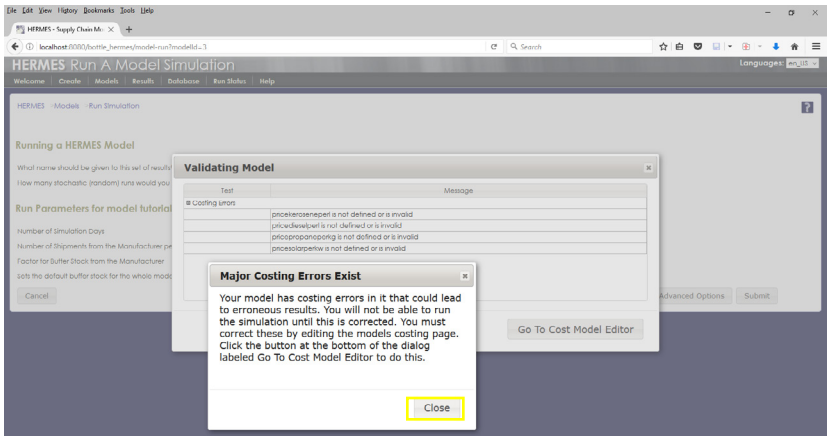
5. HERMES will automatically validate your model before trying to run it.



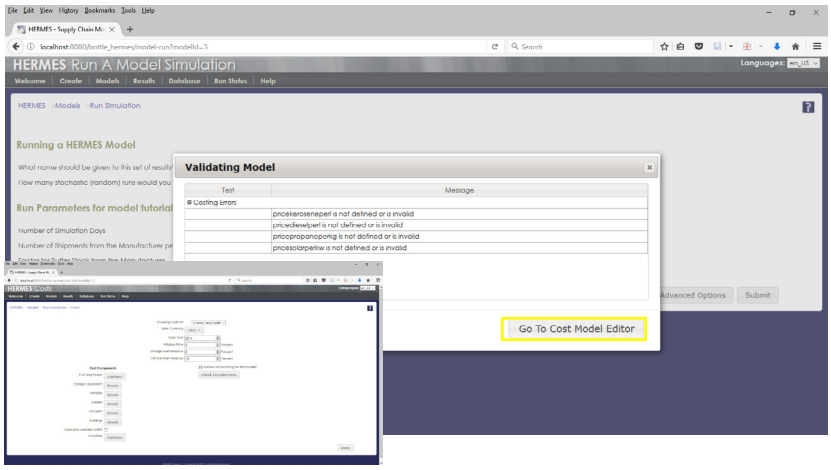
6. If there are errors, you will get one or more error messages (*for structure and cost errors*) as well as a dialog box listing the errors with buttons to take you to the location to fix them.

Part 2: Fix Errors

In this case, the model you created did not include costs for all the different types of fuel and power. You will correct these errors before coming back to try to run the simulation again.

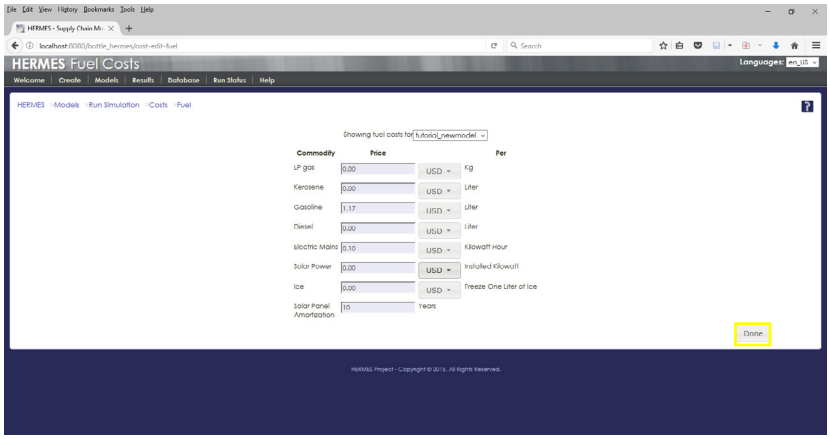


7. First click the **"Close"** button on the costing errors message.

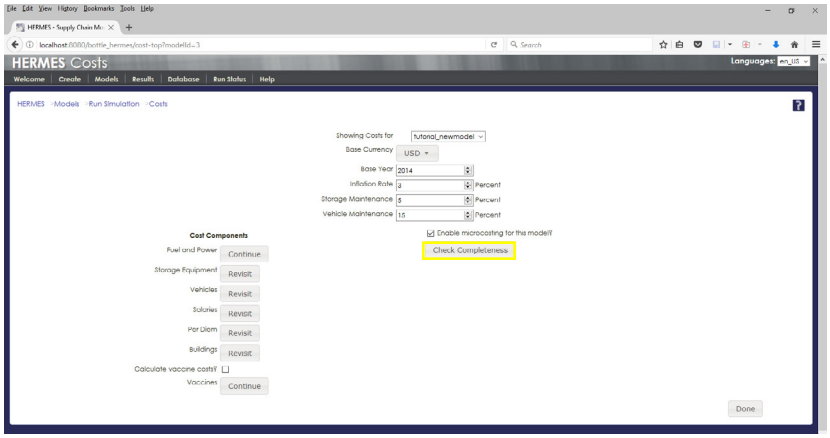


8. You can now more clearly see the errors in the Validating Model dialog box. Click the **"Go To Cost Model Editor"** button.

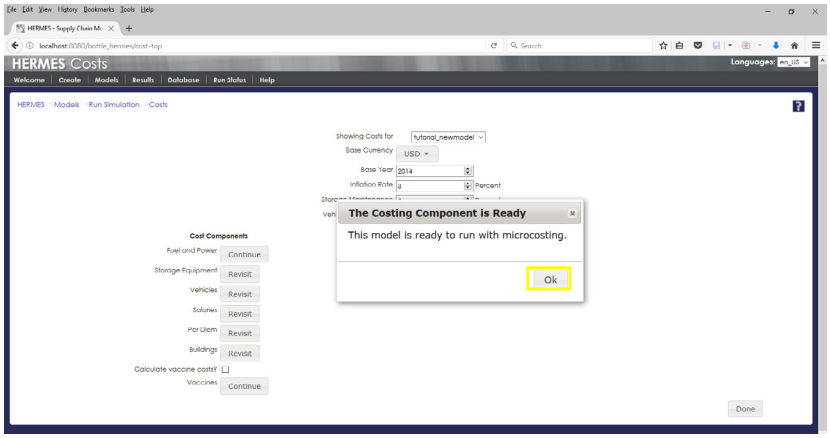
NOTE: This will open the Costs page. On the costs page, click the "Continue" button next to "Fuel and Power".



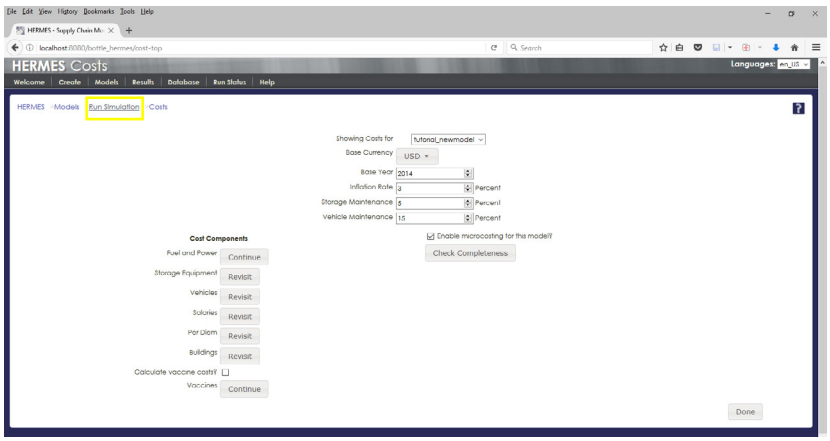
9. Enter 0 in the empty Price boxes, leaving **"Gasoline" "Electric Mains"** and **"Solar" Panel Amortization** the same. Then click the **"Done"** button.



10. On the main cost page, click the **“Check Completeness”** button.

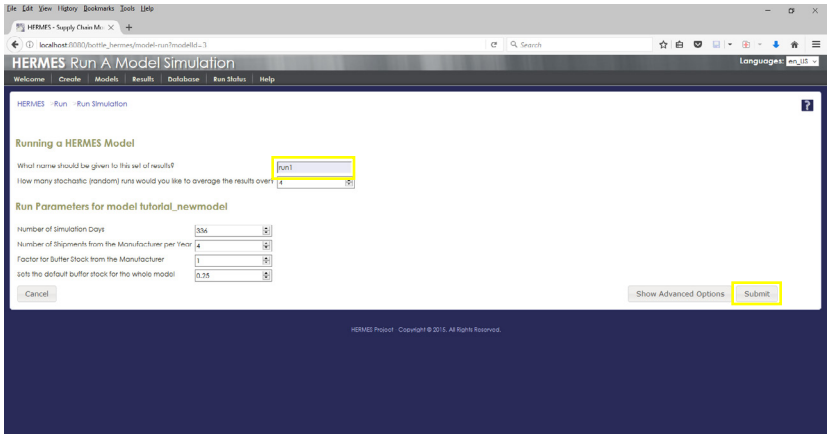


11. **“The Costing Component is Ready”** dialogue box will appear. Click the **“Ok”** button. You should now be ready to run the model with microcosting.

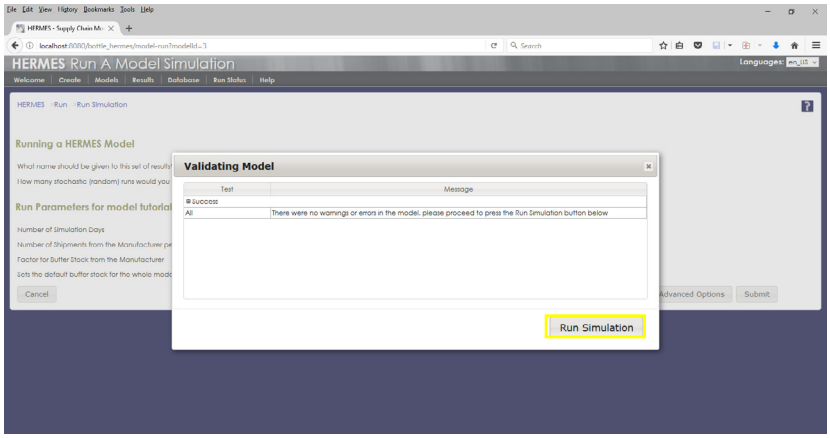


12. Click the **“Run Simulation”** breadcrumb in the top left corner to return to the Run page.

Part 3: Start Run (again)



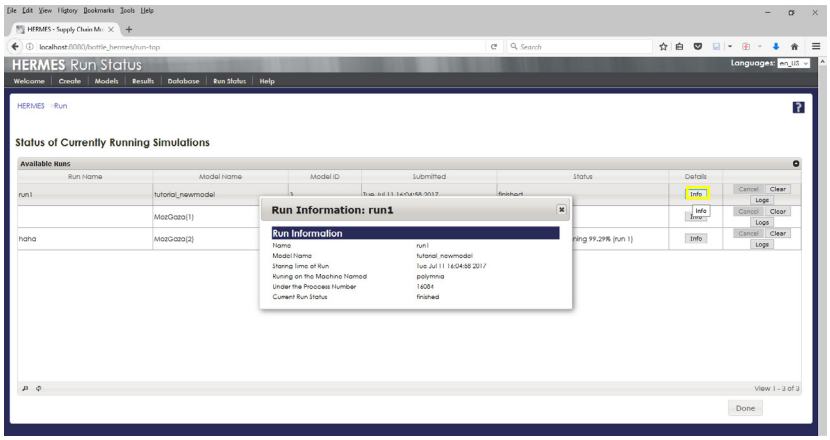
13. As above in step 4, enter a name into the text box and click the **“Submit”** button.



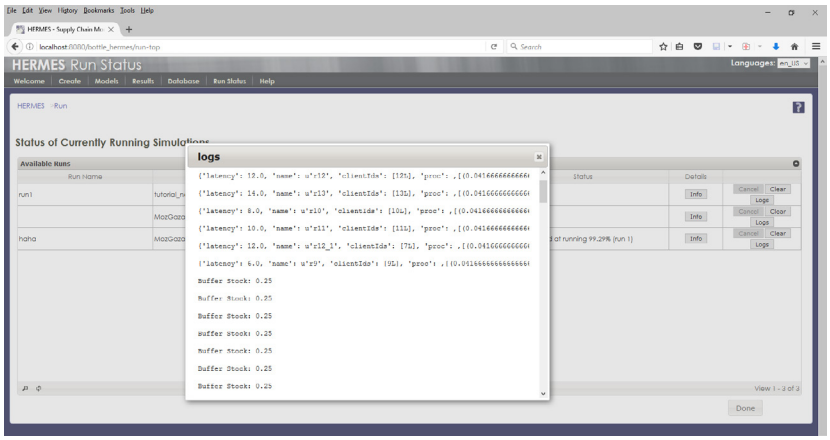
14. Now that there are no errors, the Validating Model box will inform you of your success. Click the **“Run Simulation”** button to start the simulation.

Part 4: View Run Status

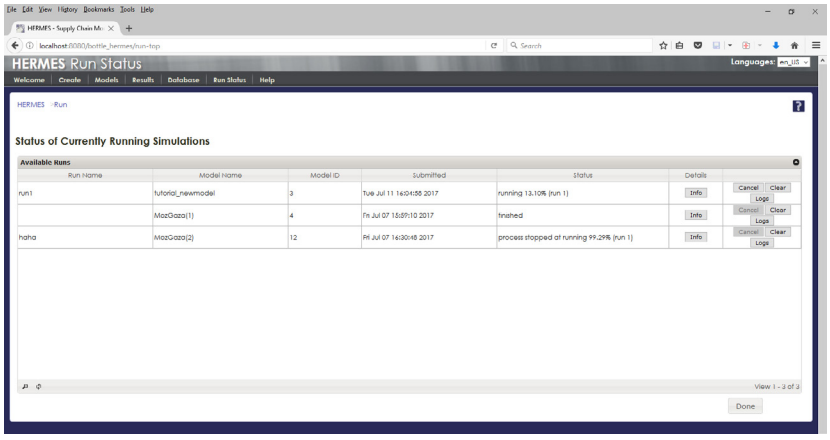
Clicking the Run Simulation button will bring you to the Run Status page. If you leave and want to view the status of your run, you can reach this page by clicking Run Status on the top menu bar.



15. As you can see from the page below, the Run Status page offers you some basic information about the runs you have previously started, as well as buttons allowing you to get more detailed information (*Info, Logs*) or remove a run from the status table (*this does not delete the results*). Clicking the **"Info"** button for run1 displays a summary of the run details.



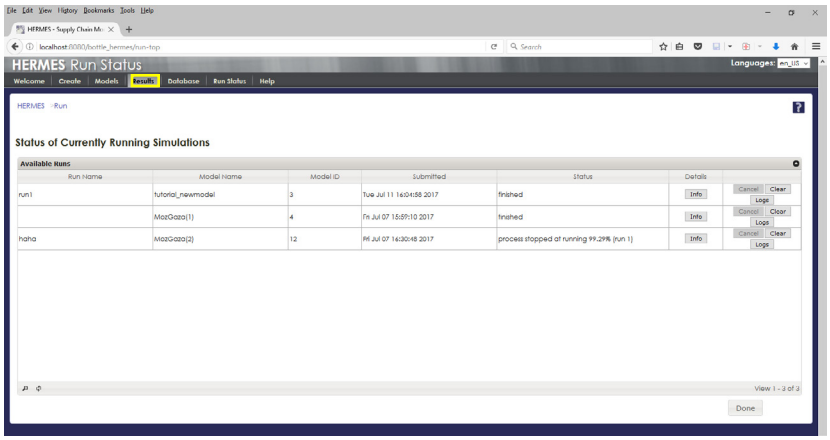
16. Clicking the **"Logs"** button displays detailed logsfor the run. The logs are a detailed description of model processes containing information that may be helpful when troubleshooting.



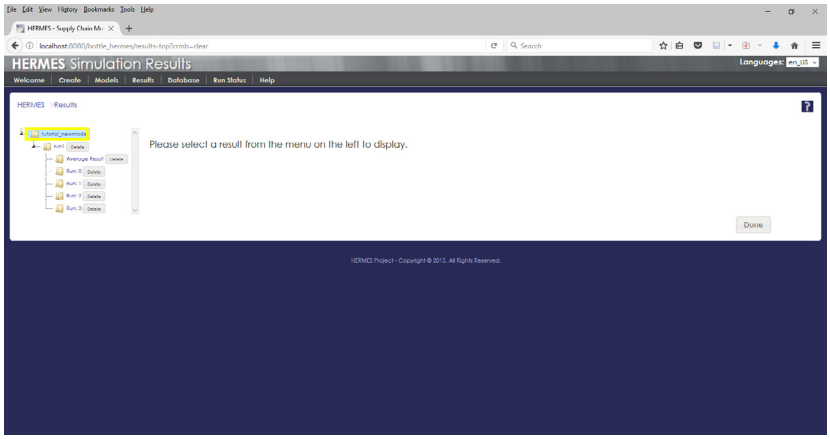
17. Once the run has finished, the status column will be updated accordingly.

Part 5: View results

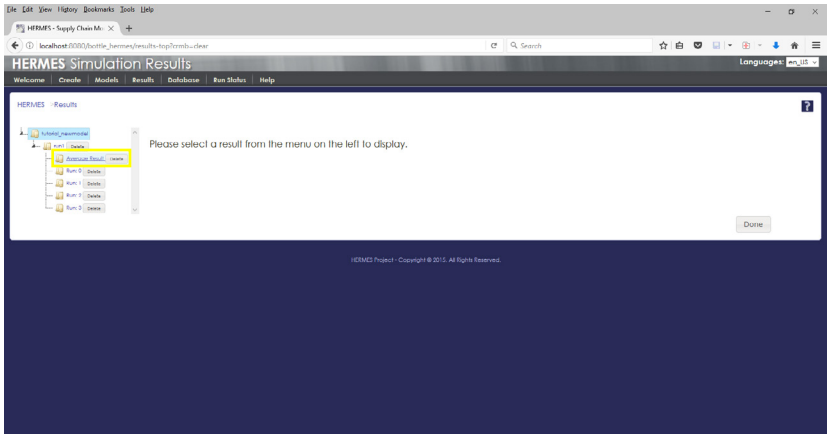
Once your simulations have finished running, you can view and analyze the results through multiple interactive visualizations and charts, as well as detailed tables.



18. Click on **"Results"** in the top menu bar to open the results page.



19. The results are organized by model and the page opens with all results collapsed. Click the model name (*tutorial_newmodel*) or the small triangle to the left to show the simulations that have been run for this model.



20. Since we left the number of simulations at the default, 4, there are four separate runs (*labeled Run:0 to Run:3*), as well as the average result of all 4, available for you to review. For now, click on the **"Average Result"** link. Due to each model being hypothetical, your results will not match these exactly.

Tabular results

21. The Vaccine Results table lists statistics for each vaccine in the dose schedule, as well as overall statistics for all vaccines combined. These results include the following supply chain measures.

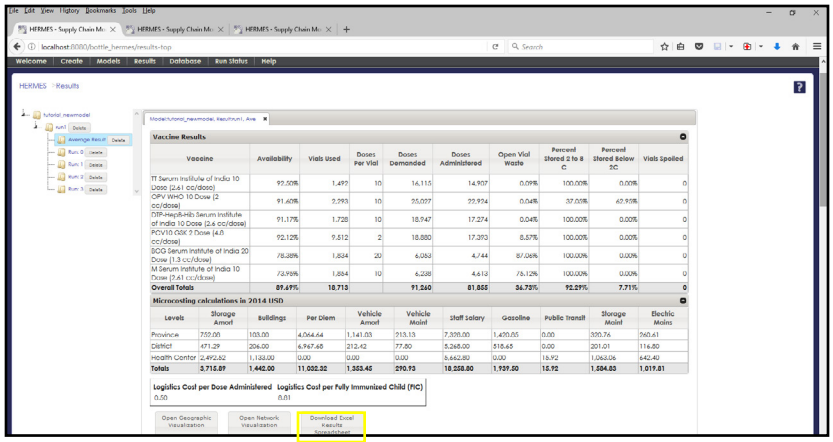
Availability expresses the Doses Administered as a percentage of the Doses Demanded. Doses Demanded indicates the number of doses of each vaccine that was needed at immunizing locations in order to administer the required vaccines to all people who arrived for vaccinations, while Doses Administered indicates the number of doses that were given to people arriving for vaccinations. This number may be lower than Doses Demanded if supply chain bottlenecks or ordering policies prevented the necessary vaccines from getting where they were needed, when they were needed.

In this particular simulation (*Model:tutorial_newmodel, Result:run1, Ave*) Availability ranges from 74% to 93% across different vaccines, with an overall average of 90%. This indicates that an average of 10% of the Doses Demanded resulted in missed opportunities, where people were turned away because the necessary vaccines were not in stock at the time.

Open Vial Waste is the percentage of all doses in vials that were opened and not used. Doses must be discarded from opened vials depending on the type of vaccine (*lyophilized or liquid, for example*) and the immunization program policies (*some programs mandate discarding all opened vials at the end of every session, while others may allow some types of opened vials to be used in future sessions*). In this model, three vaccines (*TT, OPV and DTP-HepB-Hib*) could be used for up to a month after opening, which resulted in little to no open vial wastage for these vaccines. In contrast, open vials of PCV, BCG and M vaccines would be discarded at the end of each vaccination session, leading to higher open vial wastage. PCV experienced lower wastage (*at 9%*) than the BCG and M (*>75% wastage for each*) due to each PCV vial containing only 2 doses (*as compared to 20 doses per vial for BCG and 10 for M*).

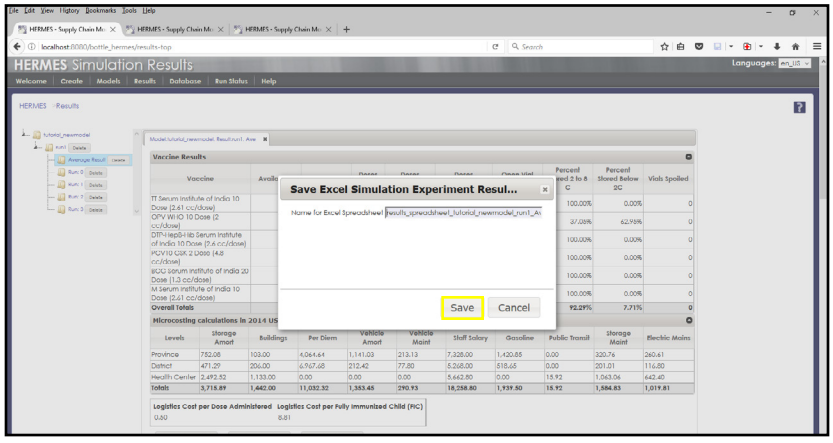
The Microcosting Calculations table (*"Microcosting calculations in 2014 USD" below*) provides supply chain costs by supply chain level and for the overall system, divided into categories such as storage amortization, storage maintenance, staff salary, buildings and gasoline costs.

An additional table (*"Logistics Cost per Dose Administered" and "Logistics Cost per Fully Immunized Child (FIC)" below*) divides the total logistics costs for the simulation by the number of doses administered as well as by the number of fully immunized children (*FIC*). In this set of results, the logistics cost per dose administered was $0.50 and the logistics cost per FIC was

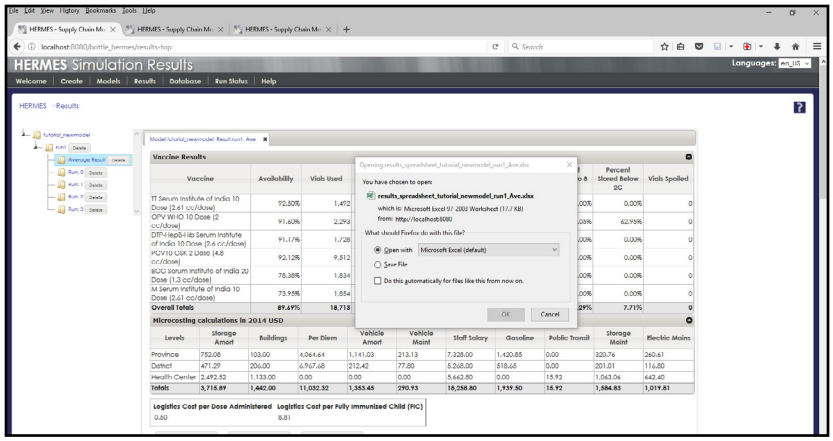


22. Click on the **"Download Excel Results Spreadsheet"** button below the tables to acquire a spreadsheet of more detailed results, which includes supply chain metrics not only for the overall system and by supply chain level, but also for each individual location and route.

NOTE: The spreadsheet contains several sheets of information about the model. The first page is an overall model summary, followed by a level-wise device inventory, store locations with cost breakdowns, route information with cost breakdowns and listings of storage devices, vehicles and vaccines.



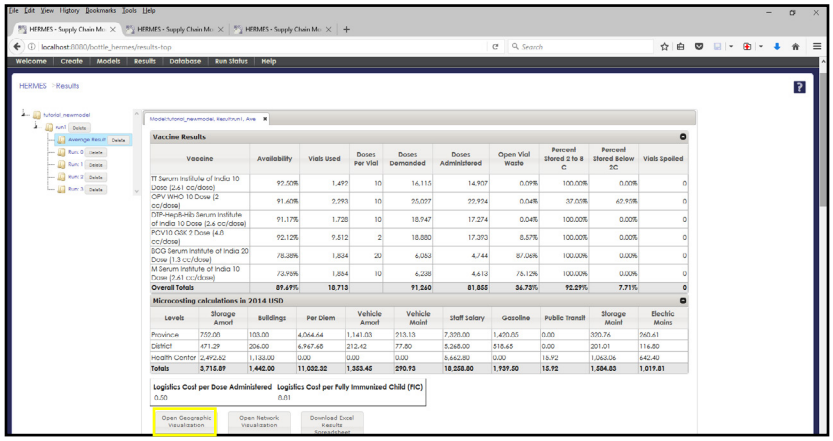
23. Click the **"Save"** button.



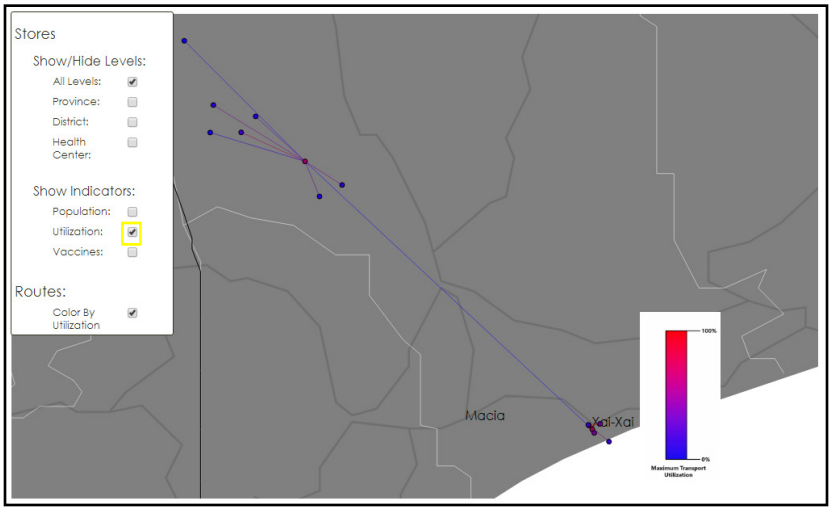
24. Use the download dialog box to either open or save a copy.

Visualizations

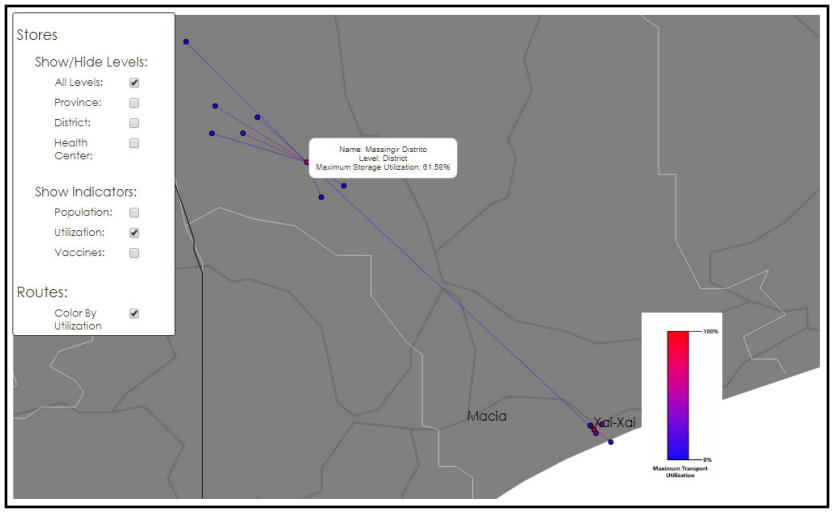
There are two types of visualizations accessible via buttons below the main tables—**"Open Geographic Visualization"** and **"Open Network Visualization"**.



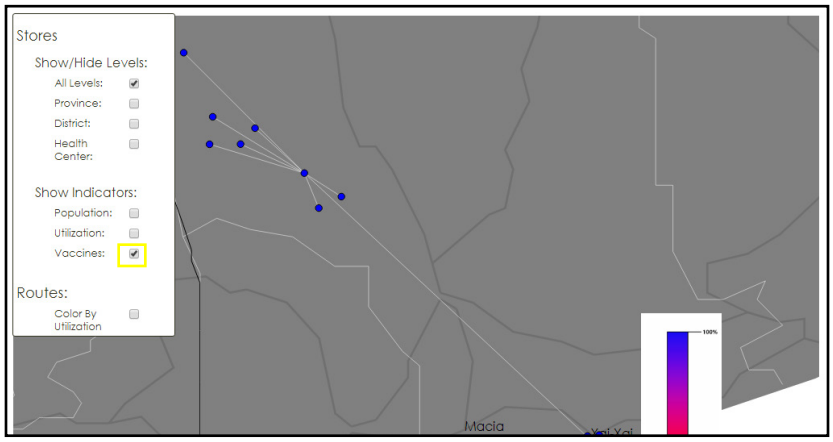
25. Click the **"Open Geographic Visualization"** button to view the supply chain locations and results on a map. This page will open in a new window and can take some time to load.



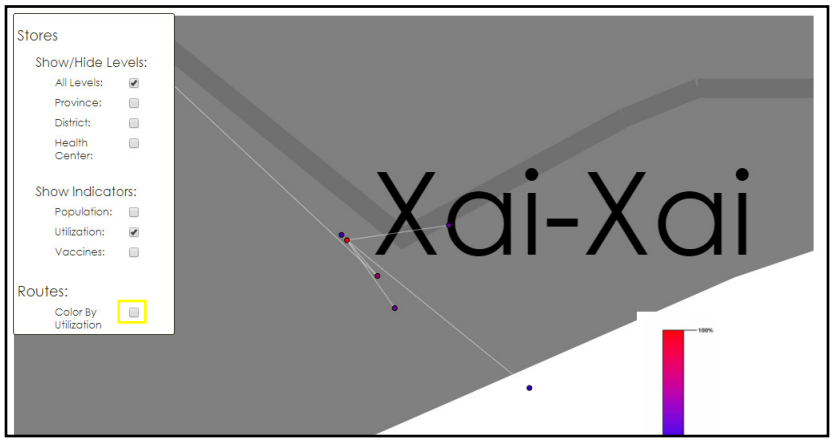
26. By default, locations are represented by circles that are sized and color coded by supply chain level. Lines between locations represent the routes connecting the province, health center and district stores to the locations they supply. You can choose other information to display from the box on the left to reveal potential supply chain bottlenecks. Check the **"Utilization"** box under **"Show Indicators"** to color locations by maximum storage utilization (*the peak percentage of available storage capacity utilized at a location at any time during the simulation*). Also select **"Color By Utilization"** under **"Routes"** to color each route by its maximum transport utilization (*the peak percentage of available vehicle capacity used at any point*).



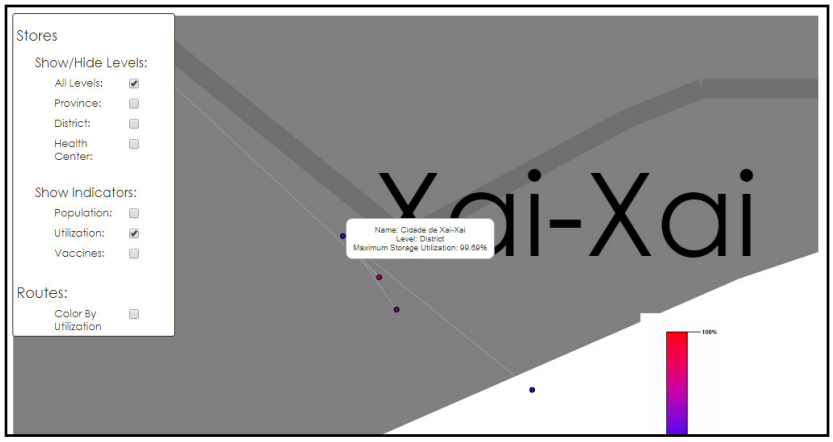
27. Hovering your cursor over a location identifies the location and supply chain level and quantifies its maximum storage utilization. For example, Massingir Distrito used approximately 62% of its storage capacity at peak utilization in this baseline scenario. This is higher than many other locations but does not indicate a current supply chain bottleneck as utilization did not reach near 100%.



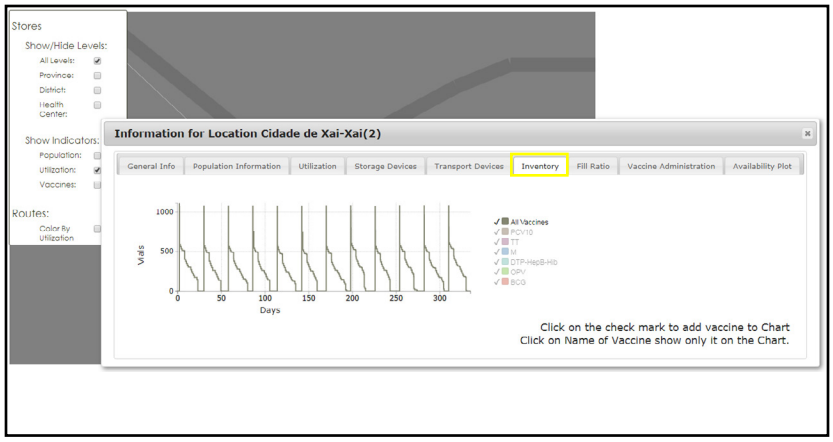
28. You can instead choose to view locations by their population size or vaccine availability results using the box on the left. Click on the **"Vaccines:"** under **"Show Indicators"** to see the vaccine availability results.



29. Zoom in and out using the scrollwheel or press and hold your Ctrl key while pressing the + key to zoom in or the - key to zoom out. Zoom in where the southernmost locations in the model are found and click on the **"color by utilization"** button.

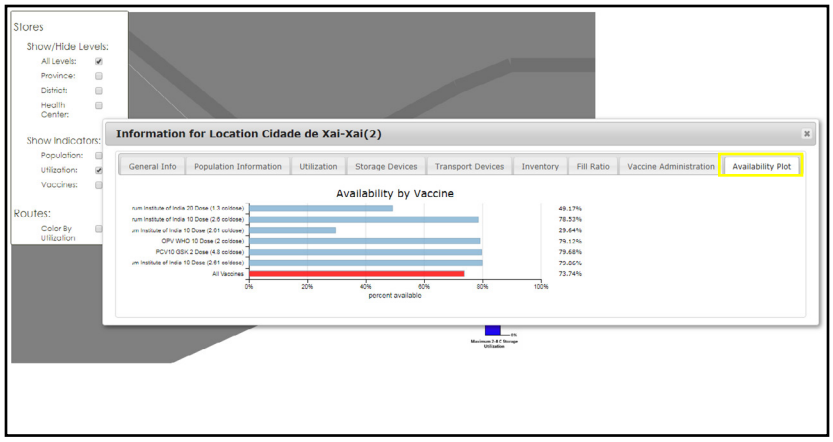


30. Hovering your cursor over the location that is most red in color (*red indicates the greatest maximum storage utilization*) reveals the **"Cidade de Xai-Xai"** district store with the highest peak utilization of greater than 99%. This indicates a storage bottleneck, as the storage device at this district store was filled to capacity before it could store all of the vaccines it needed for at least part of the simulation.

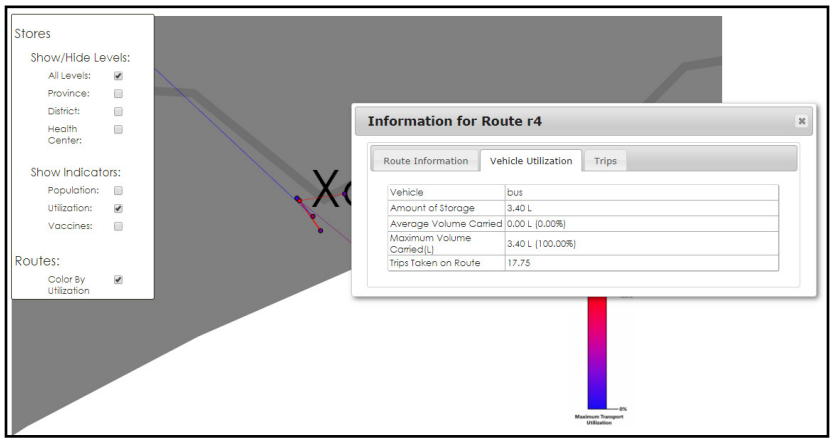


31. Clicking on a location or route provides specific, detailed information and results for your selection. Click on the **"Cidade de Xai-Xai"** district store and select the **"Inventory"** tab to display an interactive plot of the daily stock inventory at this location throughout the simulation.

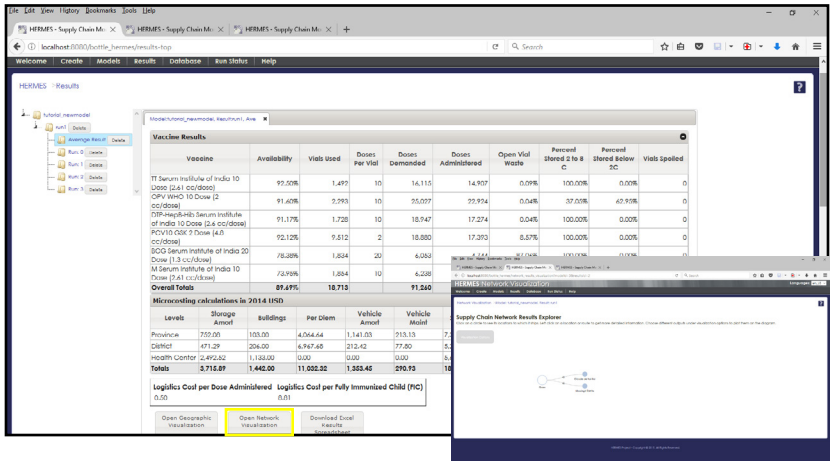
NOTE: Clicking on the name of any vaccine in the legend to the right will display only that vaccine and clicking the checkmark next to any vaccine will add that vaccine to the chart. This chart shows monthly stockouts at the Cidade de Xai-Xai district store.



32. Click the **"Availability Plot"** tab to show vaccine availability for each vaccine at this location. This chart reveals vaccine availability to be 74% among people arriving at the Cidade de Xai-Xai district store for vaccinations, indicating 26% of missed opportunities due to the stockouts here.

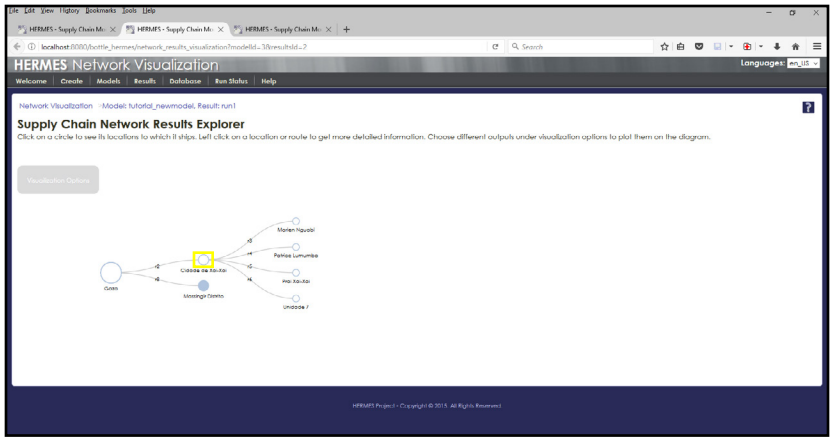


33. Explore the map using the various display options to identify transport bottlenecks. These can be found in routes using buses to pick up vaccines from the Cidade de Xai-Xai district store. These show 100% maximum transport utilization (*or volume carried*) and more than 12 trips in a one-year simulation, indicating extra instances of picking up vaccines beyond the monthly trips attempted.

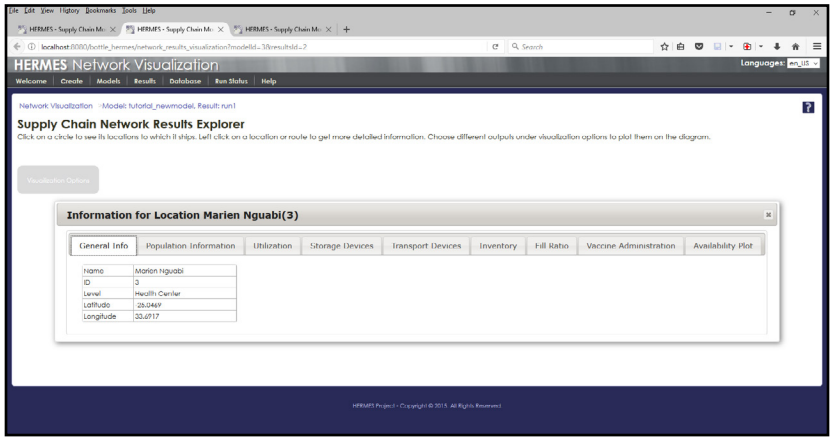


34. While the geographic visualization is only available for locations with geographic coordinate data, similar types of results can be displayed for any model in a network visualization. Click the **"Open Network Visualization"** button from the results page.

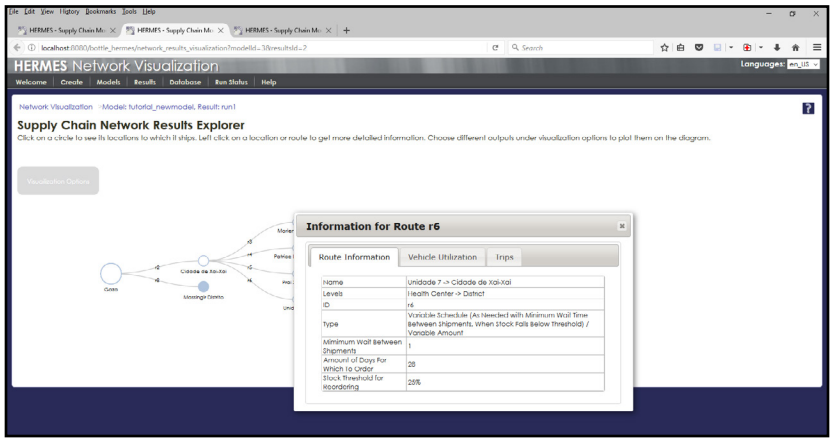
NOTE: This will open in a new window.



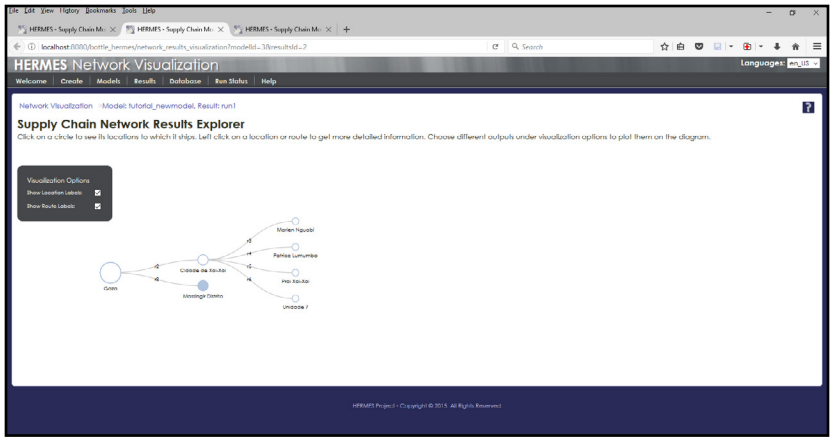
35. A filled in blue circle means there are locations below that one. Left click on the Cidade de Xai-Xai circle to expand the locations below.



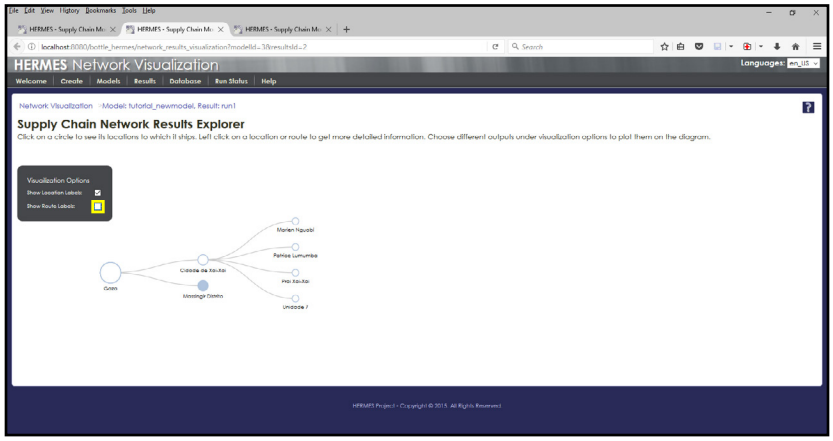
36. Right click on Marien Nguabi to display information about that location then close the window.



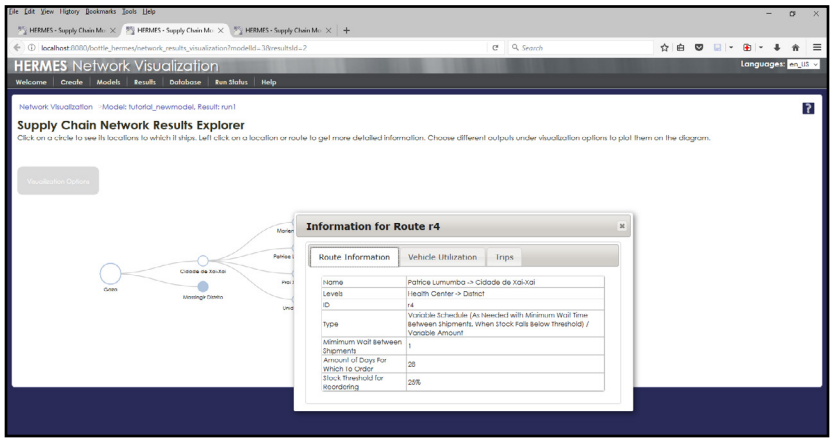
37. Right click on **"r6"** to get information about that route then close the window.



38. You can adjust what labels are shown on the diagram using the **“Visualization Options”** box on the top left. When you place your cursor over each button, it expands to show the available options.

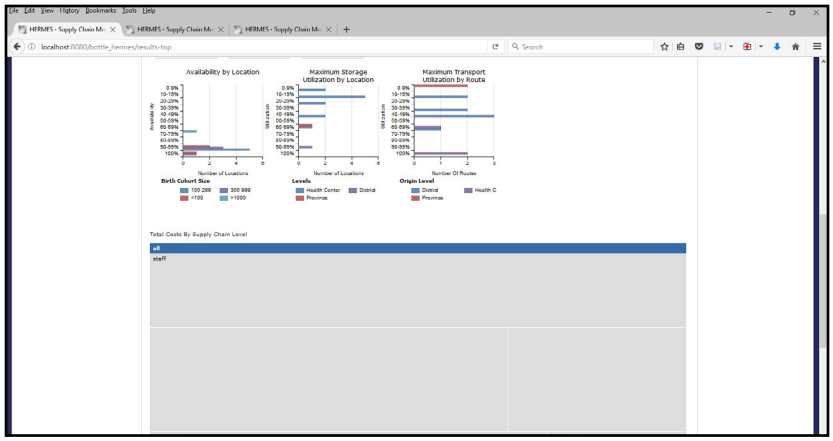


39. Uncheck **“Show Route Labels”** to remove them from the visualization.



40. Even though the routes are not labeled, you can still show their information by right clicking on the line.

Histograms

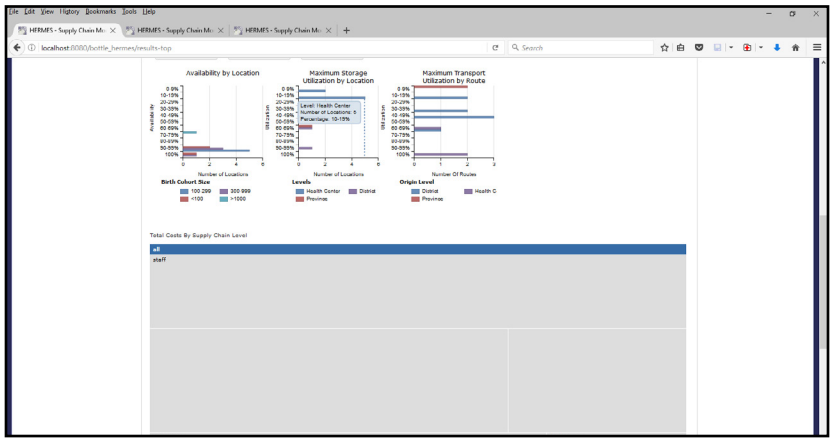


41. There are three histograms positioned below the visualization buttons. These histograms display the distribution of overall vaccine availability, maximum storage utilization and maximum transport utilization across locations.

In our model, these show that availability was greater than 90% at the majority of the health centers, but the one with the largest population (*which we now know to be the Cidade de Xai-Xai district location*) experienced lower availability in the range of 70-79%.

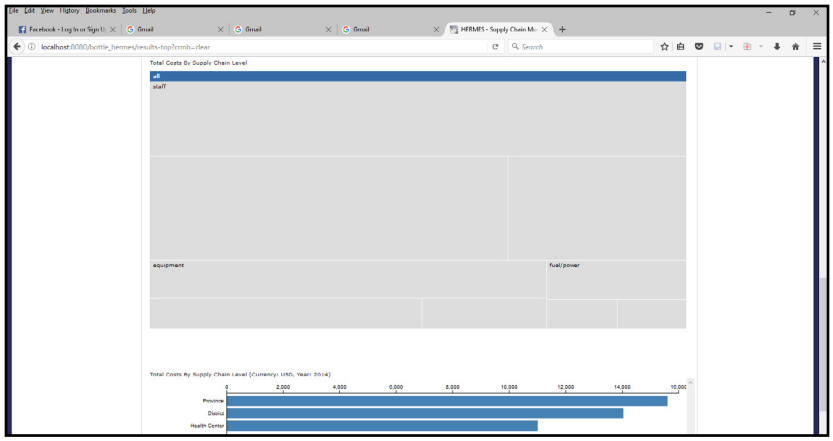
The maximum storage utilization by location histogram shows one district (*Cidade de Xai-Xai*) potentially facing storage capacity constraints (*with peak utilization in the range of 90-99%*) while all other locations in the supply chain appeared to have sufficient capacity.

The maximum transport utilization also indicates a lack of bottlenecks in most routes, with two health centers utilizing their full transport capacity (*and potentially taking extra trips if allowed*).



42. Each of these will show further information if you hover your cursor over one of the lines in the bar graph.

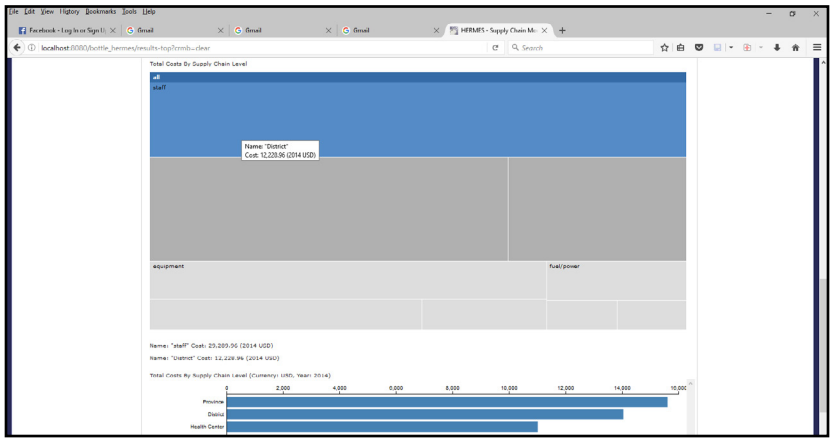
Interactive cost diagrams



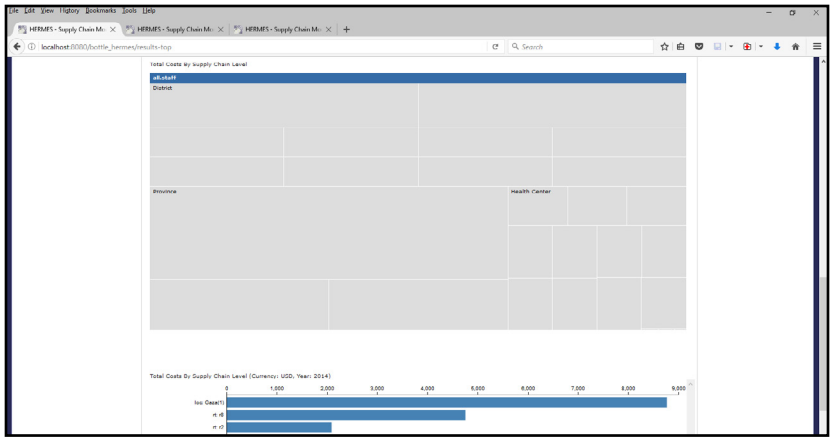
43. Total costs by supply chain level are represented by a treemap and bar chart, both of which are interactive.

The zoomable treemap allows for a quick visualization of the major cost driving categories and the relative cost of each level, location and route. The treemap displays boxes labeled with categories of costs, with the relative size of each box representing the relative share of costs attributed to that category. In this model, the costs of staff salaries comprised the greatest share of costs, followed by equipment costs and fuel/power costs.

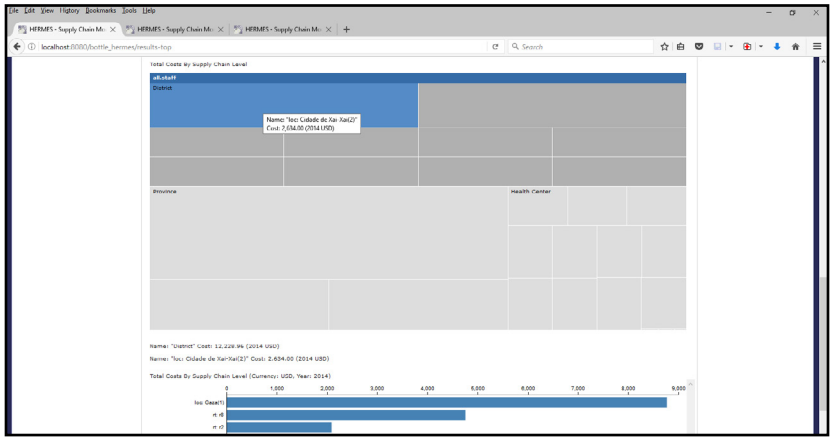
Clicking any box will **"zoom in"** the treemap to the selected category, now further broken down into subcategories. To zoom out to the previous level of costs, click on the blue bar at the top of the treemap, which displays a label of the current category.



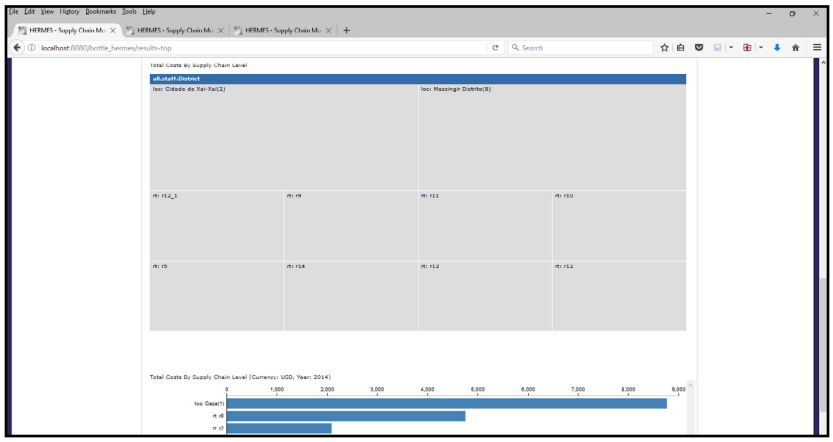
44. If you hover over a block of the treemap, information about that field and level will appear both in a pop up box and below the grid. The total for that field will also be shown below the grid.



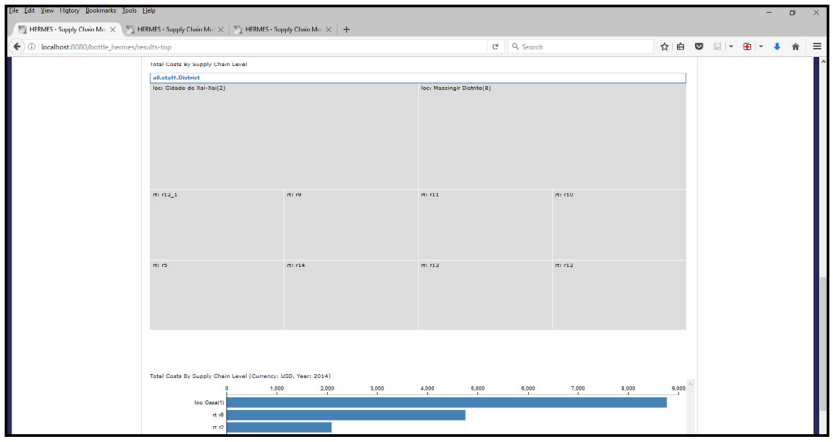
45. Click on the top staff box. The treemap will zoom in to show the staff broken out by locations. The blue bar at the top changes to reflect that you are looking at **“all.staff”**



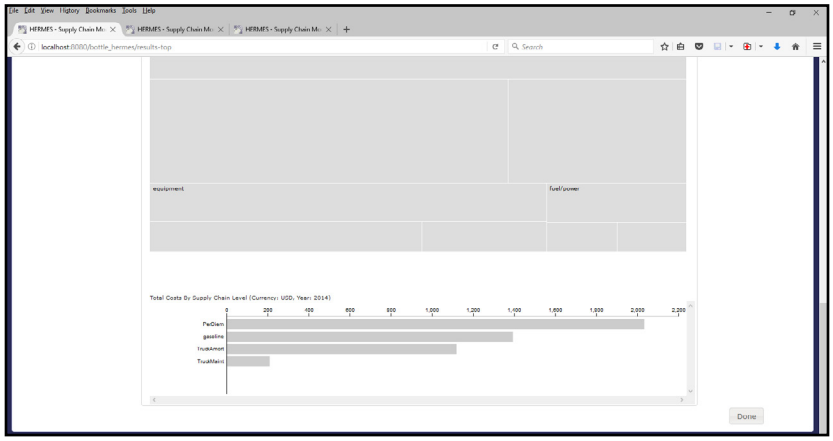
46. Similar to in the above level, you can hover over another box to get information.



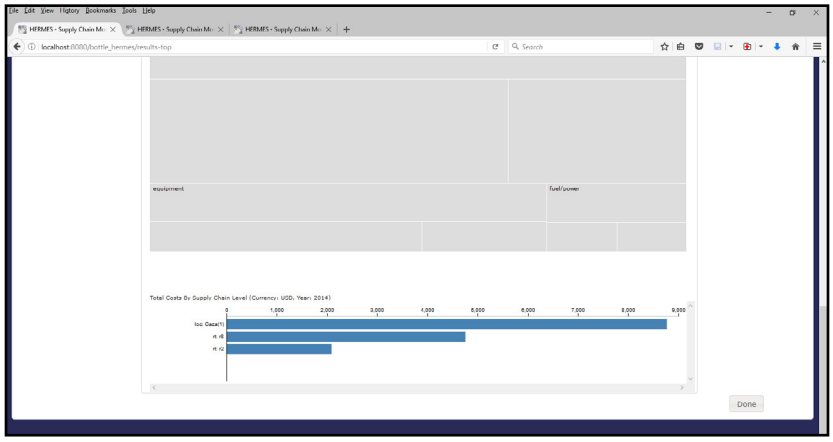
47. Click in the top left box to drill down into all staff at the district level (*reflected in blue bar at top now saying* **“all.staff.District”**)



48. If you hover over the blue bar at the top, it will turn white. Click on it to go back up a level.



49. An interactive Costs Bar Chart initially displays total costs by level. Clicking any level will regenerate the bar graph to show the costs accrued at each location and route at the selected level. Clicking any location or route will display the costs by category at that location or route. Return to the previous view by clicking in any empty white space in the chart. Click on the middle bar to show the breakdown of the costs for route r8.



50. Click in the white area below the lowest bar to reset the chart so you can choose another location or route.

Part 6: Next steps

You have now completed the HERMES tutorial on running your new model and exploring results. See other tutorials for experiments you can perform with your model, such as introducing new vaccines, adding storage devices and removing a supply chain level.

REFERENCE:

1. Haidari LA, Brown ST, Wedlock P, Lee BY. Map of different vaccine supply chain efficiency measures. Vaccine. 2017;35(1):199-200.

Tutorial 3 | Introducing a New Vaccine

Now that you created a model and ran simulations to produce some results, the next three tutorials allow you to experiment with different scenarios. The first scenario is the introduction of a new vaccine.

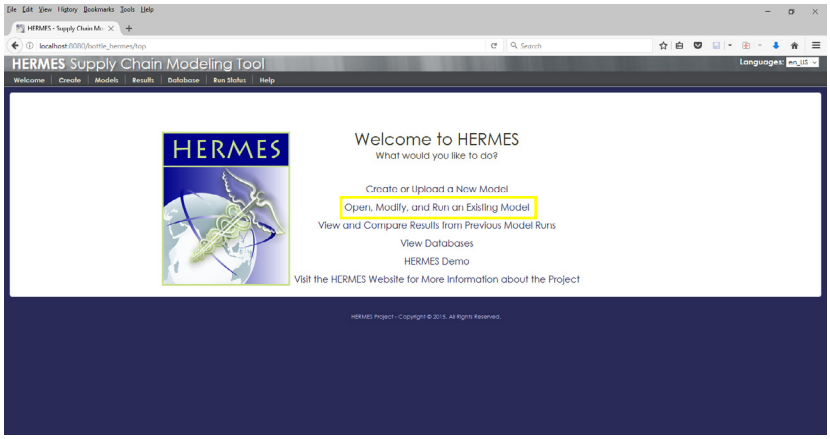
With new disease threats and outbreaks occurring all over the world, policymakers, governments and Ministries of Health need to consider the development and introduction of new vaccines. In this tutorial, we will take a look at the operational and economic effects of introducing two vaccines – the rotavirus vaccine and injectable polio vaccine – into the model (NOTE: these two vaccines were selected because they're commonly used in this region.)

It's important to keep in mind that while the introduction of a new vaccine into a supply chain can be beneficial, it can also have a number of unintended consequences. For example, bottlenecks may occur in cold-storage and transport due to an increased number of doses flowing through the system that may lead to reduced vaccine availability for the consumer. Previous modeling work using HERMES has helped show how adding one or more vaccines into a supply chain can lead to bottlenecks in storage and transport and how varying different factors (such as shipping frequency, storage space and population demand) can alter this effect.[1,2]

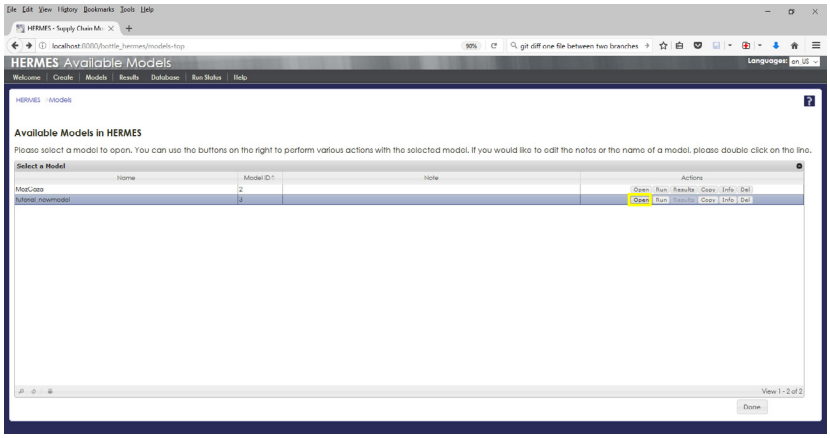
These instructions will guide you through introducing two new vaccines as well as an additional dose of another vaccine, to create an experimental scenario based on an existing model. The following steps will add the rotavirus and injectable poliovirus vaccines to the model and allow you to specify the dose schedule for these new vaccines. You will also add an additional dose of the measles vaccine to the vaccine schedule in your model for experimental purposes.

This tutorial utilizes the model you created in the "Creating a new model" tutorial (Tutorial 1). You can also find this model in the tutorial materials provided to you.

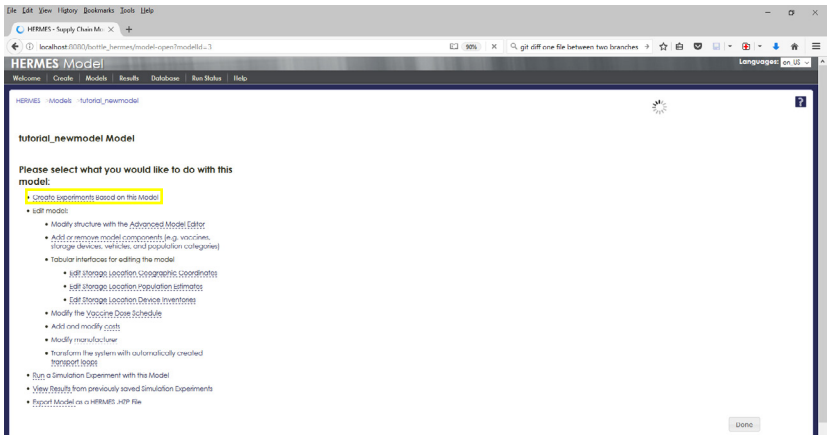
Begin vaccine introduction experiment workflow



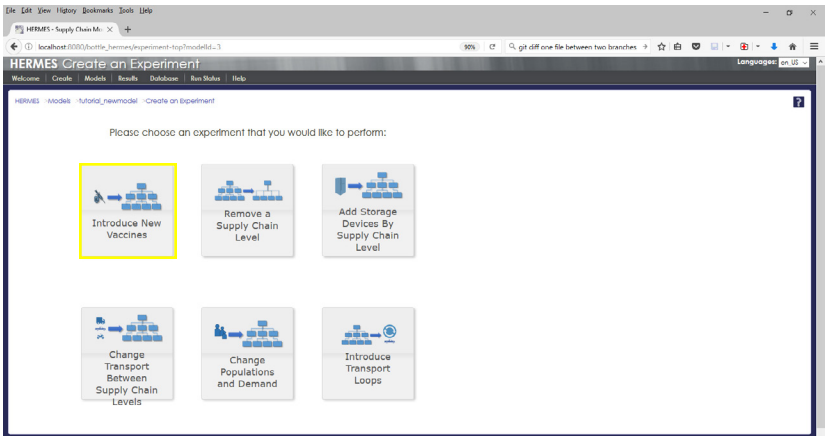
1. On the Welcome Page, click "**Open, Modify, and Run an Existing Model**"



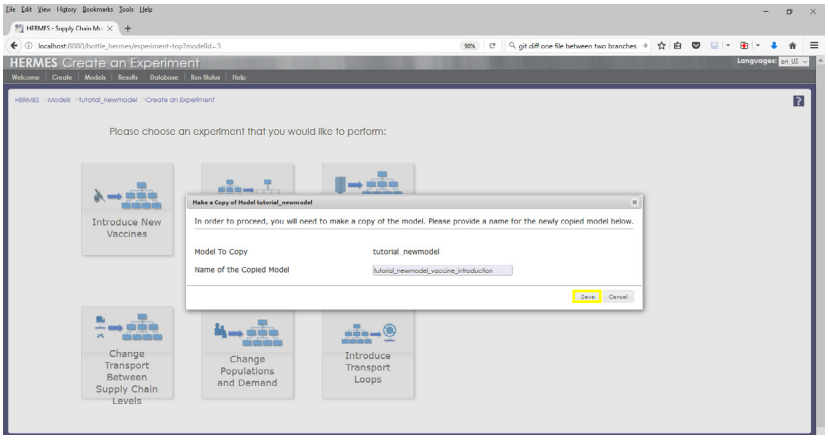
2. Click the "**Open**" button in the tutorial_newmodel row under "**Actions**".



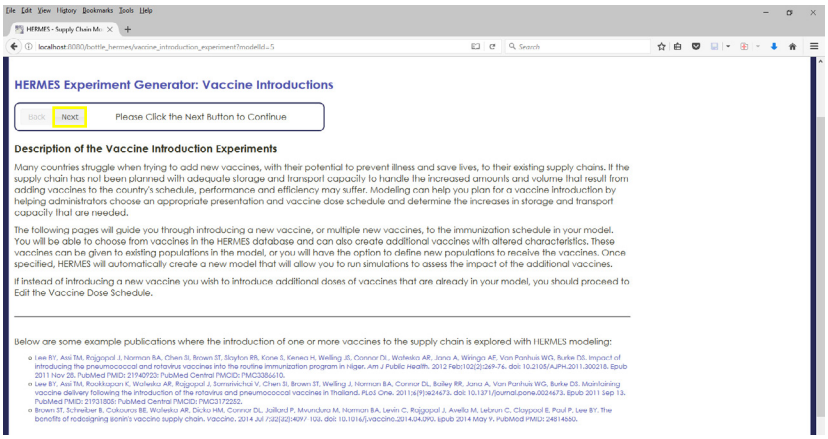
3. This opens the main model page. Click on "**Create Experiments Based on this Model**".



4. Click on the "**Introduce New Vaccines**" box.

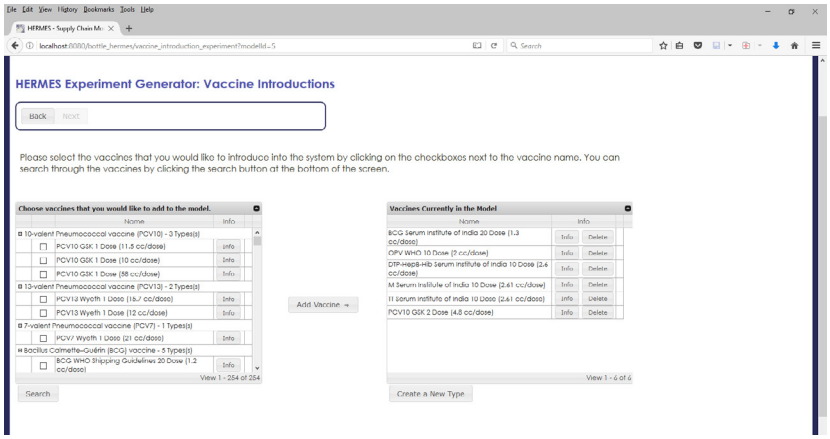


5. You will be prompted to create a copy of the model to run. Making a copy allows you to keep the original model as a baseline comparator to the experimental model you are creating. Enter a new name for the model copy (or use the one automatically filled in) and click the "**Save**" button.



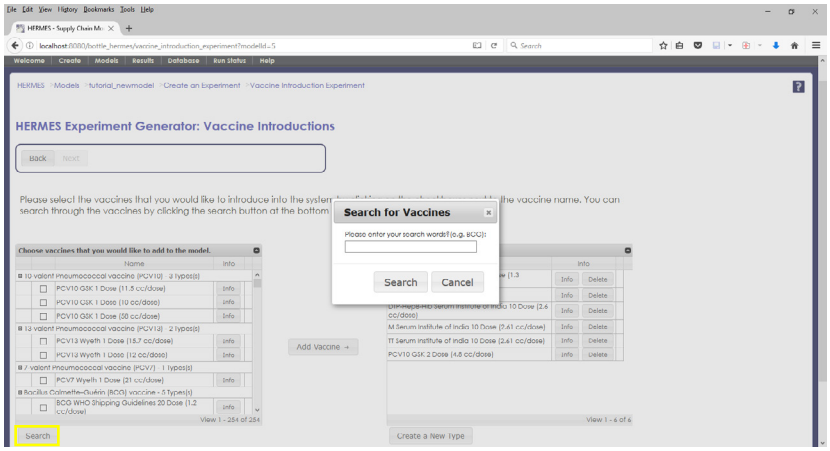
6. This page offers additional information on the vaccine introduction scenarios you can include using this experiment generator. Click the "**Next**" button when you are done reading and ready to move to the next page.

Add new vaccines

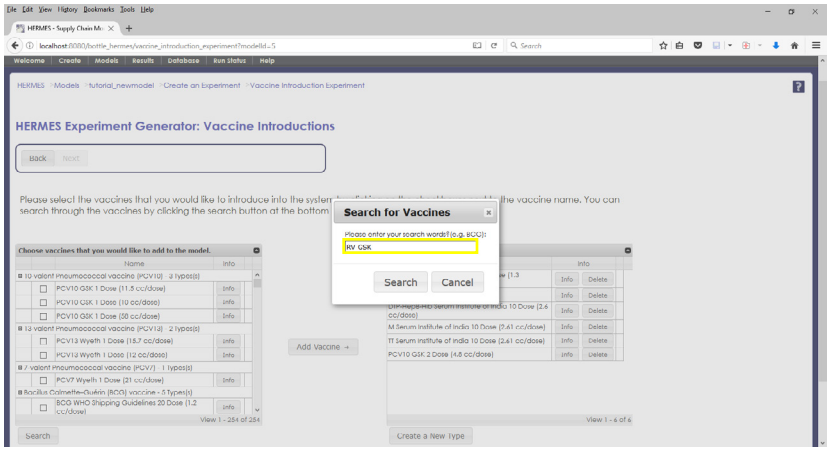


7. From this page, you will be adding two new vaccines. You can see the vaccines that are already present in the model in the table on the right. The table on the left shows vaccines that exist in the database that can easily be added to your model by following the steps listed below.

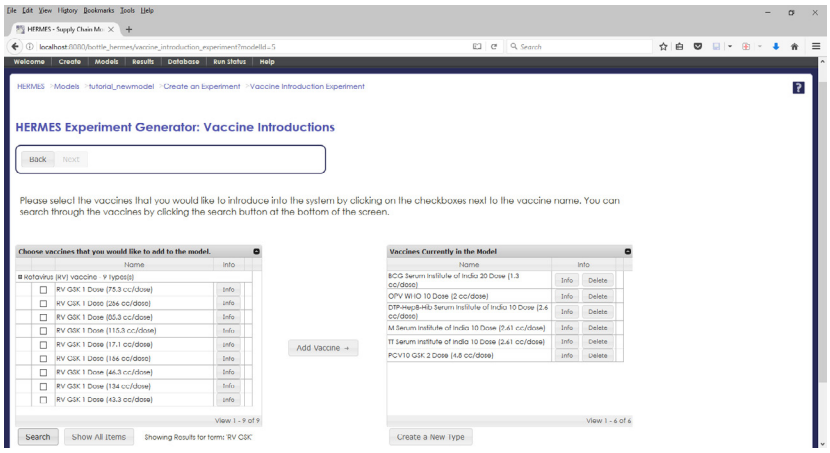
   NOTE: The "**Next**" button will remain greyed out until you add at least one new vaccine to your model.



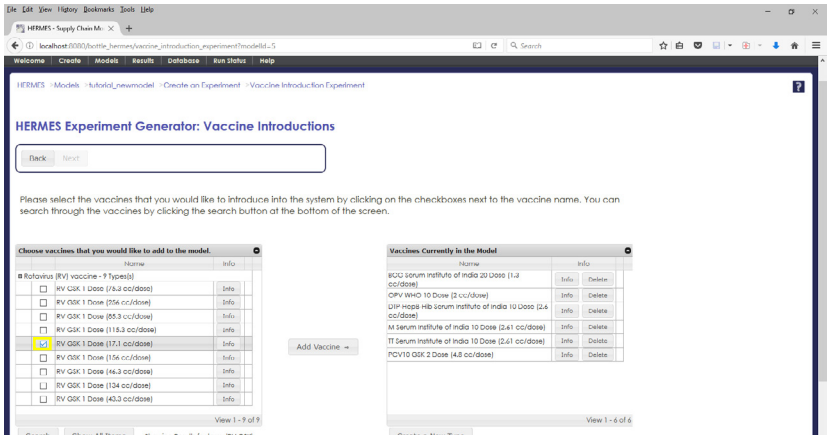
8. The first vaccine we need to add is rotavirus: "**RV GSK 1 Dose (17.1 cc/dose)**". The easiest way to locate a vaccine in the table on the left is to press the "**Search**" button that is below that table. Then, the dialogue box below will appear.



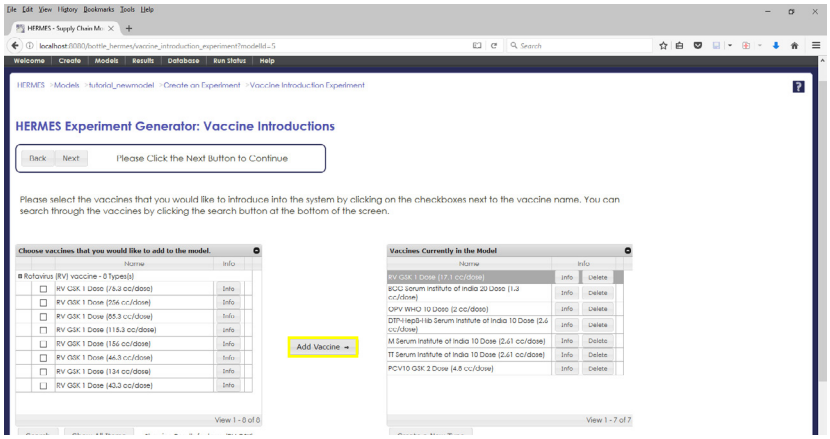
9. Type "**RV GSK**" into the search box to display only rotavirus vaccines manufactured by GSK.



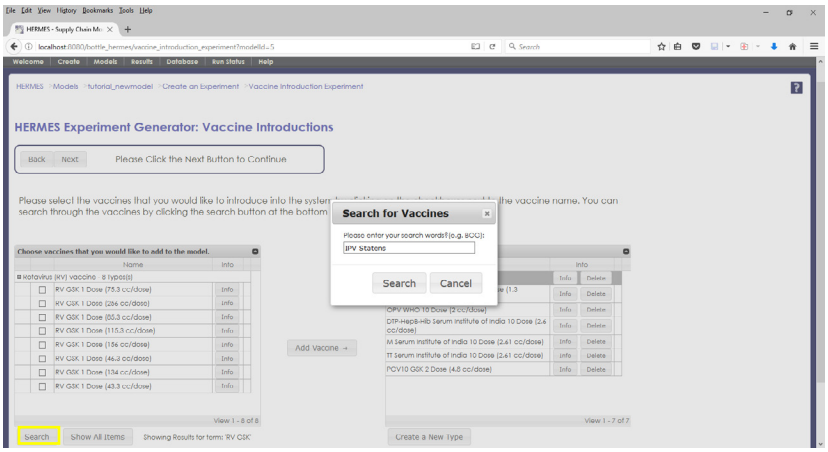
10. Then press the Search button. HERMES will update the table to only show vaccines matching your search criteria. Several presentations of rotavirus vaccine from the manufacturer GSK are shown, which differ on characteristics such as the number of doses per primary container and the cold chain volume required per dose in secondary packaging. Clicking the "**Info**" button next to any vaccine will display detailed information about its characteristics.



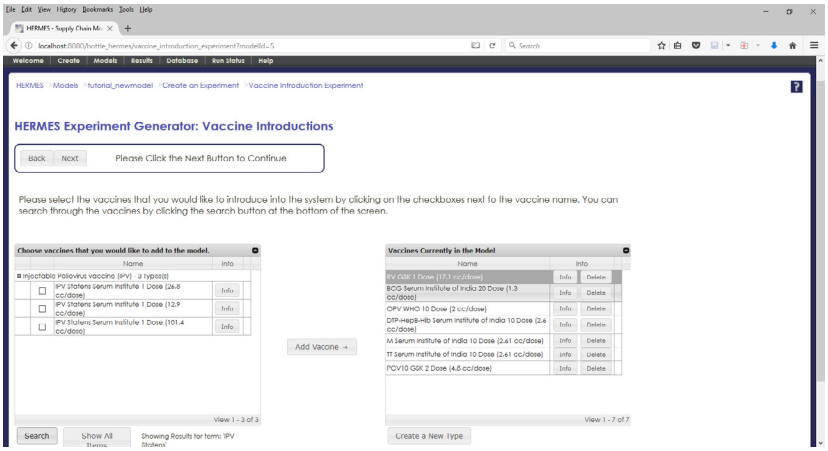
11. Pick the "**RV GSK 1 Dose (17.1 cc/dose)**" by clicking the check box next to it in the table on the left.



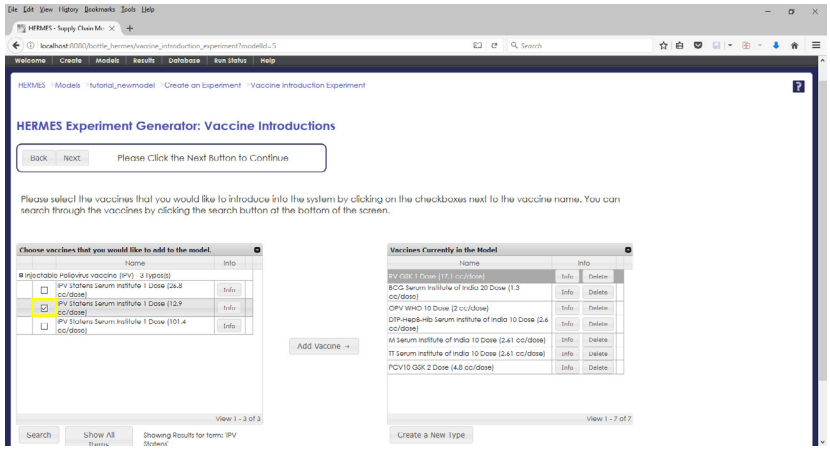
12. Press the "**Add Vaccine**" button located between the two tables. You will see the vaccine appear in the table on the right.



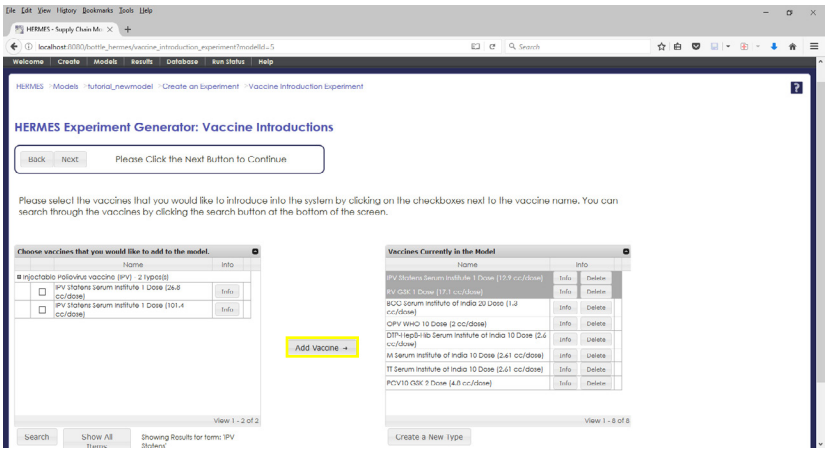
13. Press the "**Search**" button again to look for the second vaccine, injectable poliovirus, and enter "**IPV Statens**" in the search box.



14. Then press the "**Search**" button in the dialogue box to filter out all vaccines except IPV manufactured by Statens Serum Institut.

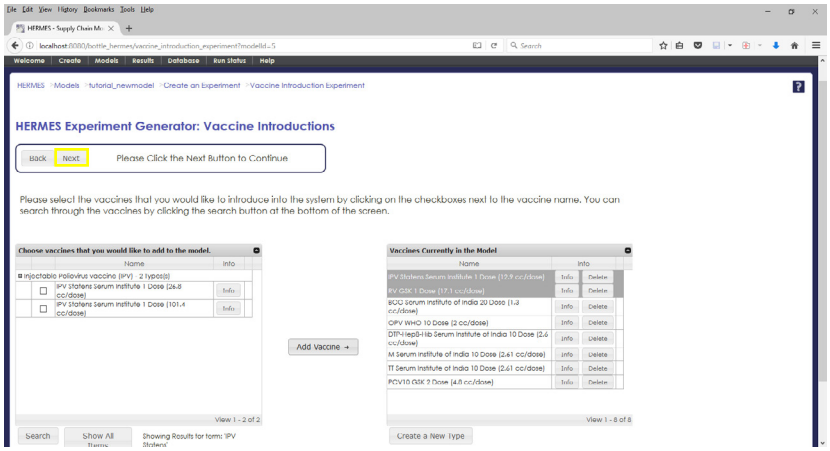


15. Choose "**IPV Statens Serum Institute 1 dose (12.9 cc/dose)**"

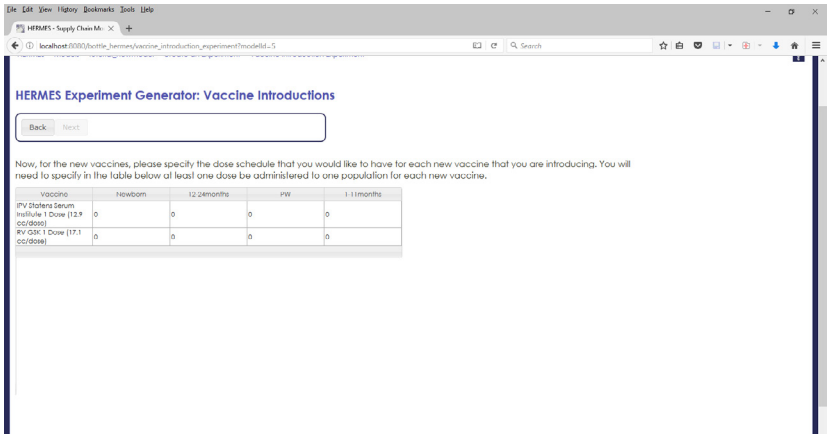


16. Cont. - Add it to your model by pressing the "**Add Vaccine**" button.

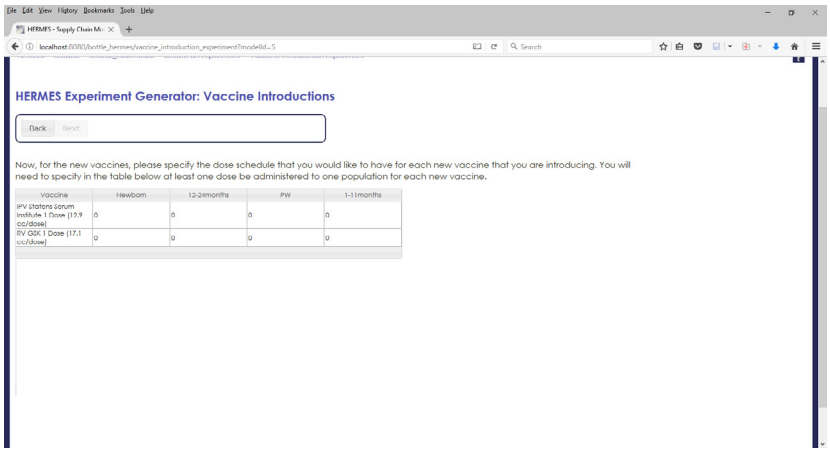
Specify dose schedule for new vaccines



17. Click the "**Next**" button to access the page where you can update the vaccine dose schedule for the two vaccines you just added, which will be administered to infants under one year of age in the model.



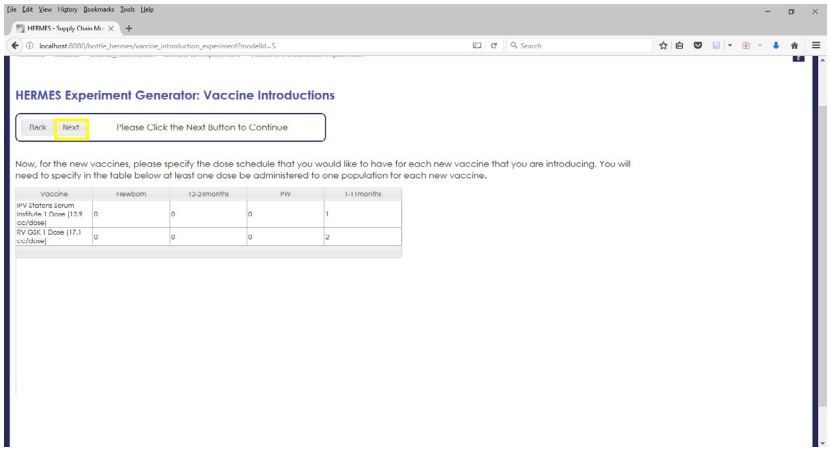
NOTE: This how your screen should now appear



18. You'll need to now update the table by clicking on the appropriate row and entering the number in the population column you want to update. For this model, you will want to **add 1 dose** of "**IPV Statens Serum Institute 1 Dose (12.9 cc/dose)**" for **"1-11 months**" and 2 doses of "**RV GSK 1 Dose (17.1 cc/dose)**" for "**1-11 months**". Changes are saved when you press the Enter key on your keyboard while in the row you are changing.

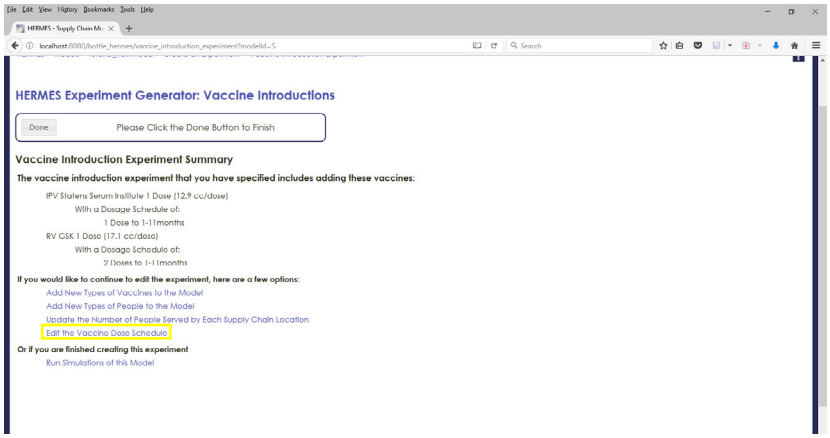
NOTE: The "**Next**" button will remain greyed out until you update the table. All vaccines need to have at least one dose given to one population or an error box will pop up and you will be prevented from proceeding.

Alter dose schedule for other vaccines

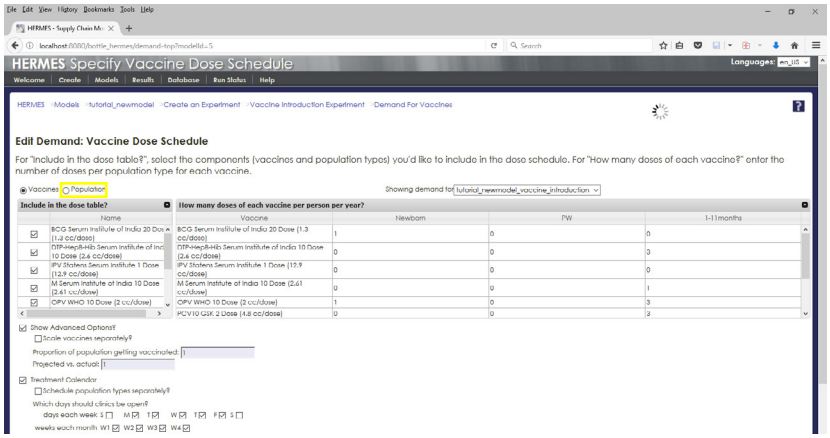


19. Press the "**Next**" button.

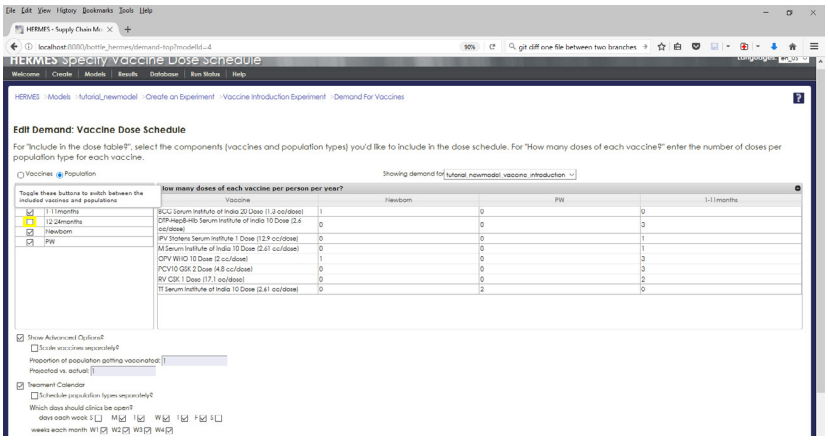
NOTE: This new page offers you a variety of options to continue interacting with the experiment as well as a link to run the simulation.



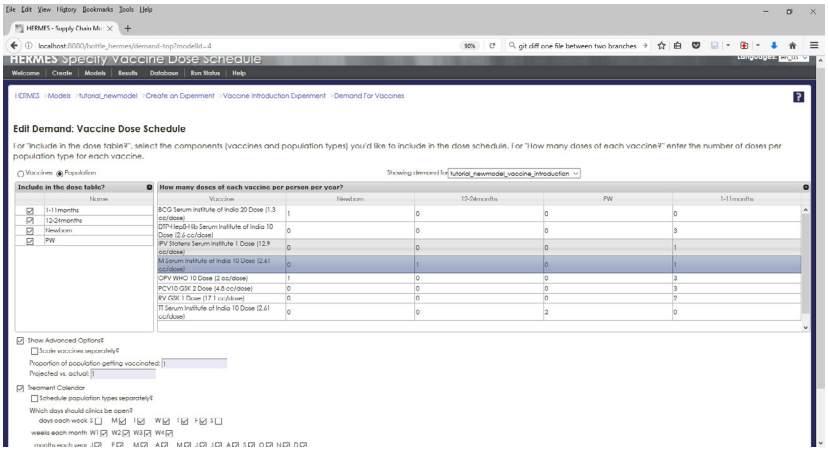
20. Before you run the simulation, click on "**Edit the Vaccine Dose Schedule**"



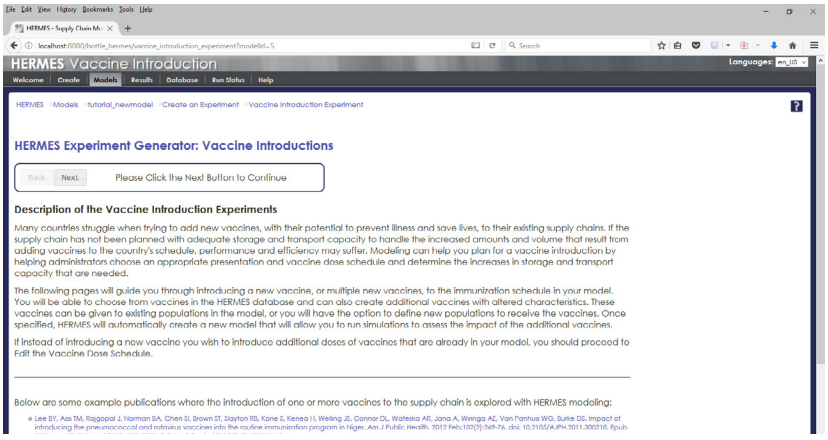
21. You will be updating the schedule to **add 1 dose** of the Measles (M) vaccine to the "**12-24months**" population. First click the "**Population**" radio button near the top left of the page (next to Vaccines which is selected by default).



22. Click the box next to "**12-24months**" (in between 1-11 months and Newborn) to include that population in the scheduling table to the right.

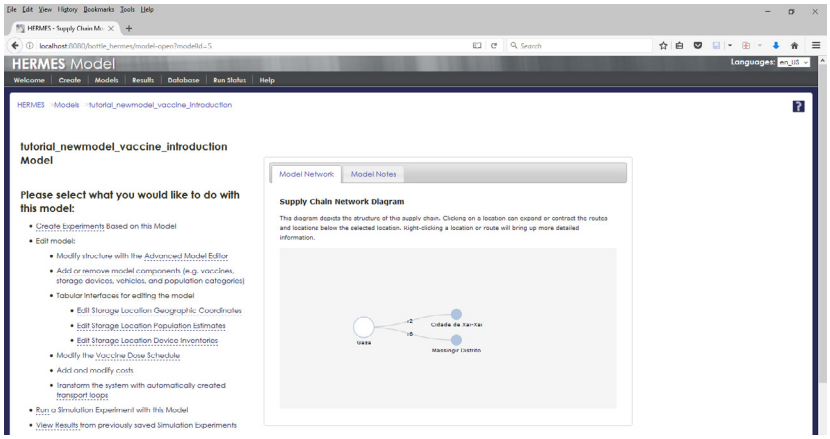


23. Update the table to add **1 dose** of "**M Serum Institute of India 10 Dose (2.61 cc/dose)**" to the "**12-24months**" population by clicking on the row with M, updating the "**12-24months**" column and then pressing the "**Enter**" key. Then press "**Done**".

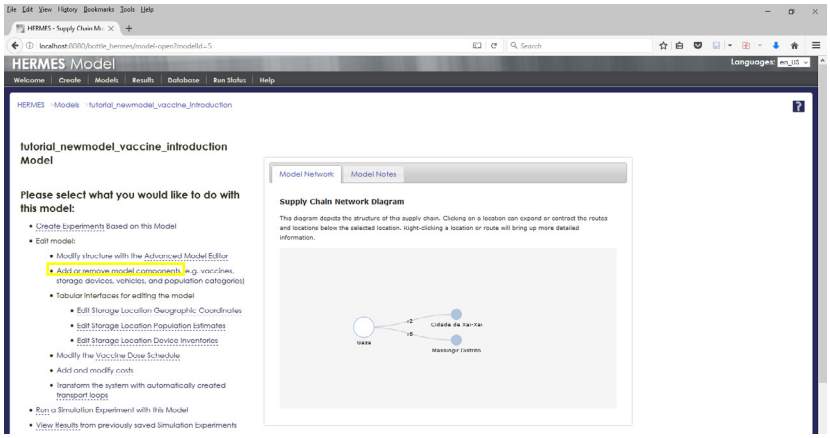


You have now introduced rotavirus and injectable poliovirus vaccines, as well as an additional dose of measles vaccine, to the model.

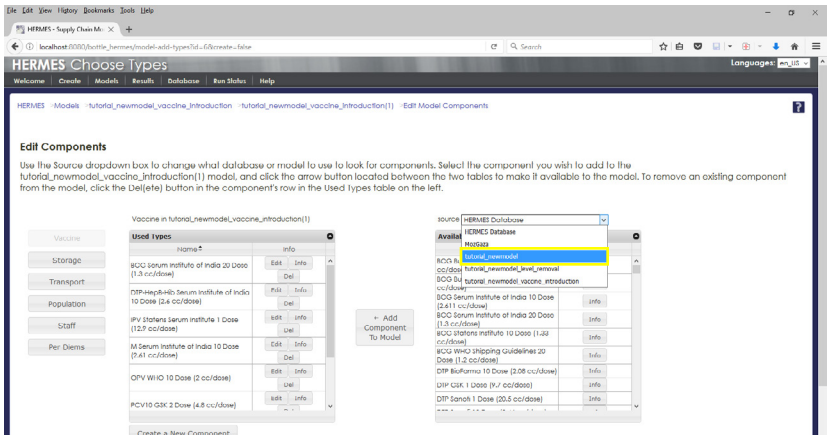
View changes to model



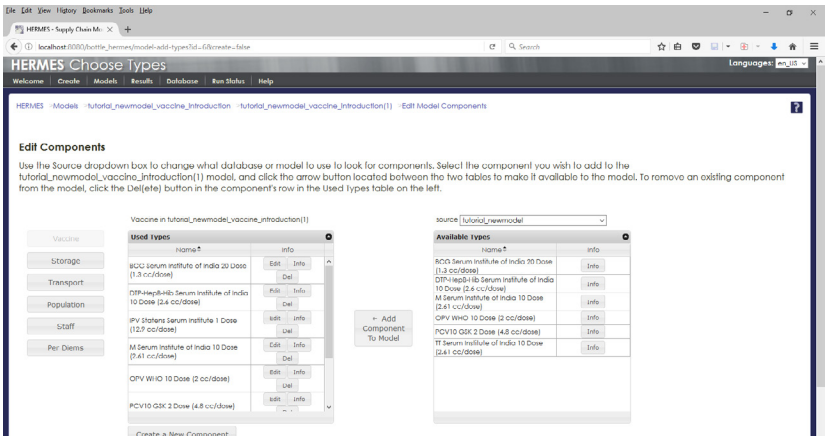
24. Before running the simulation, take a look at the changes in the model. To do this, open the model "**tutorial_newmodel_vaccine_introduction**" (or whatever you named it in step 5) by going to the **Models page** and clicking "**Open**" in the "**tutorial_newmodel_vaccine_introduction**" row.



25. Click on "**Add or remove model components**" which is the second sub-bullet underneath "Edit model:"

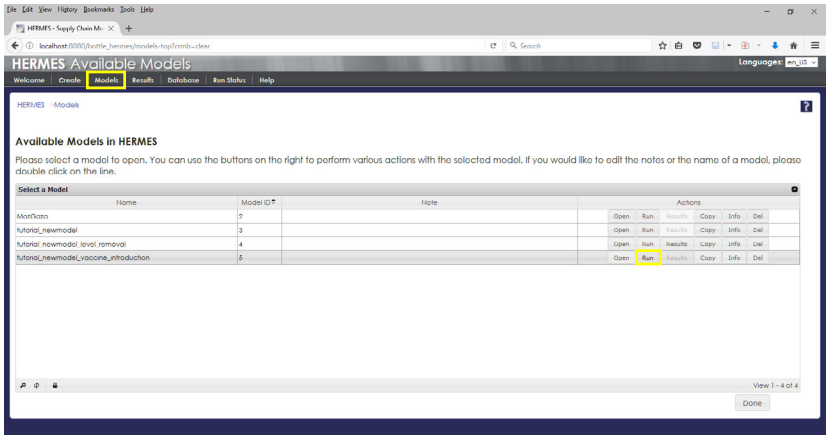


26. In the source dropdown box above the right hand table, choose "**tutorial_newmodel**"



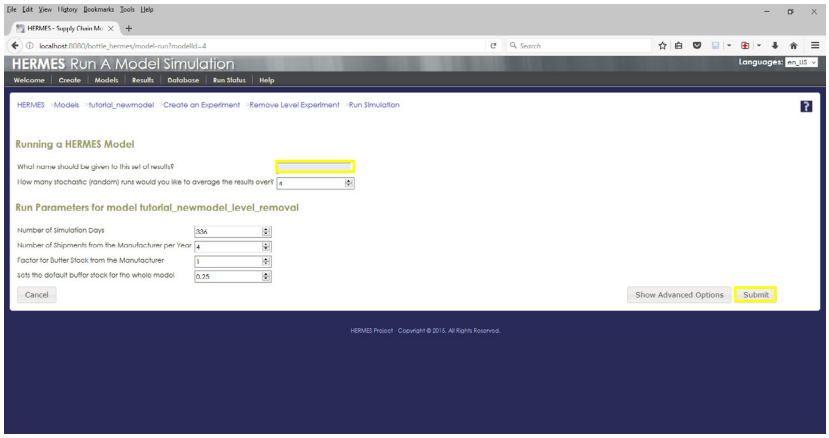
27. This will load the vaccines available in the original model in the right hand table. Notice that the table on the left now includes the viruses you added in the experiment (for used types in the current model).

Run simulation



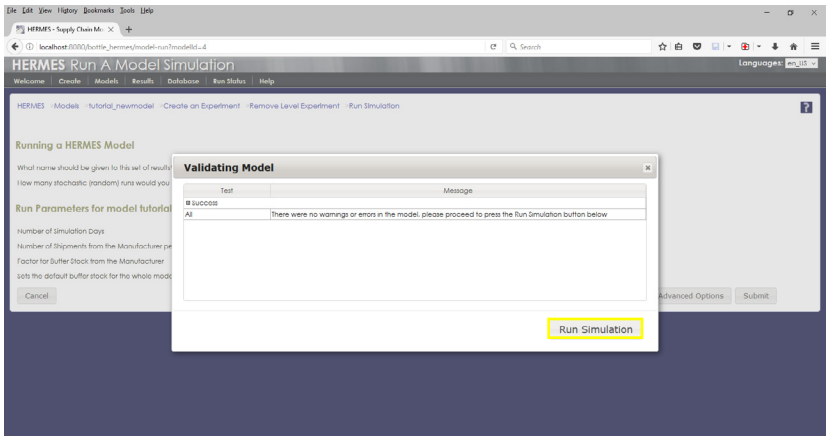
28. Click on "**Models**" in the top menu bar to get to the models page. Then click the "**Run**" button in the row with your vaccine introduction model, which is "**tutorial_newmodel_vaccine_introduction**" in this tutorial.

NOTE: Step 28 will open the "**Run Simulation**" page.



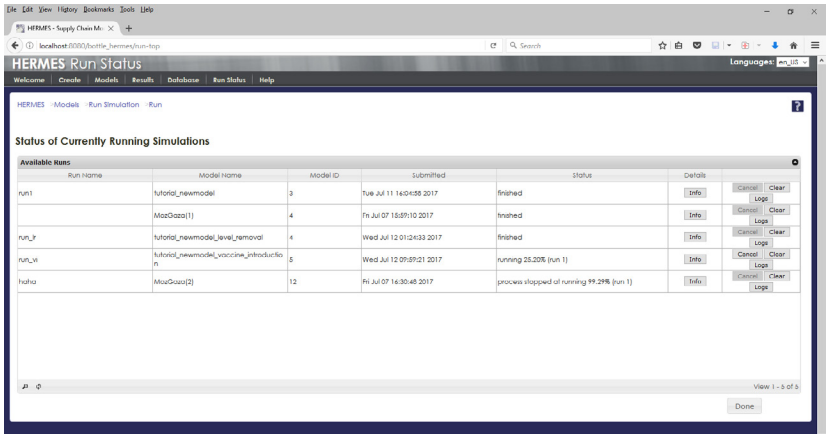
29. Type a name for your model and click the "**Submit**" button. There should be no warnings or errors in the model.

NOTE: if there are warnings or errors, please see the Troubleshooting section for further instructions.



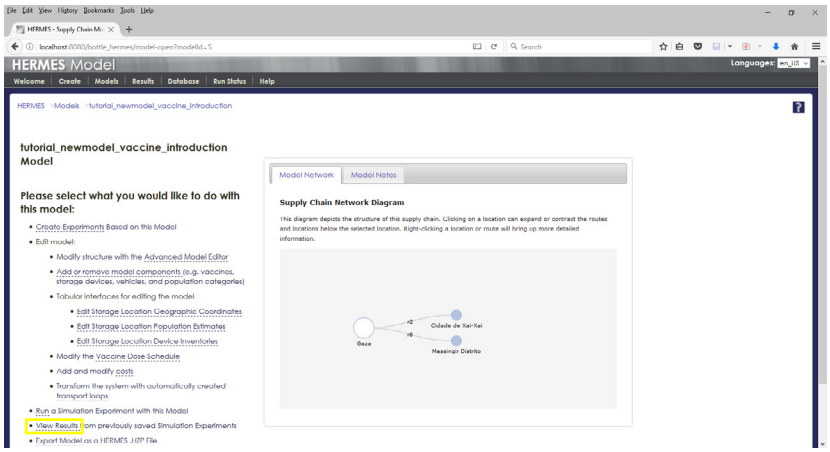
30. Click "**Run Simulation**".

NOTE: The run status page will open and you can watch the progress of your run.

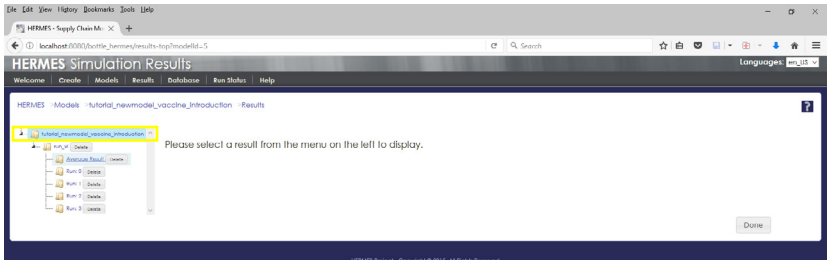


View results

Once your simulations have finished running, you can view and analyze the results through multiple interactive visualizations and charts, as well as detailed tables, and compare them to your original or baseline model.

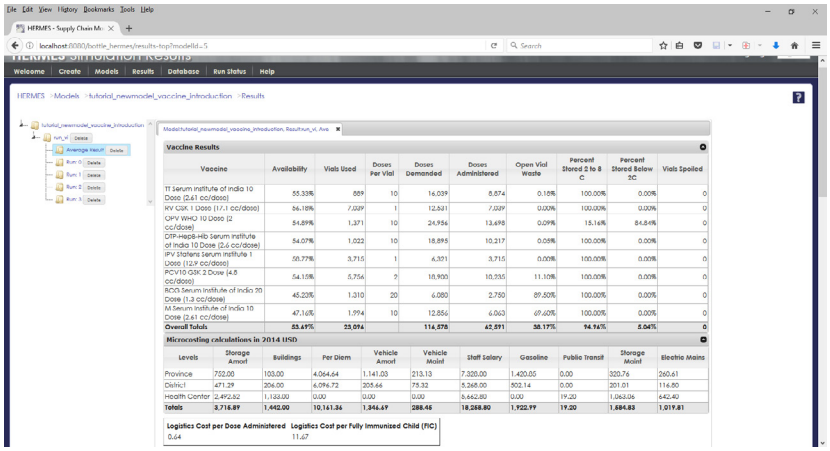


31. On the main model page, click on "**View Results**" (near the bottom of the page) to open the results page.



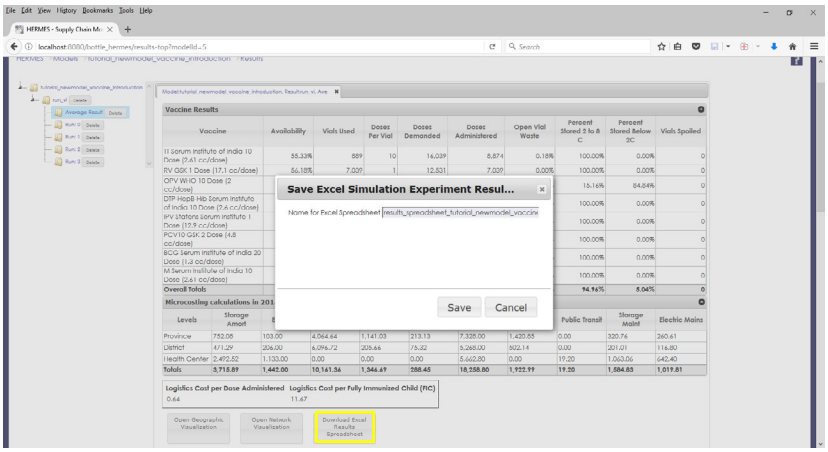
32. Expand the "**tutorial_newmodel_vaccine_introduction**" tree and select the Average Results

Tabular results

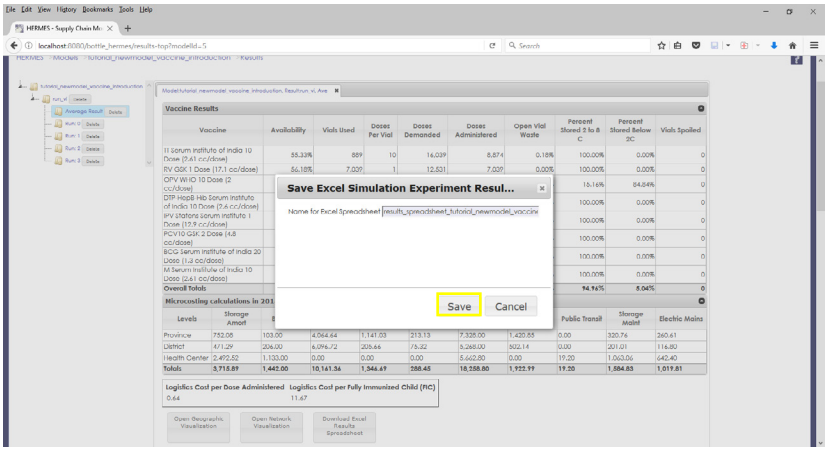


33. As you can see on the screenshot, introducing RV, IPV and a second dose of M vaccine caused overall vaccine availability to drop from 90% to 54%. The new vaccine introductions caused fewer doses to be administered (62,591) than at baseline (81,855) due to their larger cold chain volume per dose, as compared to most vaccines in the schedule at baseline.

    Logistics costs rose to $0.64 per dose administered (from $0.50 before the introductions) and $11.67 per fully immunized child (from $8.81).

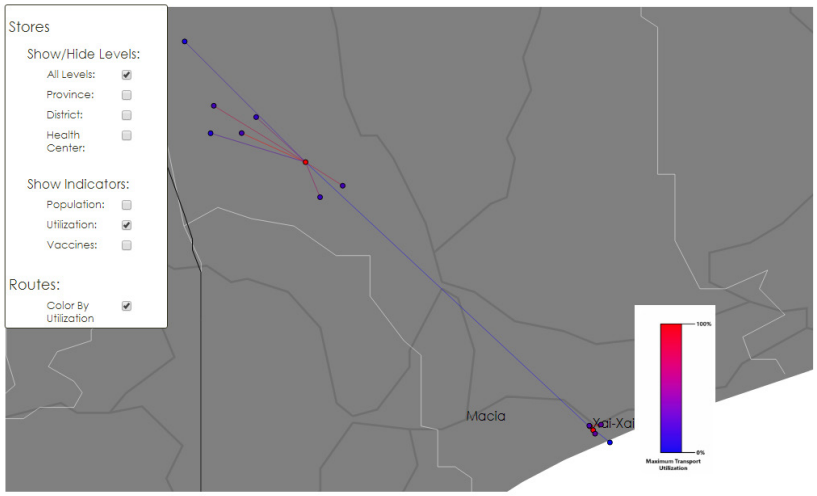


34. Click on the "**Download Excel Results Spreadsheet**" button below the tables to acquire a spreadsheet of more detailed results, where you can compare supply chain metrics not only for the overall system and by supply chain level, but also for each individual location and route.

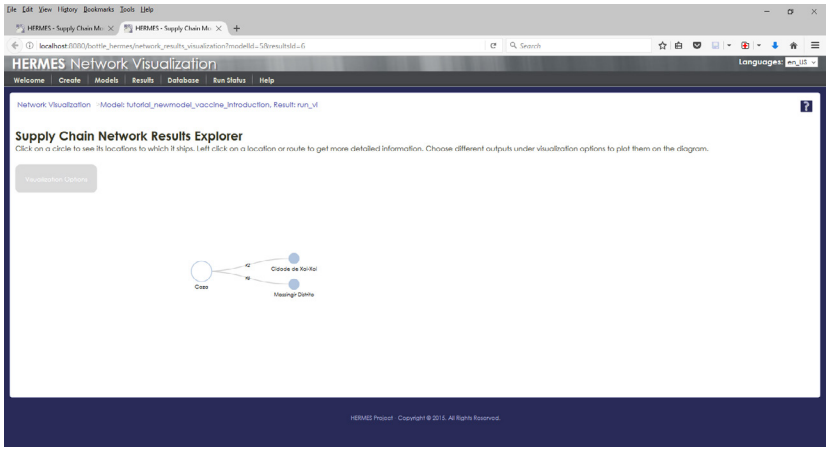


35. Click the "**Save**" button and then use the download dialog box to either open or save a copy.

Visualizations

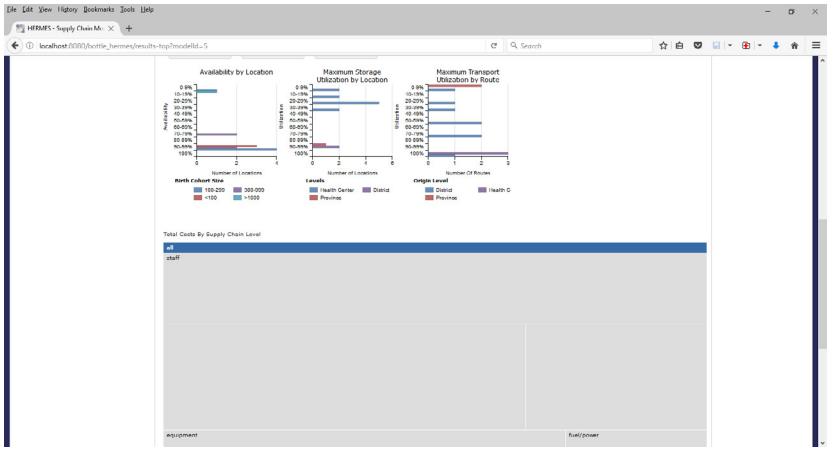


36. Click the "**Open Geographic Visualization**" button to view the supply chain locations and results on a map. This page will open in a new window and can take some time to load. Click the "color by utilization" buttonand explore the map to identify which locations and routes experience bottlenecks after the vaccine introductions.



37. Go back to the "**Results**" page and click the "**Open Network Visualization**" button. This page will also open in a new window. This diagram is the same as that on the main model page, but there is more room here to maneuver with it. You should notice that the structure has not changed from the original model.

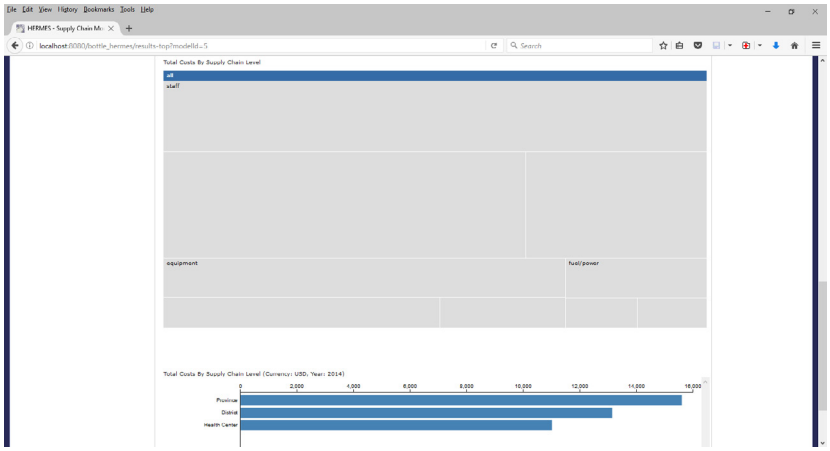
Histograms



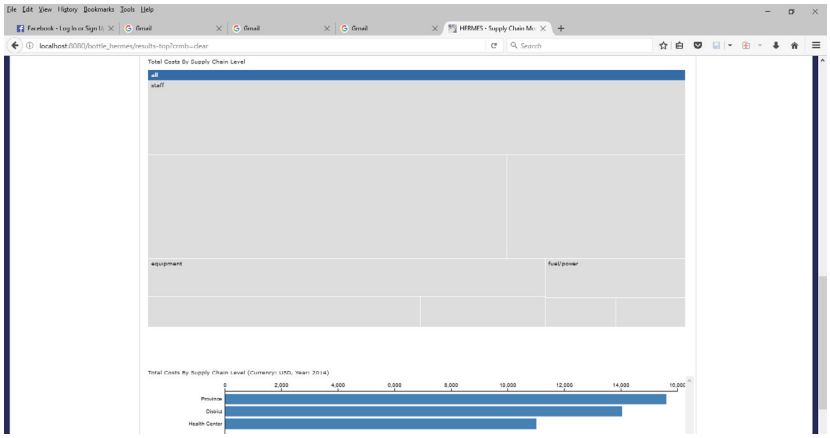
38. Go back to the Results page and scroll to the colored histograms. The vaccine availability histogram now shows two locations with availability below 20%, and two in the range of 70-79%. The storage utilization histogram shows storage constraints at both district stores and the province level store (whereas previously only one district store faced a storage constraint). The transport utilization histogram shows that all three routes originating from health centers (to pick up vaccines via public transit) face bottlenecks after vaccine introductions, as does a newly constrained route originating from the district level.

Total costs by supply chain level

39. Comparing the new treemap & barchart to the old can be an easy way to notice some differences. In this case the changes are not very dramatic.



after vaccine introduction



before vaccine introduction.

40. Take some time to interact with the results.

Next steps

You have now completed the HERMES tutorial on introducing vaccines to a model. See other tutorials for additional experiments you can perform with your model, such as modifying supply chain capacity by level.

1. Lee BY, Assi T-M, Rajgopal J, et al. Impact of introducing the pneumococcal and rotavirus vaccines into the routine immunization program in Niger. American journal of public health. 2012;102(2):269-276.

2. Lee BY, Assi T-M, Rookkapan K, et al. Maintaining Vaccine Delivery Following the Introduction of the Rotavirus and Pneumococcal Vaccines in Thailand. PLoS ONE. 2011;6(9):e24673.

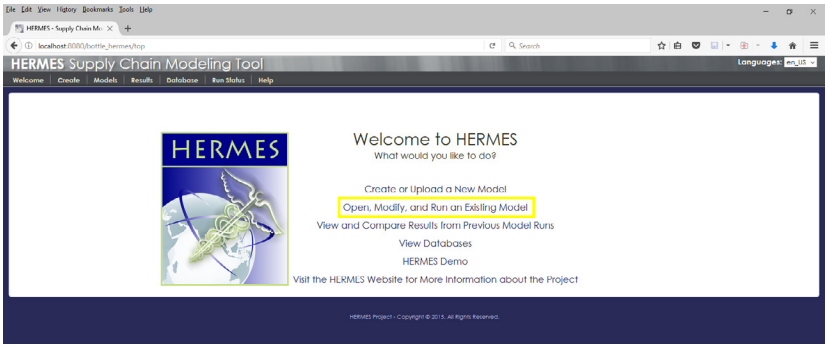
Tutorial 4 | Adding storage devices by supply chain level

This tutorial will allow you to experiment with adding storage devices by level (Province, District and Health Center) into the supply chain. This experiment shows the effect of a new storage device on overall vaccine availability. For example, adding storage devices could allow X more doses of vaccines to flow through the system, resulting in a Y% increase in vaccine availability. Examples of secondary and tertiary effects include the effects on transport utilization (does transport capacity need to increase as well?) and logistics costs (increased capital, electricity, and personnel costs). Previous modeling work has highlighted these effects.

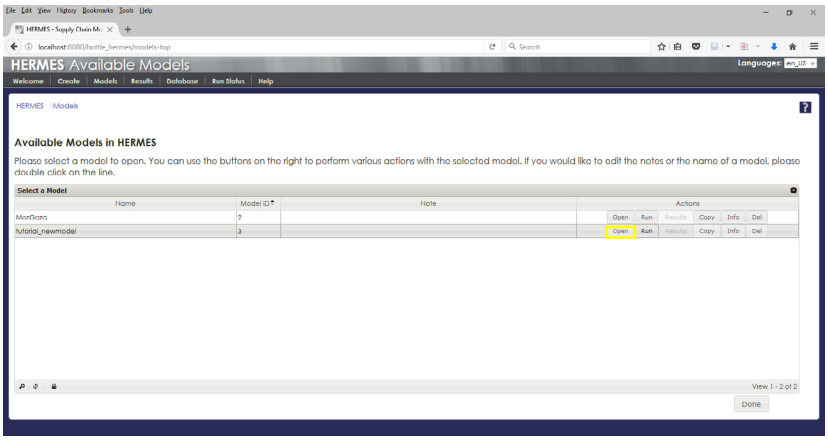
These instructions will guide you through adding cold storage devices to all locations in a supply chain level to create an experimental scenario based on an existing model. The following steps will add a refrigerator to each district level location in your model, which was previously shown to face storage capacity constraints at a district store.

This tutorial utilizes the model you created in the “Creating a new model” tutorial. You can also find this model in the tutorial materials provided to you.

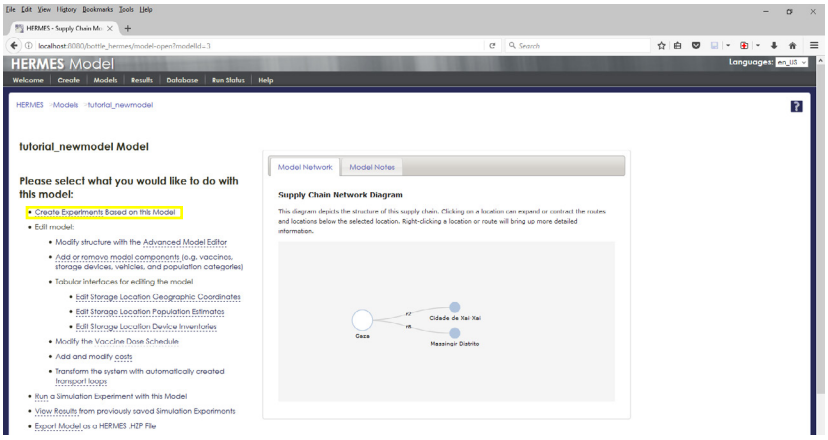
Begin add storage devices by level workflow



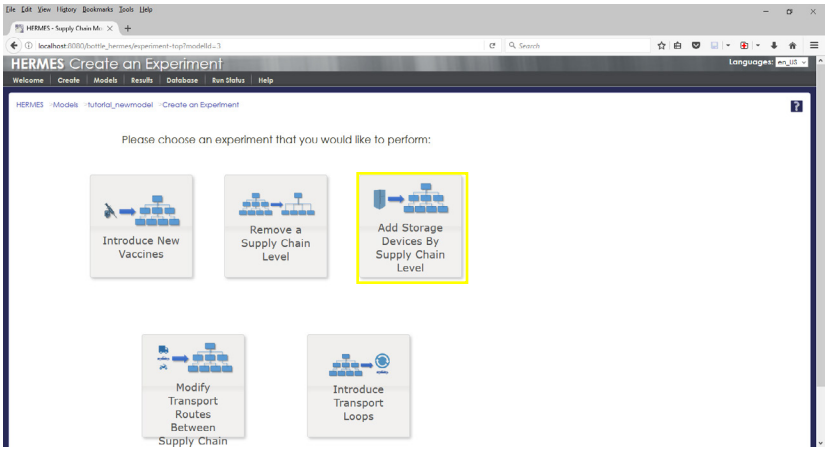
1. On the Welcome Page, click “**Open, Modify and Run an Existing Model**”



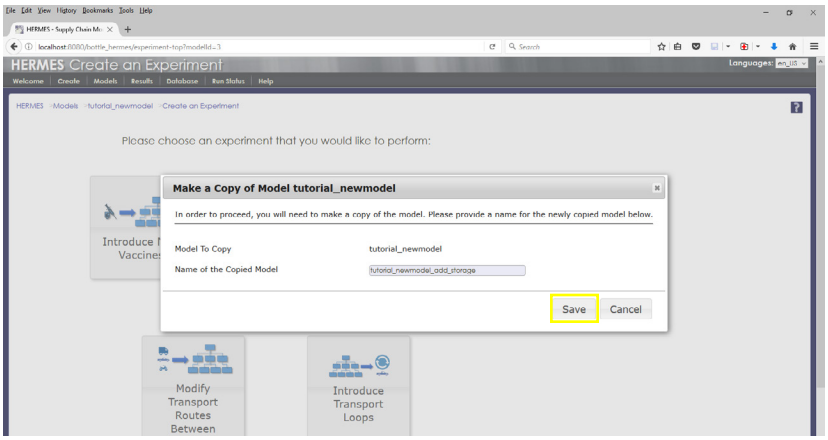
2. Click on the "**Open**" button in the "**tutorial_newmodel**" row.



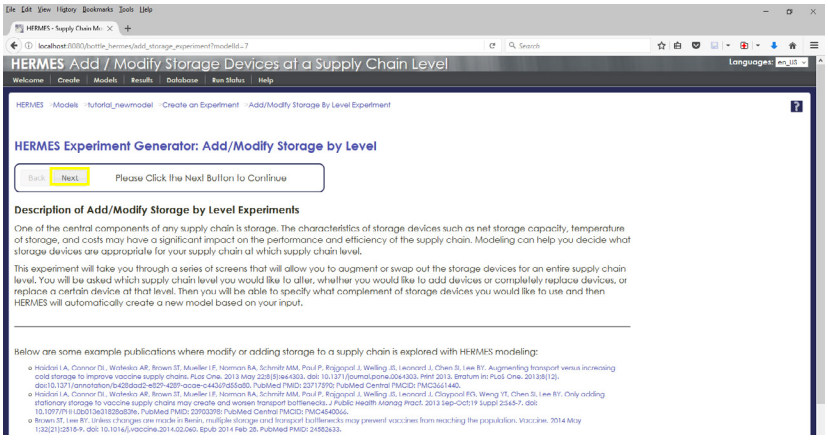
3. **NOTE:** This opens the main model page. Click on "**Create Experiments Based on this Model**" (top bullet) to open the Create an Experiment page.



4. Click on the "**Add Storage Devces by Supply Chain Level**" box.

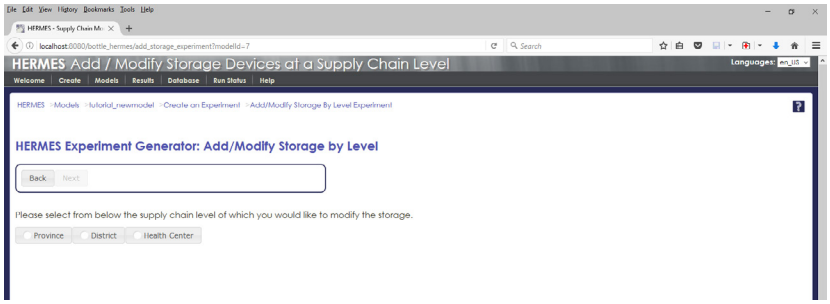


5. You will be prompted to create a copy of the model to run. Making a copy allows you to keep the original model as a baseline comparator to the experimental model you are creating. Enter a new name for the model copy (or use the one automatically filled in) and click the "**Save**" button.

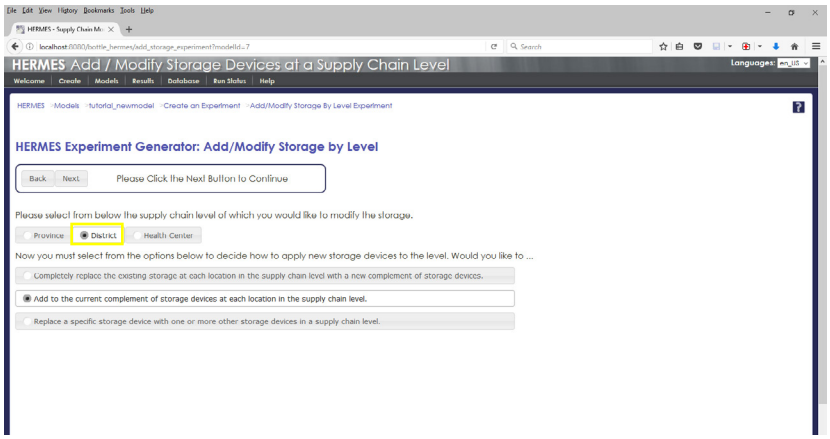


6. This page offers additional information on the modified storage capacity scenarios you can model using this experiment generator. Click the "**Next**" button when you are ready to move to the next page.

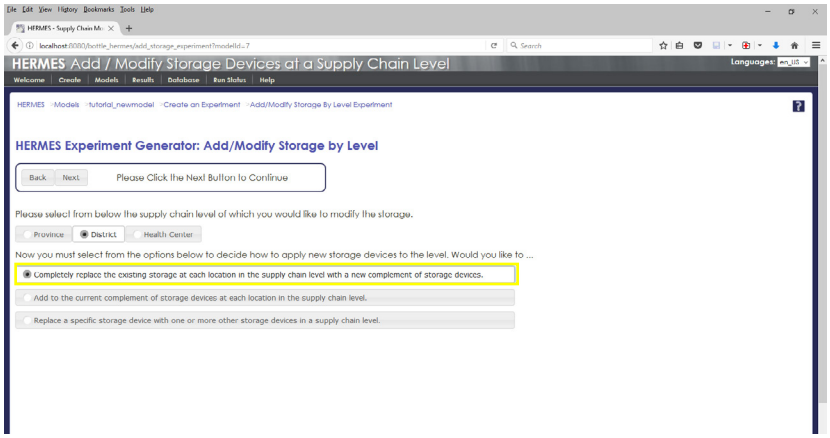
Specify level and type of modification



7. Click "**Next**" to initiate your choices for adding or modifying storage at a specific level.

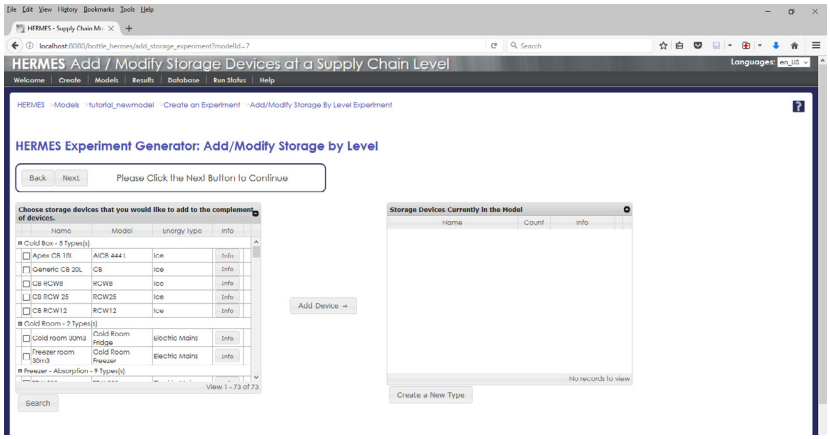


8. Select "**District**" as the level whose storage you would like to modify. This will open another selection below.

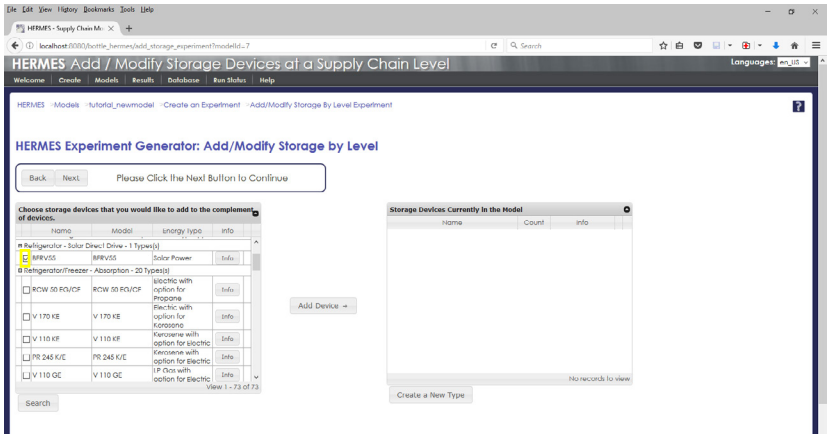


9. Select "**Completely replace the existing storage at each location...**" as the type of action you want to perform.

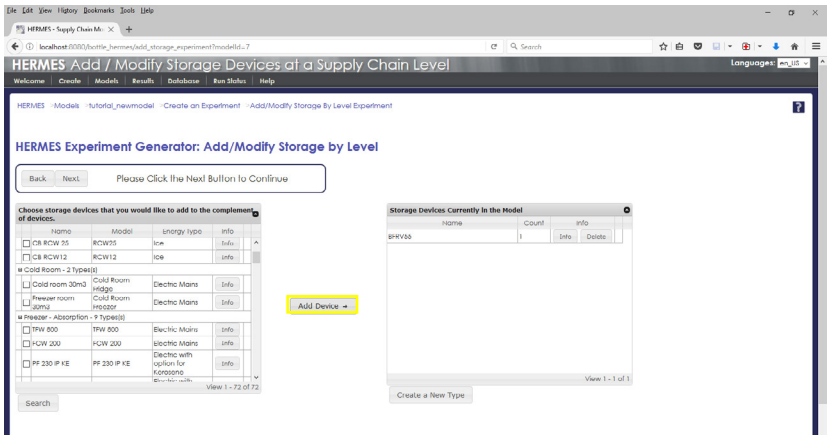
Select storage devices



10. Click "**Next**". You are now on the screen that allows you to choose the new device(s) to be added at the level selected.

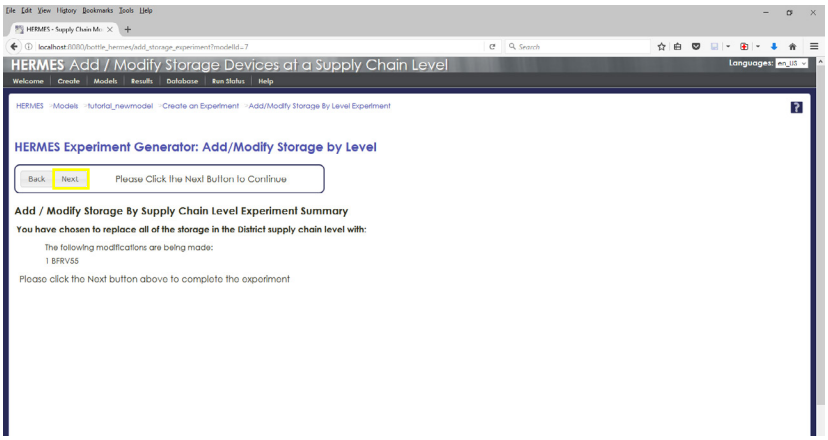


11. In the table on the left, choose "**BFRV55**", which is the only item under "**Refrigerator – Solar Direct Drive**". You can locate it either by scrolling through the table or using the Search button below the table. Once you've found it, click the check box next to it.



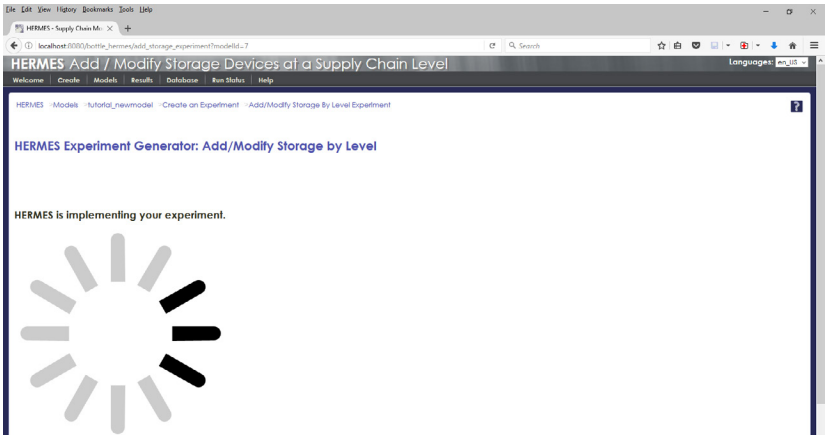
12. Now click on the "**Add Device**" button in the middle of the page to update the "**Storage Devices Currently in Model**" table.

NOTE: If you wanted to add more than one to each location at the level, you could change the count in the table on the right by clicking on the row. Or if you added the wrong type, you could delete it and then add the correct type.

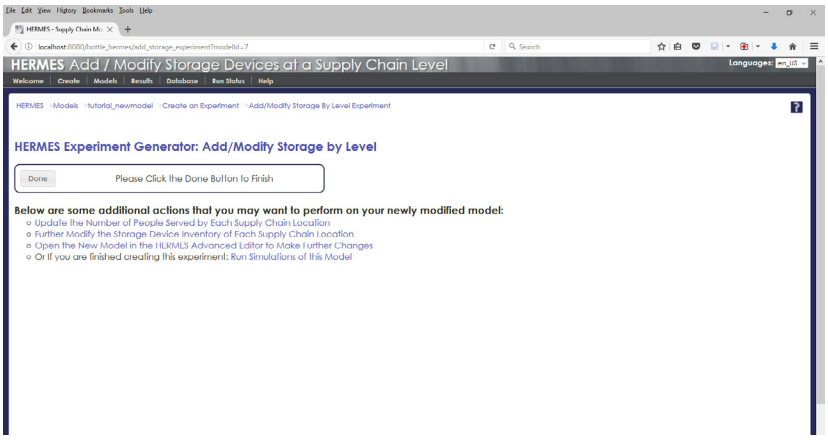


13. Once you are satisfied with the complement of storage devices you are adding to your selected level, click the "**Next**" button to get a summary page.

NOTE: If something looks wrong, you can always use the "**Back**" button to fix it before changing the model.

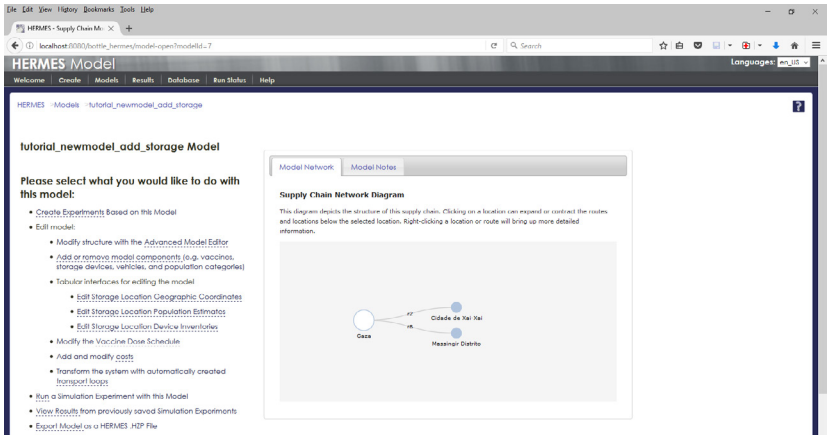


14. Click the "**Next**" button to have HERMES adjust the model by updating the storage at each location at the District level to have one BVRV55 solar refrigerator and nothing else. This might take a few seconds or a few minutes depending on how large your model is (It shouldn't take more than 10 secs for this model.)

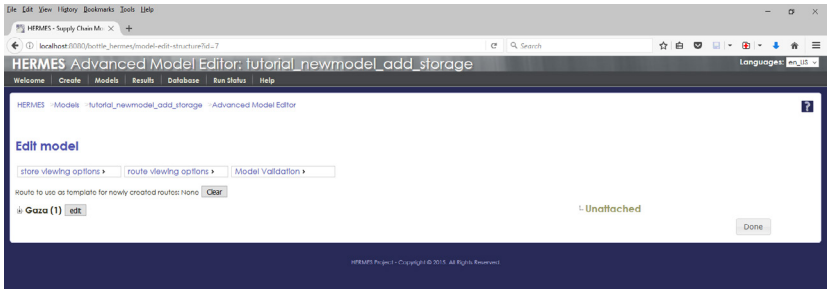


15. When the model has been adjusted, the page will be updated with some further possible actions.

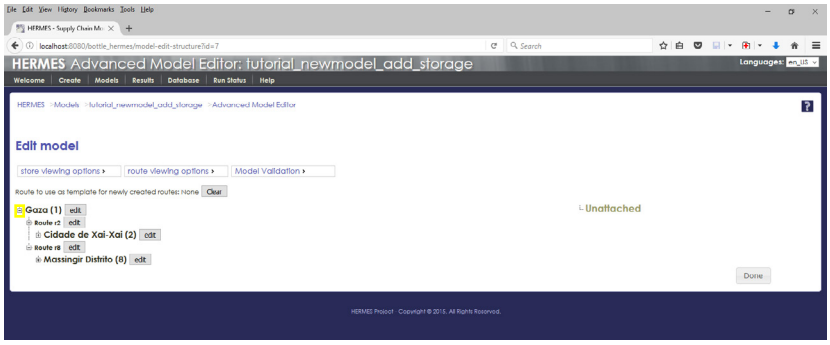
View changes in model



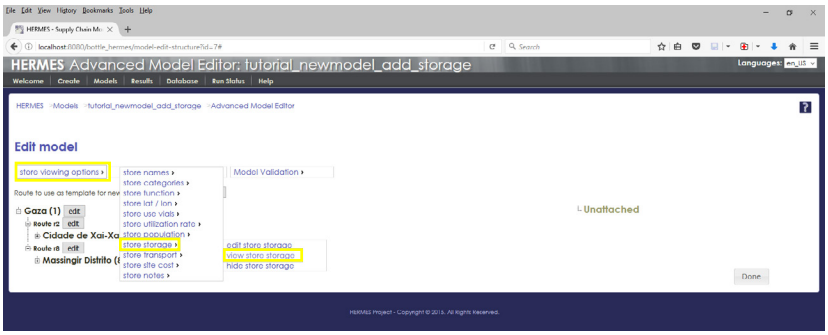
16. Take a look at the changes in the model. Open the model "**tutorial_newmodel_add_storage**" (or whatever you named it in step 5) by going to the "**Models**" page and clicking "**Open**" in its row.



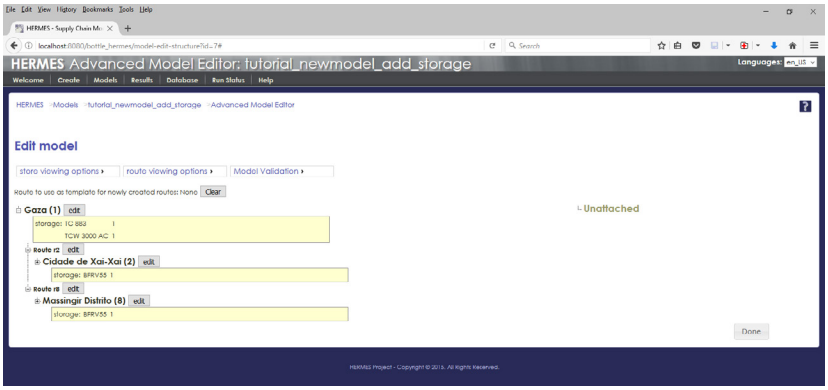
17. Click on "**Advanced Model Editor**" at the top of the page.



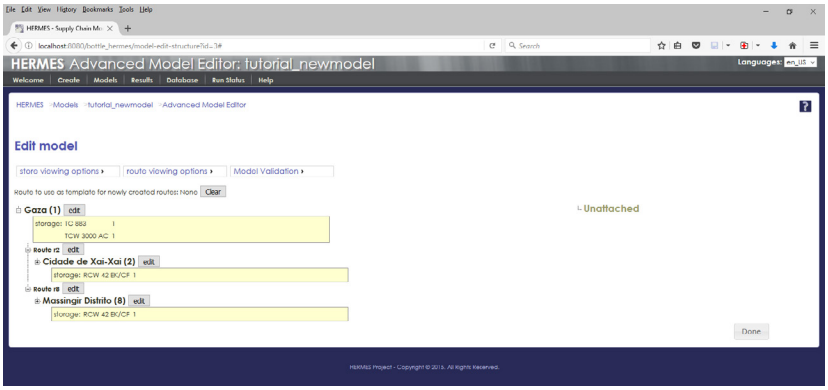
18. Click on the plus sign next to "**Gaza (1)**" so you can see the District levels.



19. From the store viewing options dropdown box in the top left, select “**store storage**” and “**view store storage**”.

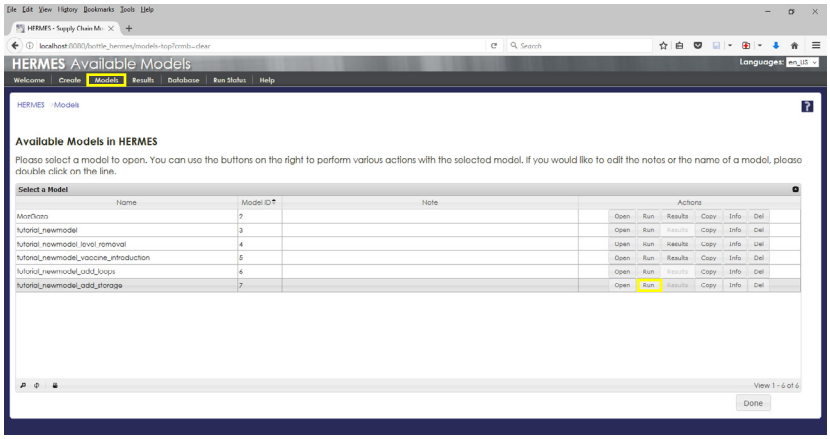


20. You should see that the districts **Cidade de Xai-Xai** and **Massingir Distrito** each contain **1 BFRV55**, as you would expect.

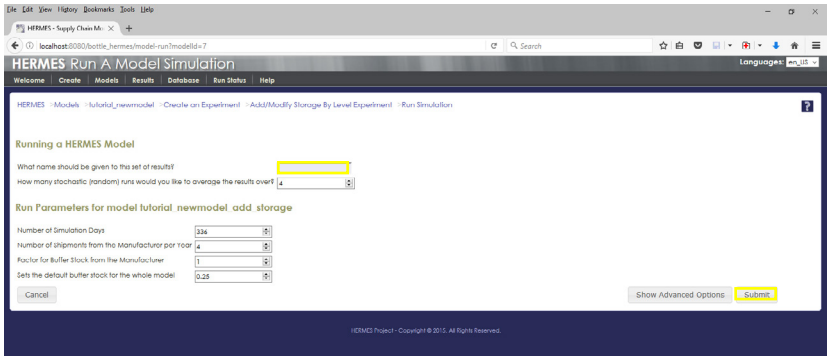


21. If you perform steps 16-20 but open the original **tutorial_newmodel** instead, you should see that the two districts each have **1 RCW 42 EK/CF**, not the **BFRV55** you just substituted. If you have previously run results on your original model, you will first need to make a copy before opening the Advanced Model Editor.

Run the simulation

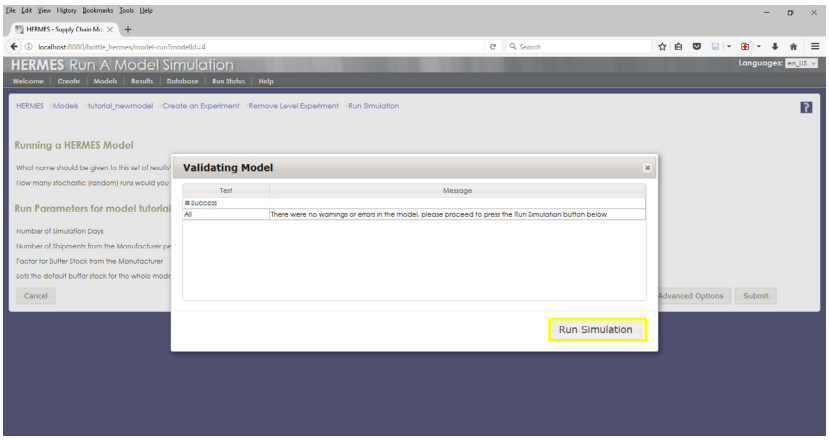


22. Click on "**Models**" in the top menu bar to get to the models page. Then click the "**Run**" button in the row with your vaccine introduction model, here **tutorial_newmodel_ add_storage** to open the "**Run Simulation**" page.

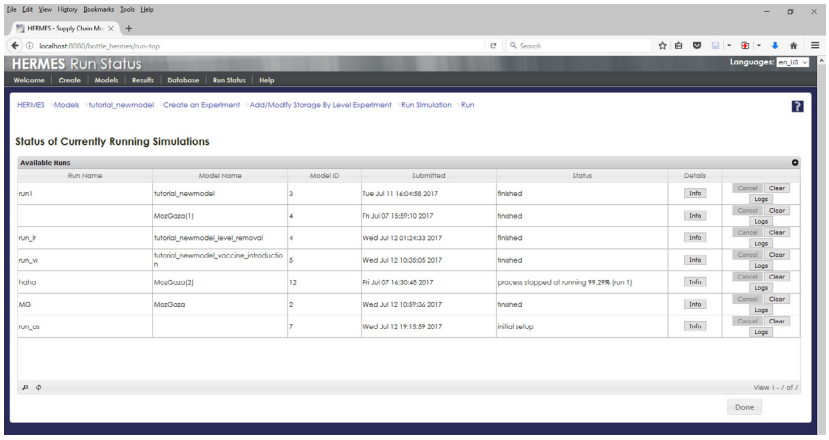


23. Type a name for your model in the box next to "**What name should be given to this set of results?**" and click the "**Submit**" button.

NOTE: There should be no errors in the model.



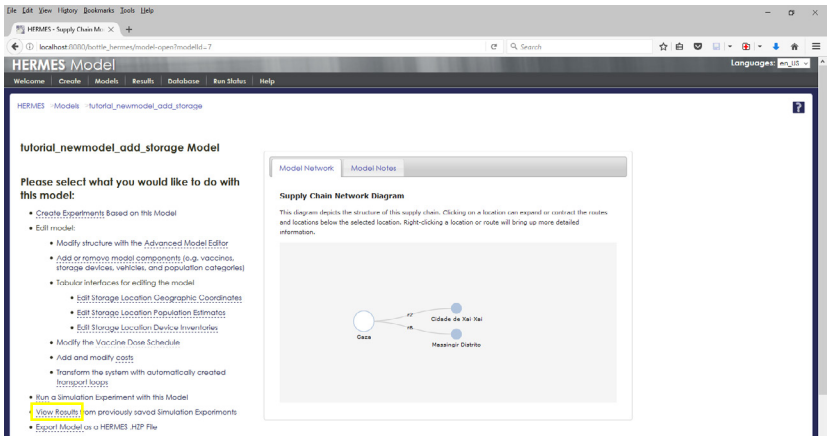
24. Click the "**Run Simulation**" button.



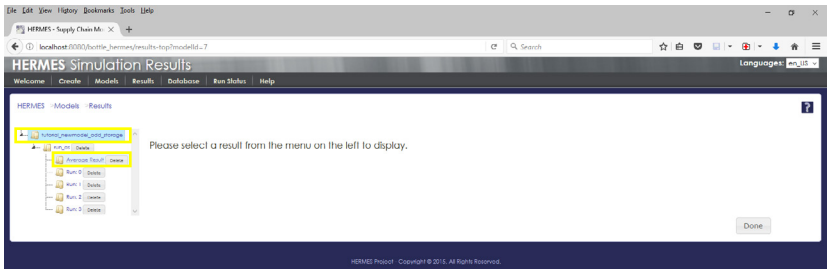
NOTE: The run status page will open and you can watch the progress of your run.

View results

Once your simulations have finished running, you can view and analyze the results through multiple interactive visualizations and charts, as well as detailed tables, and compare them to your original or baseline model.



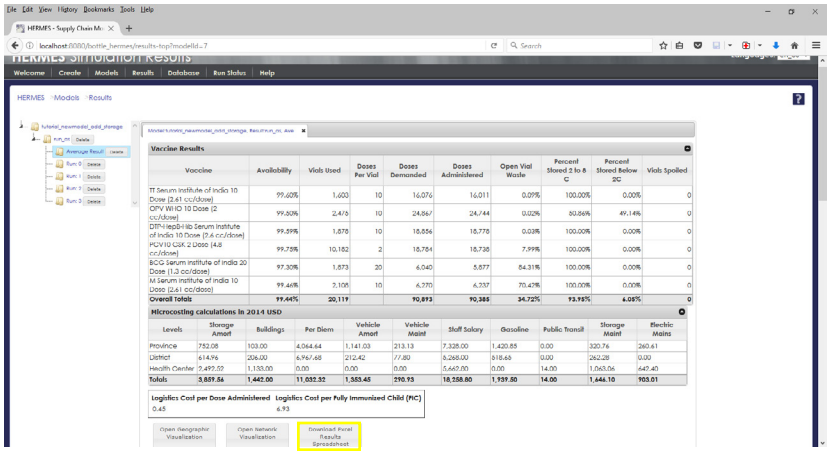
25. On the main model page, click on "**View Results**" (near the bottom of the page) to open the results page.



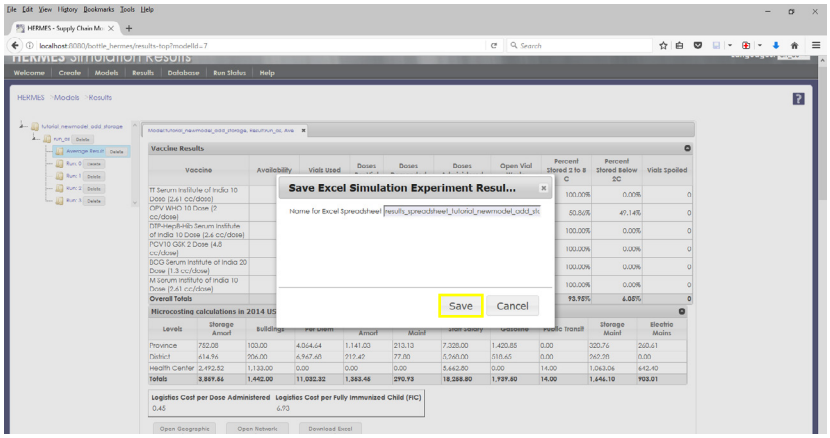
26. Expand the "**tutorial_ newmodel_add_storage**" tree and select the "**Average Results**"

Tabular results

27. Adding a refrigerator to the district level stores increased vaccine availability to greater than 99% (from 90% at baseline, or before adding storage). The increased number of doses caused the logistics cost per dose administered to drop to $0.45 (from $0.50 before adding the refrigerators) and the logistics cost per fully immunized child to fall to $6.93 (from $8.81).

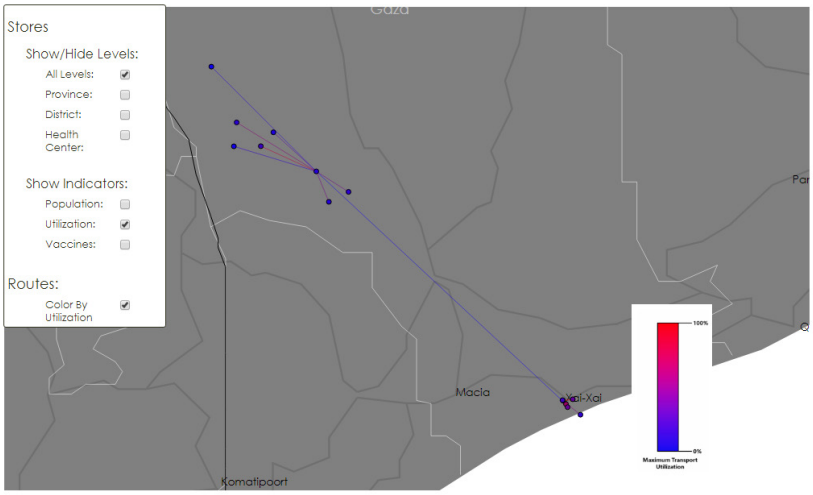


28. Click on the "**Download Excel Results Spreadsheet**" button below the tables to acquire a spreadsheet of more detailed results, where you can compare supply chain metrics not only for the overall system and by supply chain level, but also for each individual location and route.



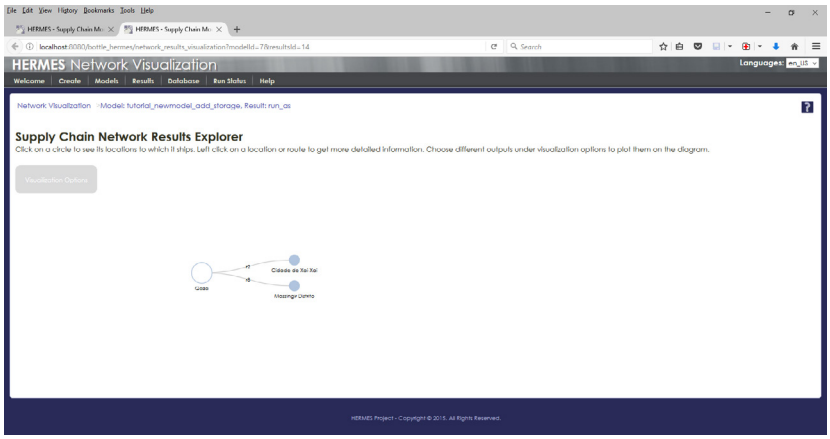
29. Click the "**Save**" button and then use the download dialog box to either open or save a copy.

Visualizations



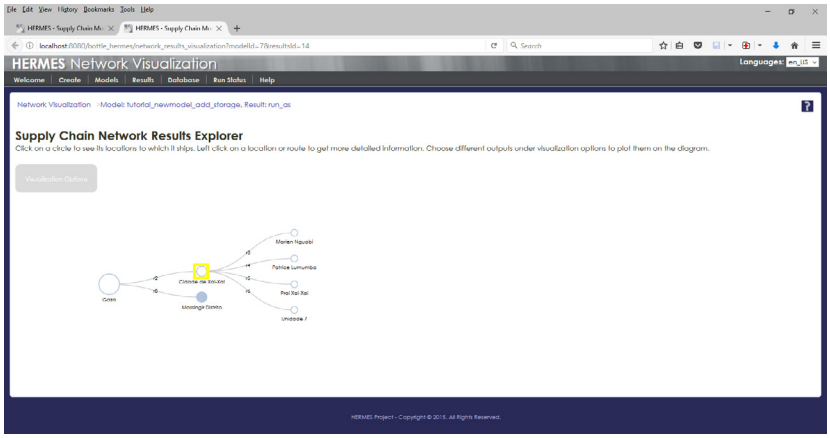
30. On the "**Results**" page, click the "**Open Geographic Visualization**" button to view the supply chain locations and results on a map.

    NOTE: This page will open in a new window and can take some time to load. Click on "Color by Utilization" and explore the map to identify whether any locations or routes experience bottlenecks after the addition of refrigerators at the district stores.



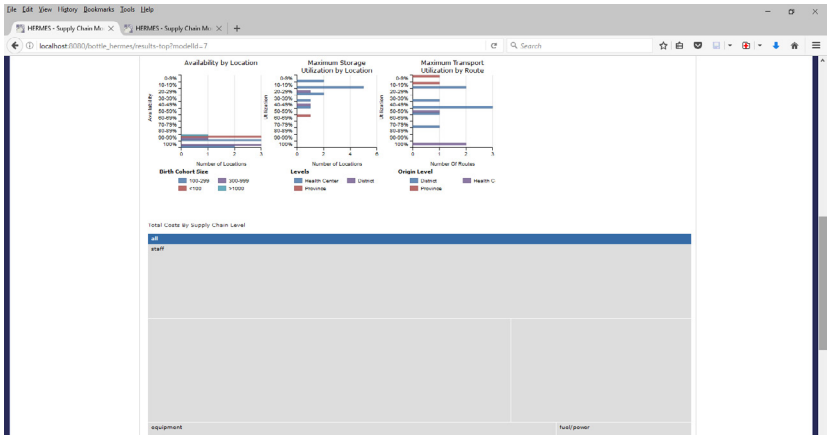
31. On the "**Results**" page, click the "**Open Network Visualization**" button.

    NOTE: This page will also open in a new window. This diagram is the same as that on the main model page, but there is more room here to maneuver with it. Take some time to explore the structure and notice that it is still the same as the original model.



32. A filled in circle means there are locations below that one, which you can see if you left click on the circle. Left click on the "**Cidade de Xai-Xai**" circle to expand the locations below.

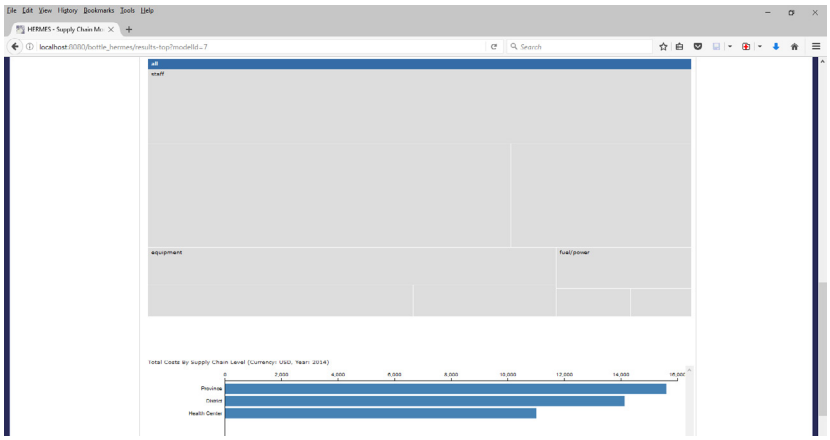
Histograms



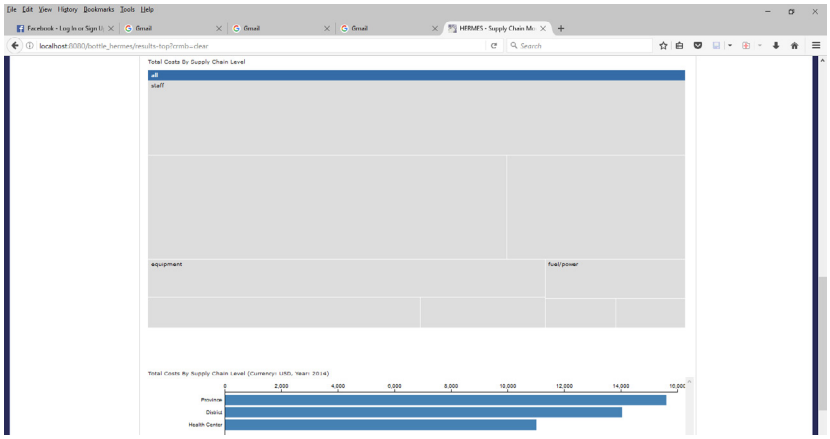
33. The vaccine availability histogram now shows all vaccinating locations achieving greater than 90% availability. The maximum storage utilization histogram also indicates that the storage bottleneck at the Cidade de Xai-Xai district store has been resolved, as all locations peak at under 70% storage utilization. The two bus routes to the district store remain constrained, however.

Total costs by supply chain level

34. Total costs by supply chain level are represented by a treemap and bar chart, both of which are interactive. Comparing the new ones to the old model can be an easy way to notice some differences. In this case, the changes are not very dramatic.



with BRFV55



with RCW

35. Take some time to interact with the results.

Next Steps

You have now completed the HERMES tutorial on adding storage devices by supply chain level to a model. See other tutorials for additional experiments you can perform with your model, such as removing a supply chain level.

1. Haidari LA, Connor DL, Wateska AR, et al. Augmenting transport versus increasing cold storage to improve vaccine supply chains. PloS one. 2013;8(5):e64303.

Tutorial 5 | Removing A Level From The Supply Chain

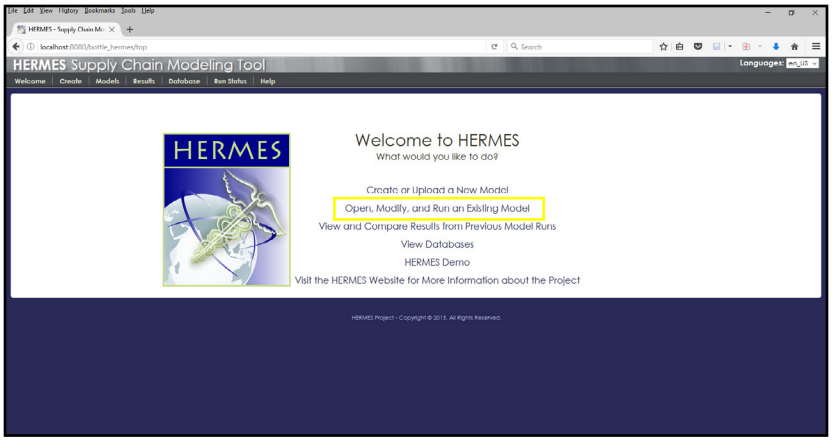
This tutorial will allow you to experiment with removing a supply chain level from the vaccine supply chain. Removing a level (regional, district, health center, etc.) from the supply chain can cut out storage costs, but can simultaneously increase transport frequency, utilization and costs. Given the substantial alterations to a supply chain that this would likely have, the HERMES model allows the user to simulate this scenario and compare the direct and indirect effects on the supply chain indicators to results in previous tutorials. For example, the removal of a supply chain necessitates a new policy for shipping to be set. In previous work, the HERMES model showed the effects of supply chain removal on the Niger vaccine supply chain under multiple shipping policies.

In this tutorial, you will re-design the supply chain to produce a two-level system, in which the provincial store delivers vaccines directly to the vaccinating locations by truck once per month, rather than distributing vaccines through the two district level stores.

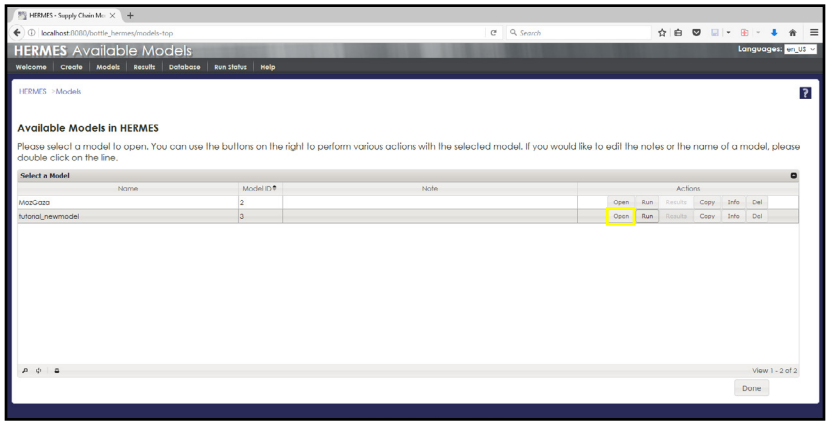
You will re-design the supply chain to transport the vaccines directly from the provincial hub (where the vaccine is introduced into the system) to the vaccinating locations by a truck once per month rather than distributing vaccines through the district level stores.

This tutorial utilizes the model you created in the “Creating a new model” tutorial. You can also find this model in the tutorial materials provided to you.

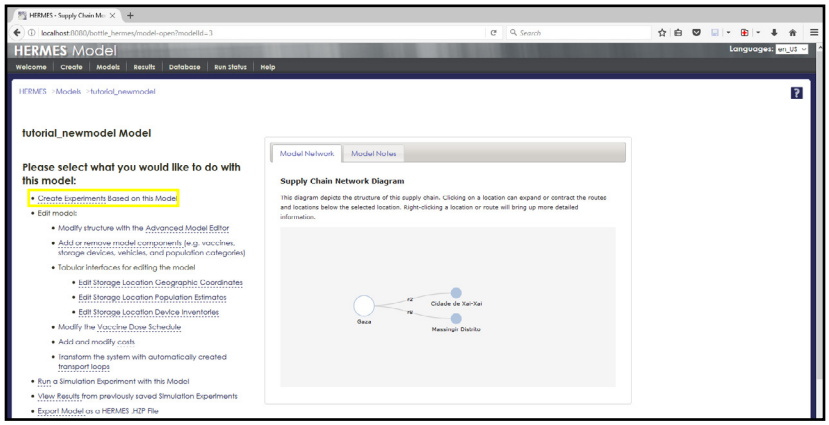
Begin supply chain level removal experiment workflow



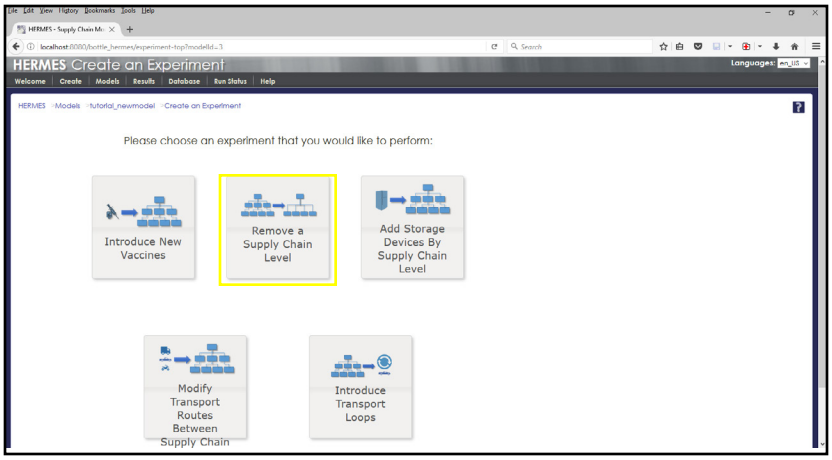
1. On the Welcome Page, click **"Open, Modify and Run an Existing Model"**



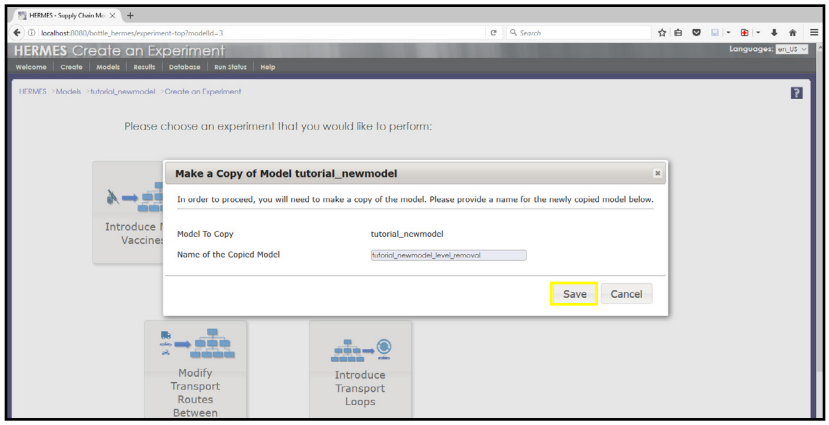
2. Click the **"Open"** button in the **"tutorial_newmodel"** row.



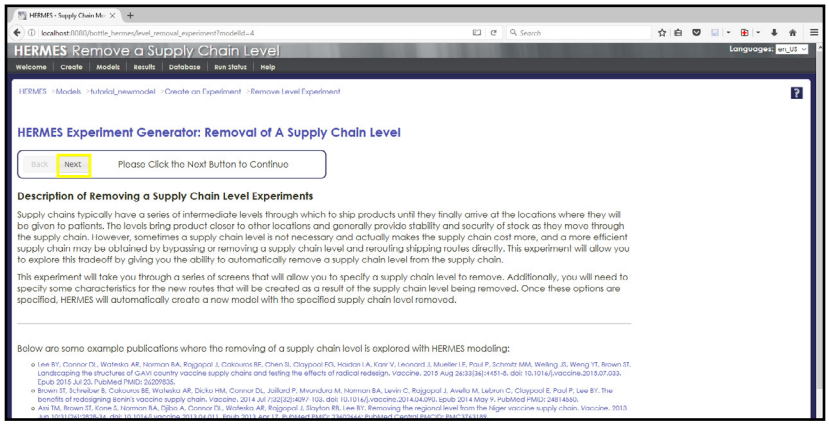
3. This opens the main model page. Click on **"Create Experiments Based on this Model"**.



4. Click on the **"Remove a Supply Chain Level"** box.

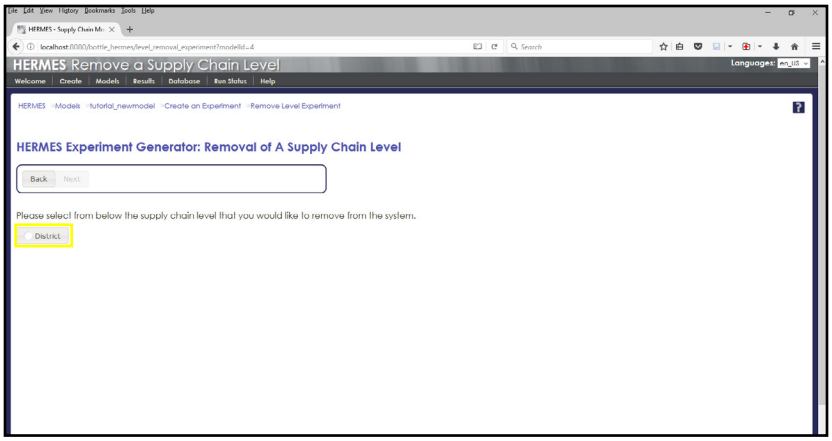


5. You will be prompted to create a copy of the model to run. Making a copy allows you to keep the original model as a baseline comparator to the experimental model you are creating. Enter a new name for the model copy (*or use the one automatically filled in*) and click the **"Save"** button.



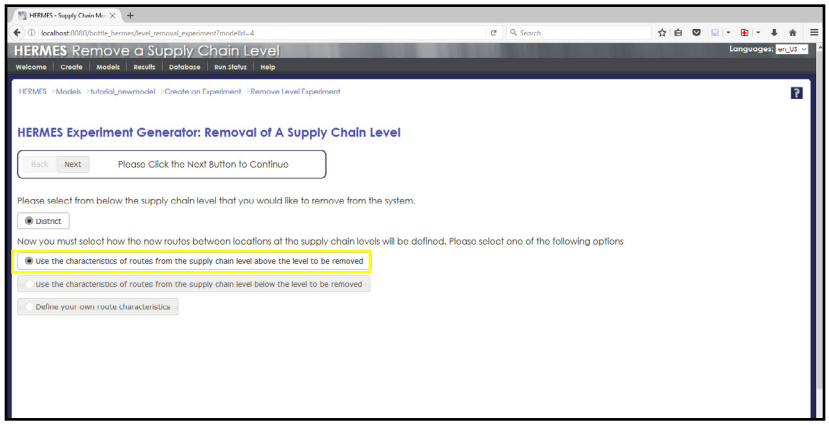
6. This page offers additional information on the different supply chain level removal scenarios you can model using this experiment generator. Click the **"Next"** button when you are ready to move to the next page.

Specify New Structure and Route Characteristics

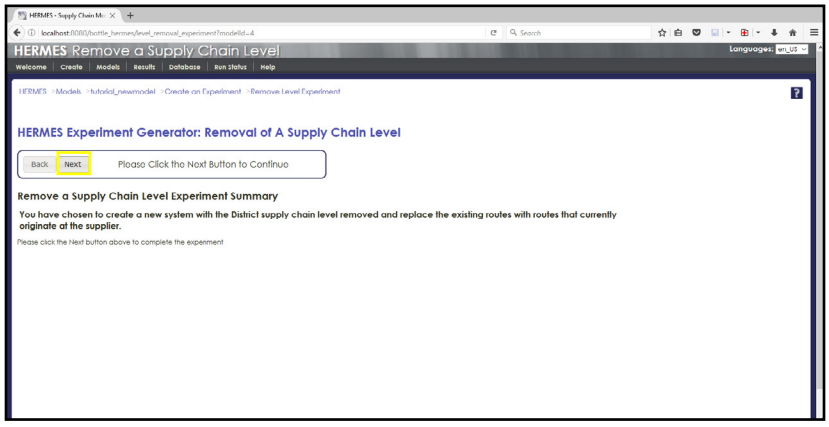


7. Select the **"District"** level for removal (*your only option in this scenario*).

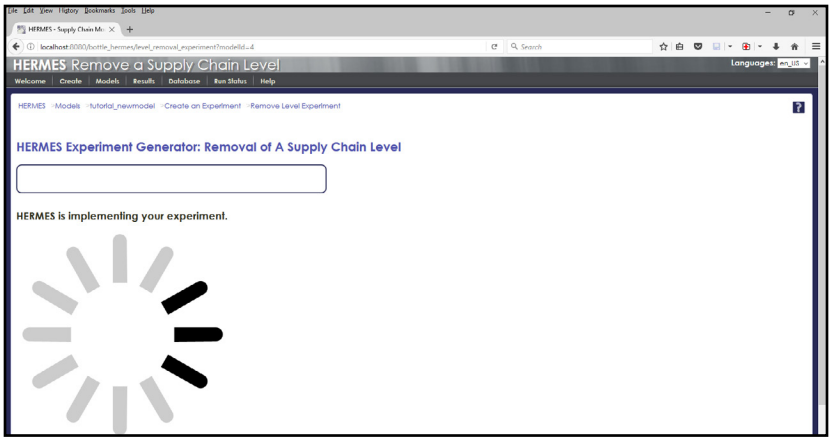
NOTE: This will reveal another set of options below.



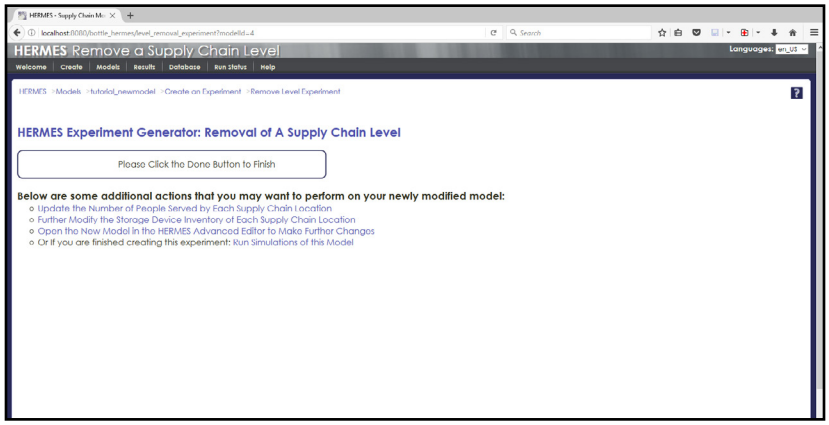
8. Select **"Use the characteristics of routes from the supply chain level above the level to be removed."** This means the provincial store will now deliver vaccines to health centers using a truck.



9. Click **"Next"** to get a summary page.

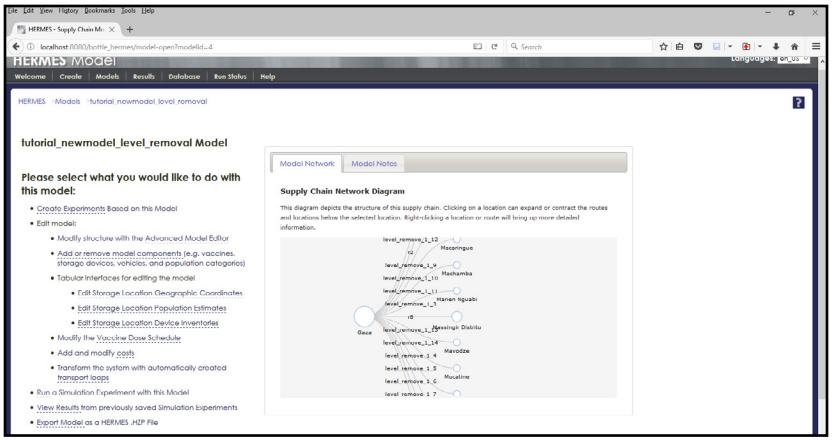


10. Click **"Next"** again to have HERMES remove the district stores and create new routes between the remaining levels. This may take a few seconds depending on how large the model is.

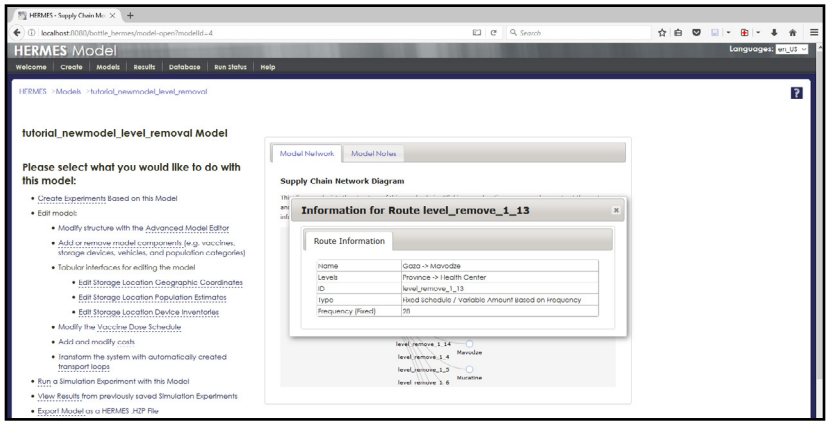


11. When the model has been adjusted, the page will update with some further options. You have now removed the district stores from the supply chain model and created routes for the province level to directly supply the vaccines to the health centers.

View Changes to Model

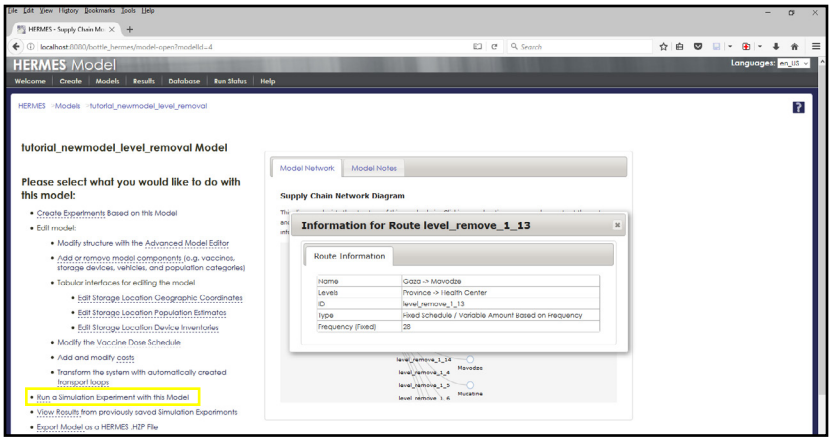


12. To view the changes in the model, open the model **"tutorial_newmodel_level_removal"** (*or whatever you named it in step 5*) by going to the Models page and clicking **"Open"** in the "tutorial_newmodel_level_removal" row. This will lead you to the page shown here.

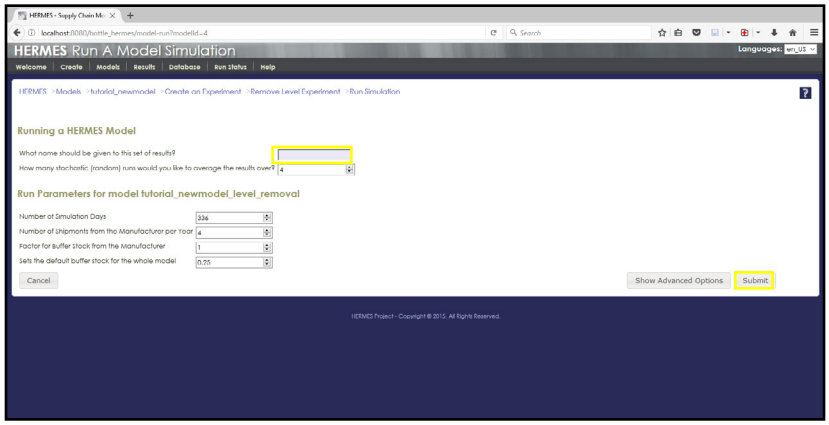


13. Notice that the routes have new names (*level_remove_X_X*) and that the structure of the supply chain network diagram looks much different than it did before. The two district level locations (*Cidade de Xai-Xai and Massingir Distrito*) still appear in the network but only as vaccinating locations rather than as distribution centers. These locations will continue to receive vaccines in order to vaccinate the populations they directly serve. Spend a few minutes exploring the new structure and right clicking on the routes to see their descriptions.

Run Simulation

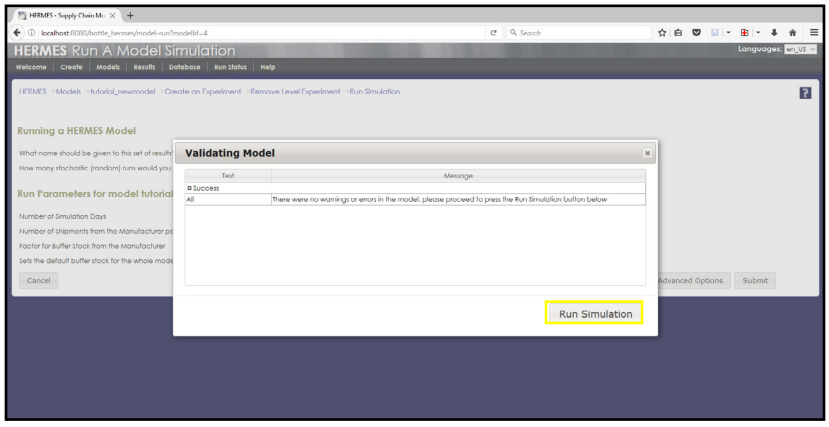


14. Click **"Run a Simulation Experiment with this Model"**



15. Type a name for your model and click the **"Submit"** button.

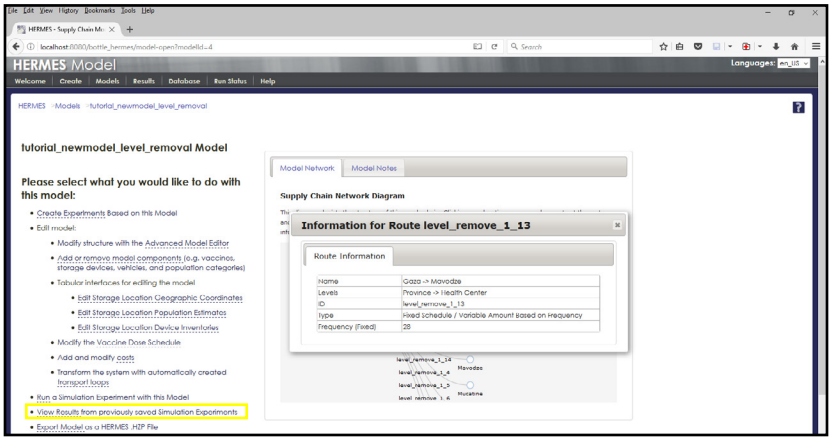
NOTE: There should be no errors in the model.



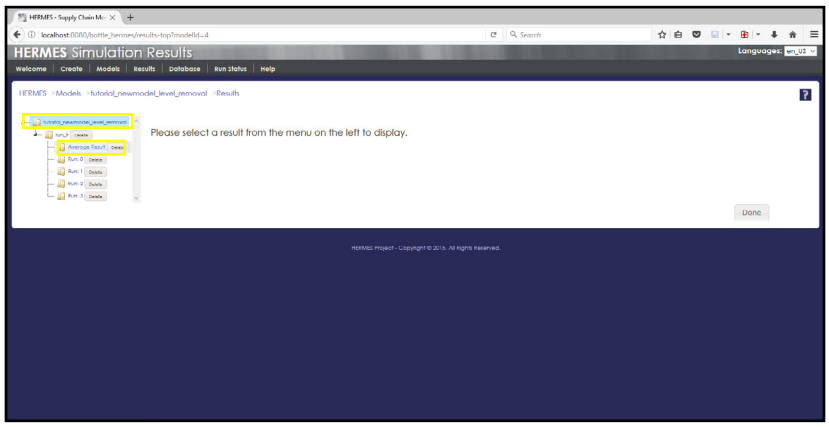
16. Click the **"Run Simulation"** button. The run status page will open and you can watch the progress of your run.

View Results

Once your simulations have finished running, you can view and analyze the results through multiple interactive visualizations and charts, as well as detailed tables, and compare them to your original or baseline model.

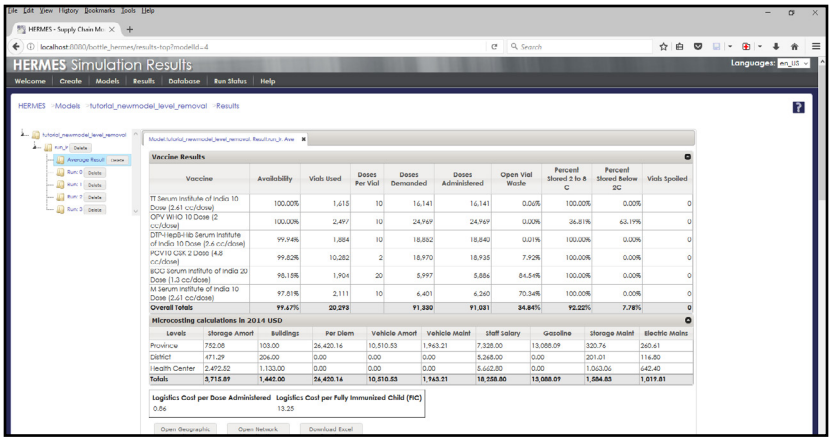


17. On the main model page, click on **"View Results from previously saved Simulation Experiments"** (*near the bottom of the page*) to open the results page.



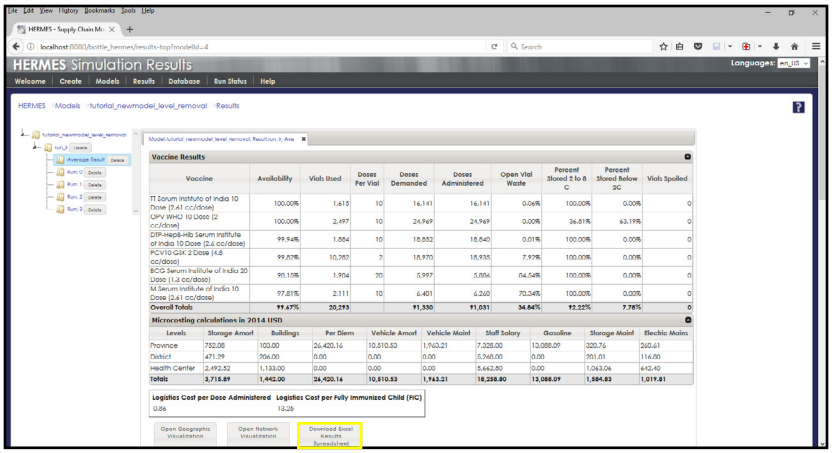
18. Expand the **"tutorial_ newmodel_level_removal"** tree and select the **"Average Results"**

Tabular Results

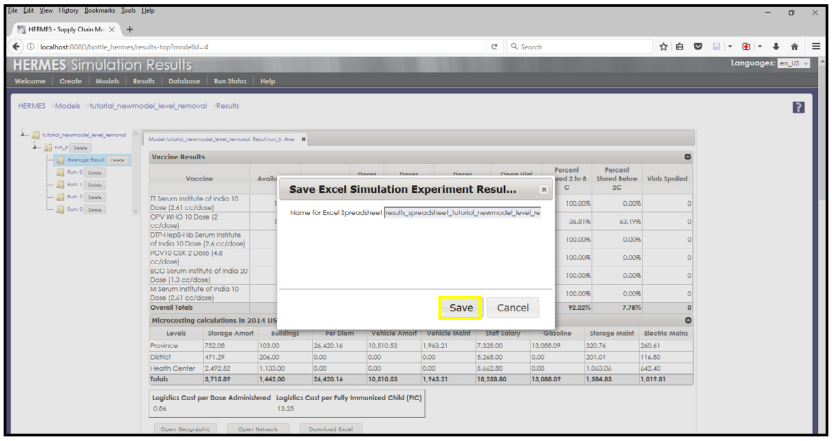


19. Removing the district level raised vaccine availability to greater than 99% (*from 90% at baseline, or before removing the district stores from the supply chain.*)

NOTE: There are no transport related costs at the district level, which now only receives vaccines to vaccinate populations that are in demand. However, transport costs increased overall as the provincial store used a more costly mode of transport to deliver to health centers (*a 4x4 truck*) than that previously used by the district stores (*motorbikes*). So despite the increased number of doses administered, the increased transport costs caused the logistics cost per dose administered to increase to $0.86 (*from $0.50 before adding the refrigerators*) and the logistics cost per fully immunized child rose to $13.25 (*from $8.81*).

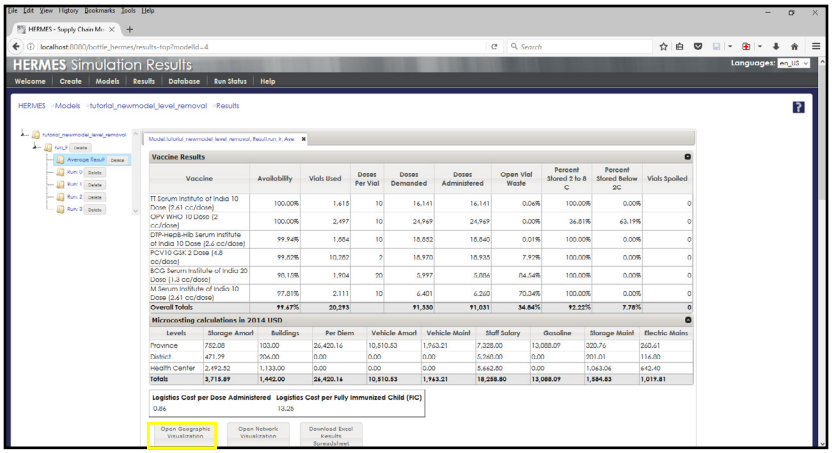


20. Click on the **"Download Excel Results Spreadsheet"** button below the tables to acquire a spreadsheet of more detailed results, where you can compare supply chain metrics not only for the overall system and by supply chain level, but also for each individual location and route.



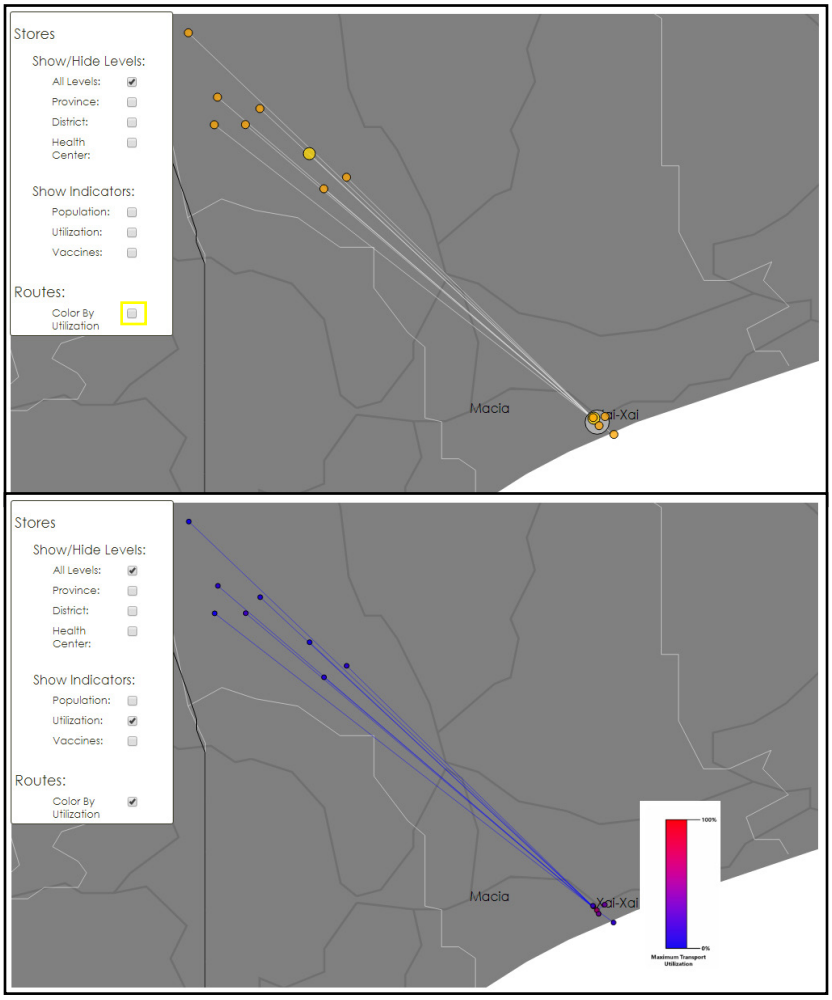
21. Click the **"Save"** button and then use the download dialog box to either open or save a copy.

Visualizations

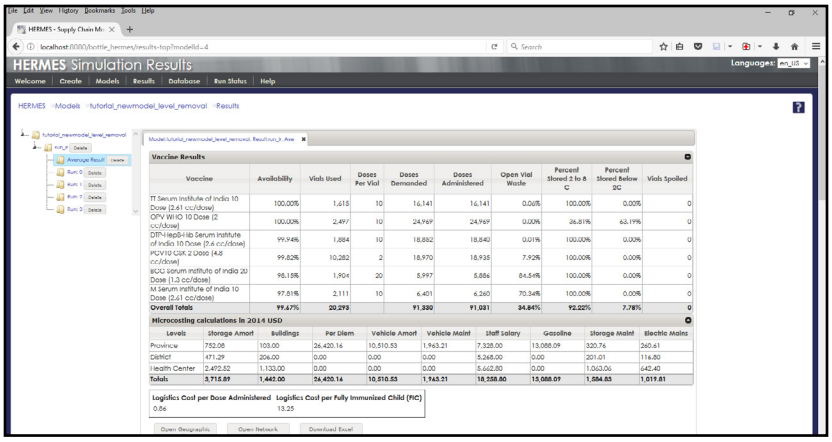


22. Click the **"Open Geographic Visualization"** button to view the supply chain locations and results on a map. This page will open in a new window and can take some time to load.

NOTE: The new supply chain structure depicted by the routes connecting the province store directly to the health centers.

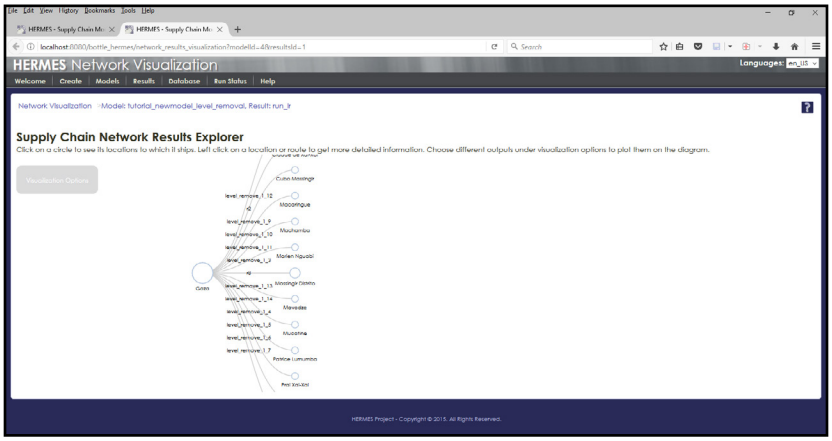


23. Click on the **"Color By Utilization"** button and explore the map to identify whether any locations or routes experience bottlenecks after the removal of the district stores from the supply chain.

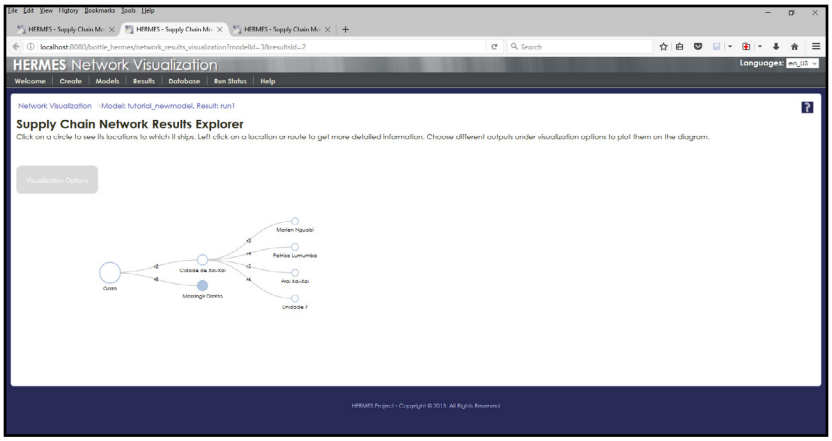


24. Click the **"Open Network Visualization"** button.

NOTE: This page will also open in a new window. This diagram is the same as that on the main model page, but there is more room here to maneuver with it.



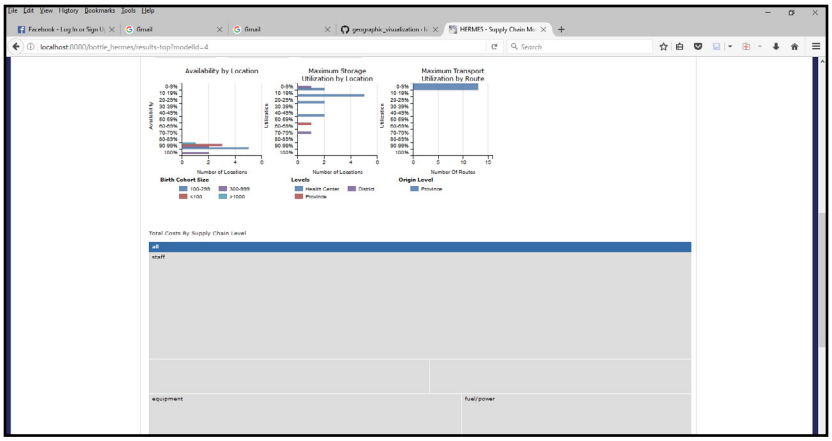
25. Compare the structure here from your new model, with the District level removed, to the original one below. Notice that everything now emanates from the Province and ends at either a District or Health Center, where before, the Districts were intermediaries.



Structure before level removal

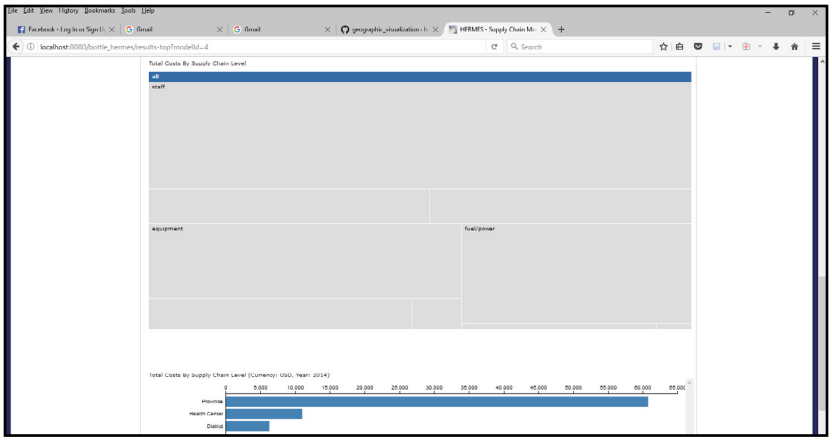
(*The solid circle for Massingir Distrito means the locations below are unexpanded*)

Histograms

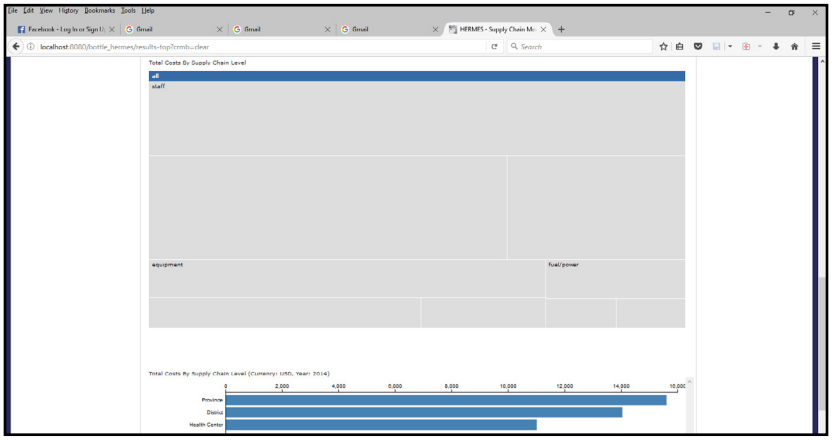


26. The vaccine availability histogram now shows all vaccinating locations achieving greater than 90% availability. The maximum storage utilization histogram also indicates no storage bottleneck after the removal of the Cidade de Xai-Xai district store, with all locations peaking at under 80% storage utilization. Furthermore, the new supply chain structure not only has no transport bottlenecks but in fact has very low transport utilization. This suggests that the vehicle used by the province store to deliver vaccines may be underutilized for this purpose (*and costly, as shown in the tabular results*).

Total Costs by Supply Chain Level



After level removal



Before level removal

27. Explore the new cost implications of the province level routes to the health centers. Comparing the new treemap & barchart to the old is an easy way to notice some differences.

28. Take some time to interact with the results.

Next Steps

You have now completed the HERMES tutorial on removing a supply chain level from a model. See other tutorials for additional experiments you can perform with your model, such as introducing new vaccines.

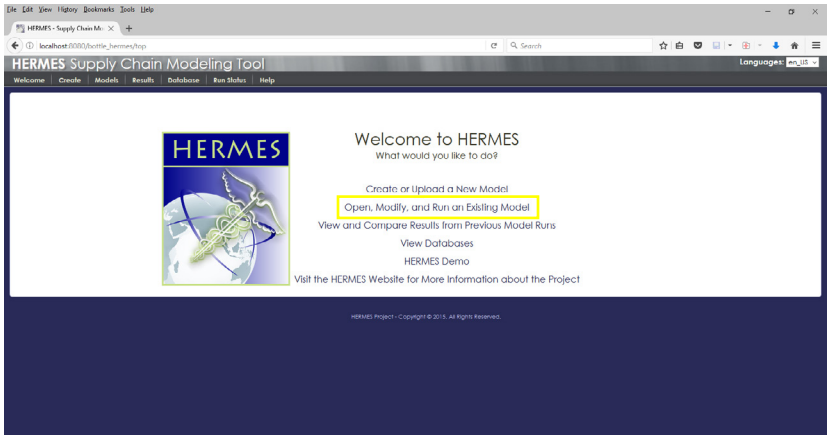
Tutorial 6 | Modify Transport Routes

In this tutorial, you will alter the tutorial_newmodel you previously created by modifying the transport equipment available to all locations at a specific level.

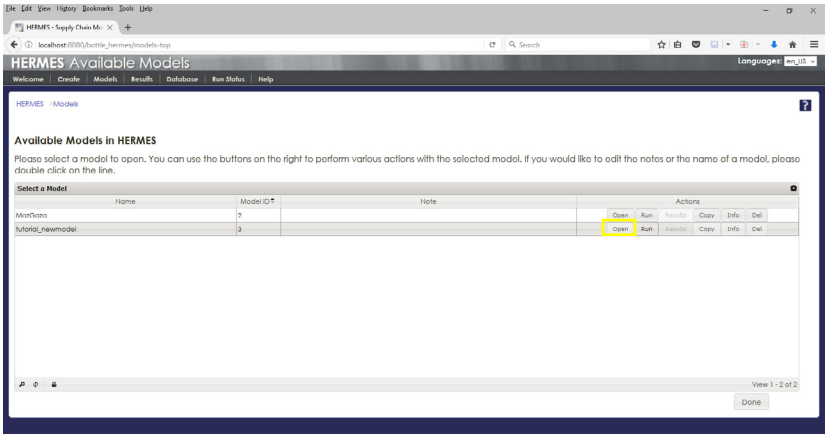
The type of vehicle or mode of transport one uses, the policy that dictates ordering and moving a product and geographic characteristics can all have a significant impact on the performance and efficiency of the supply chain. Modeling can help understand and quantify this impact.

This tutorial will walk you through making changes to transport routes in your model. The experiments will allow you to choose a collection of routes based on what supply chain level the routes originate at and which supply chain levels the routes run between. You can then specify operations to perform on the routes, such as increasing frequency of trips or changing the mode of transport. Based on the changes you make to your model, HERMES will create a new model that alters all of the selected routes.

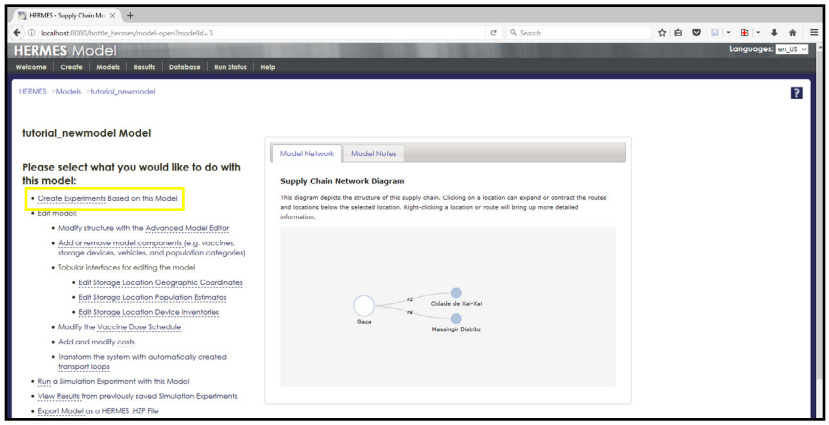
Open Model



1. On the Welcome Page, click **"Open, Modify and Run an Existing Model."**



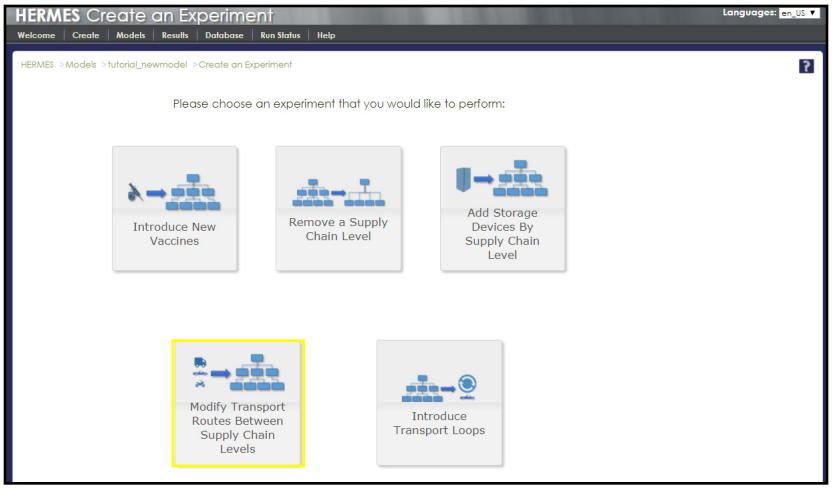
2. Click on the Open button in the tutorial_newmodel row.



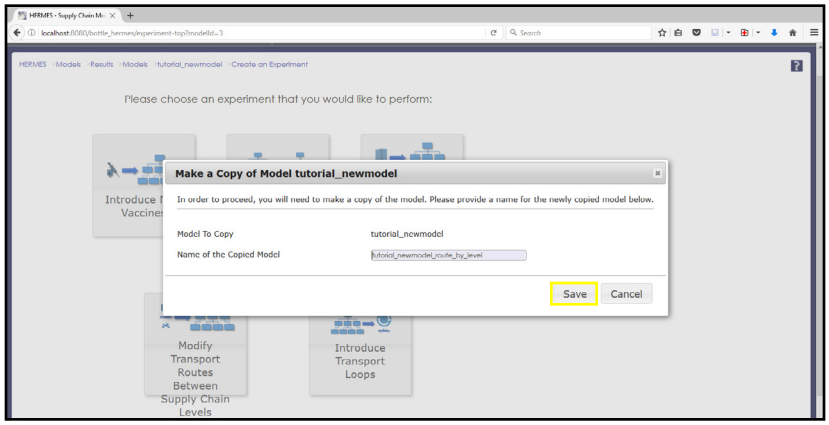
3. This opens the main model page.

4. Click on **“Create Experiments Based on this Model”**.

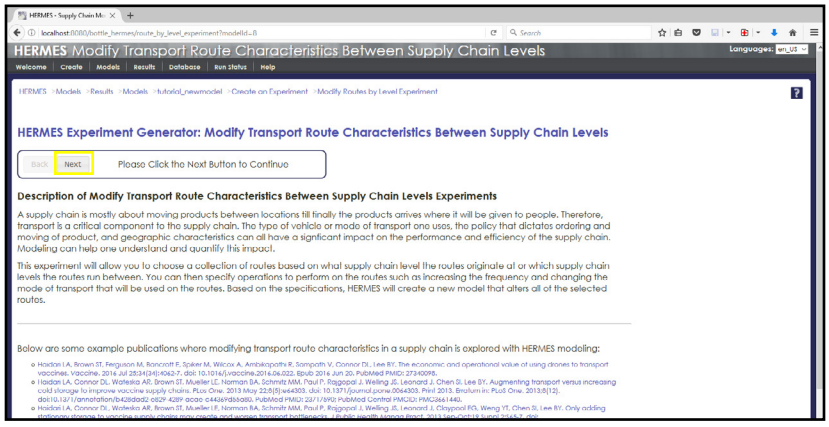
Start Experiment



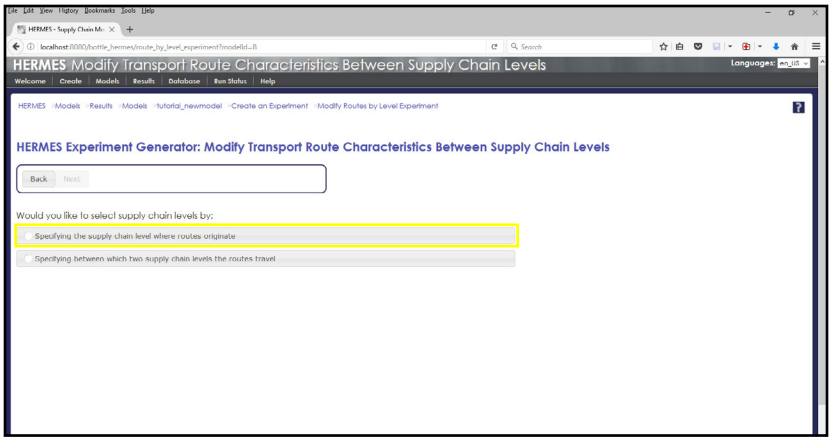
5. Click on **"Modify Transport Routes Between Supply Chain Levels"** box. You will be prompted to create a copy of the model to run.



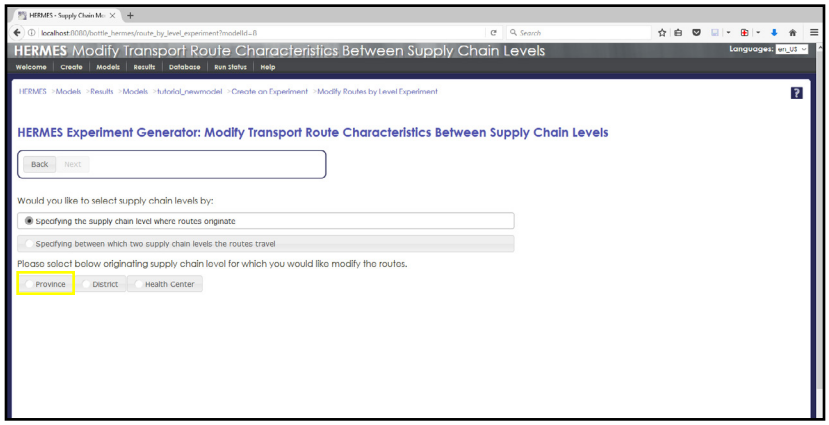
6. Click **"Save"** unless you want to change the name of the copied model first. The next page has some text describing this type of experiment.



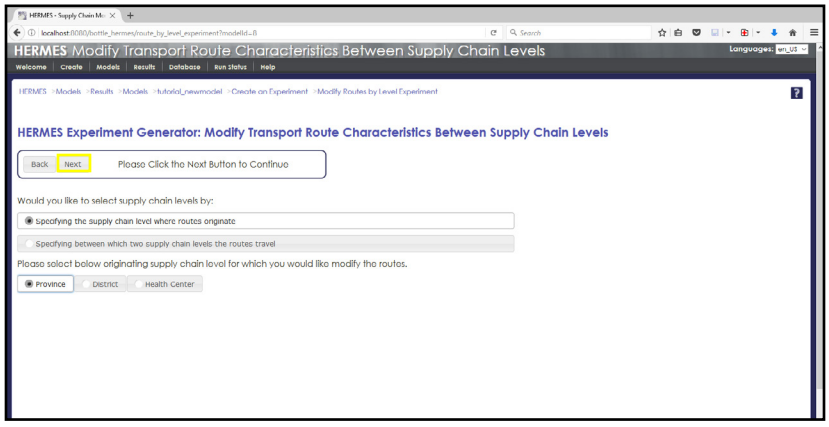
7. Click **"Next."** This is the beginning of your choices for modifying transport route characteristics between supply chain levels.



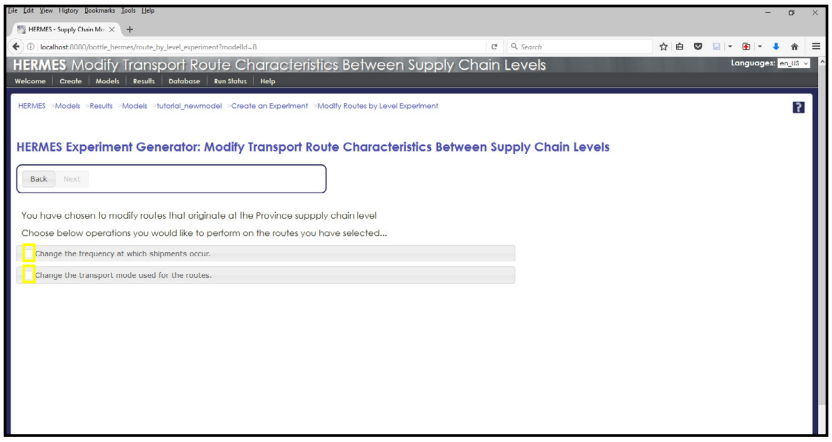
8. Select the first option, **"Specifying the supply chain level where routes originate."**



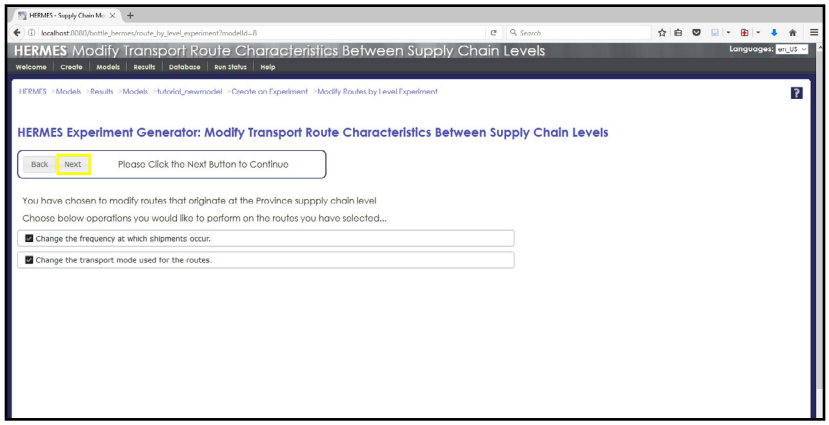
9. Now select **"Province"** as the level whose routes you would like to modify.



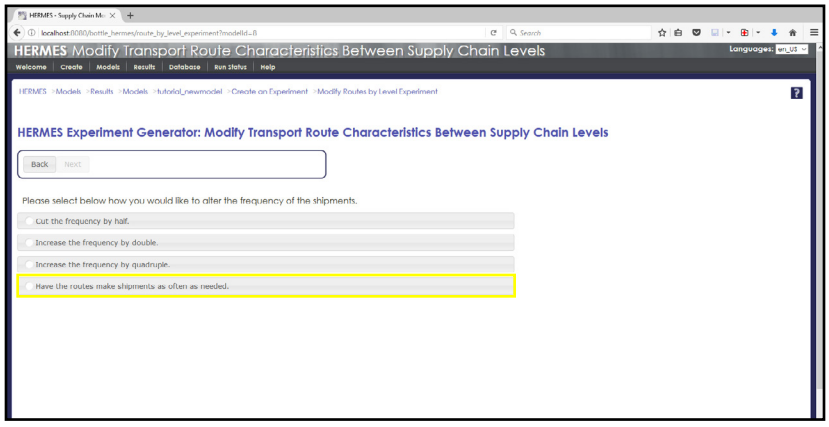
10. Click **"Next"** to add some more parameters.



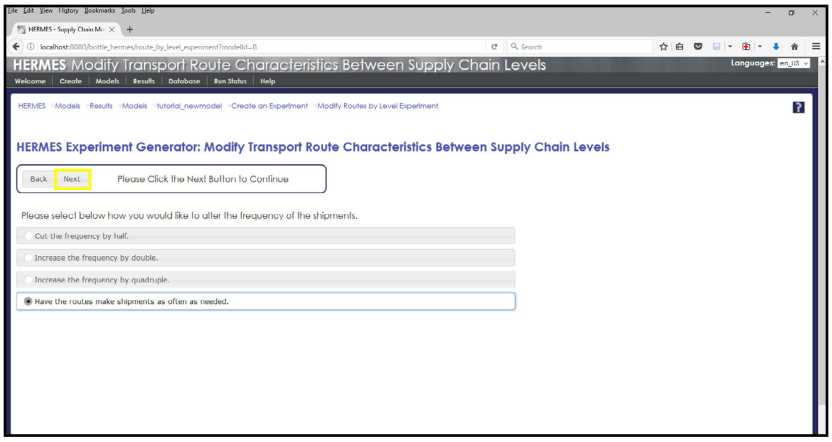
11. You will be changing both the frequency and the mode of transport for routes originating from the Province level. Select both options on the page.



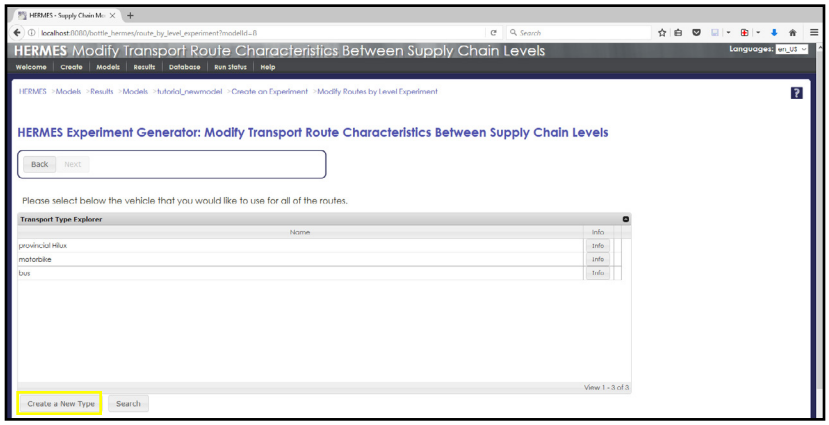
12. Click **“Next”** to bring up options for altering the frequency.



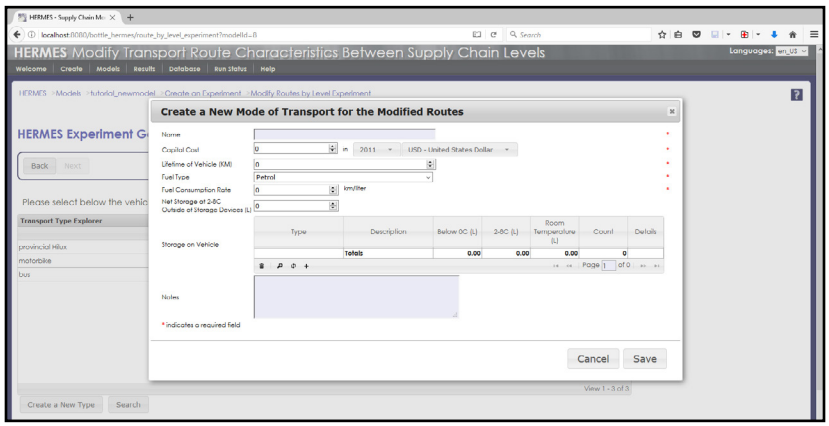
13. Select the last option, **“Have the routes make shipments as often as needed.”**



14. Click **"Next"** to bring up options for altering the mode. The table lists all available modes of transport already loaded into the model.



15. Below the table you have the option of creating a new type of transport, which is what you will be doing next. Click the **"Create a New Type button."**



16. Fill in the following information:

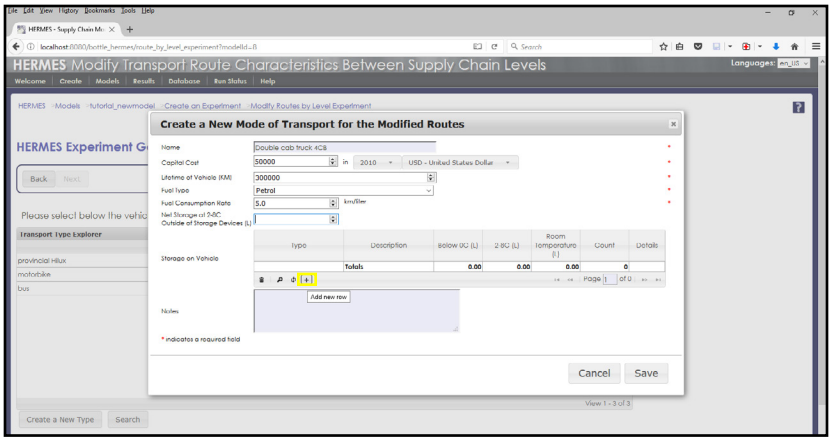
Name:
Double cab Truck 4 large CB

Capital Cost:
50,000.00 in 2010 USD

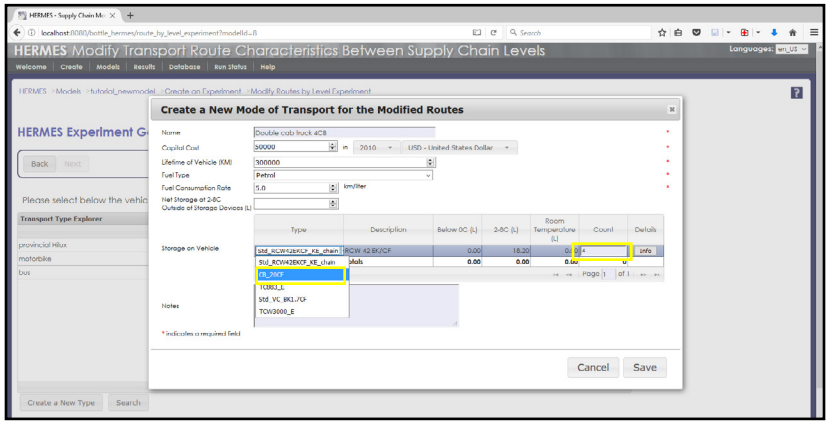
Vehicle Lifetime:
300,000 KM

Fuel Type:
Petrol

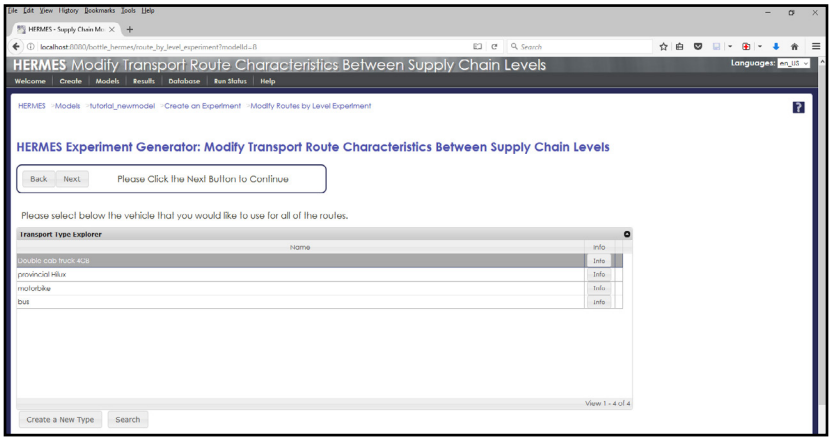
Fuel Consumption Rate:
5.0km/liter



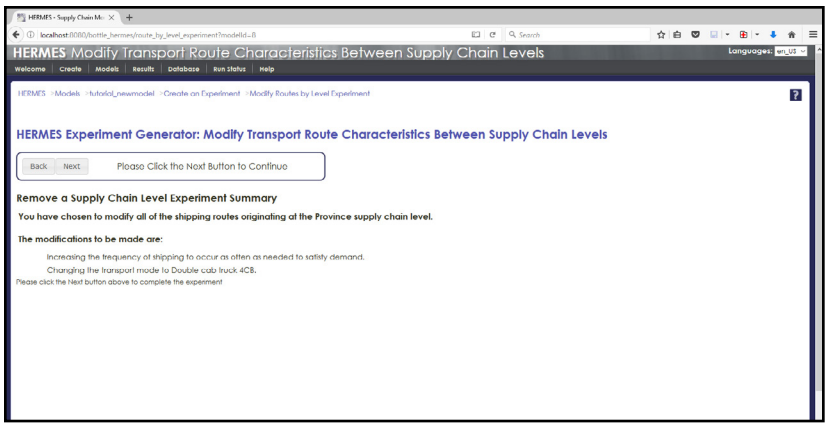
For storage on the vehicle you will need to add 4 cold boxes. To do this, click the **"+"** in the lower left corner of the storage table.



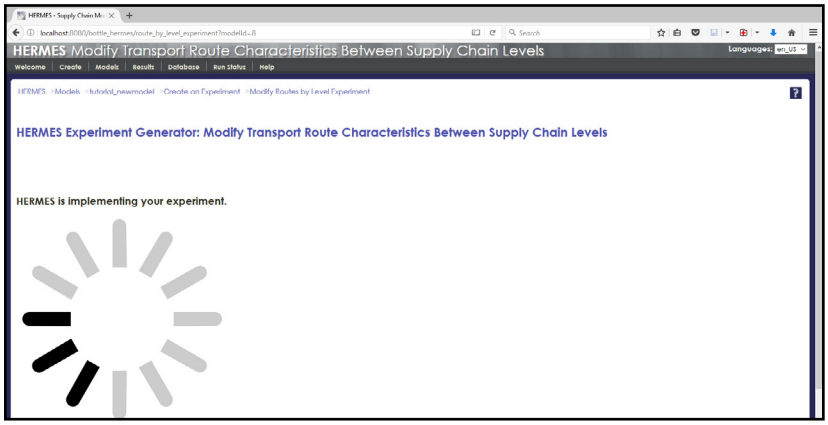
17. In the new row that's added, select **"CB_20CF"** from the type dropdown box. Change the count in that row to 4.



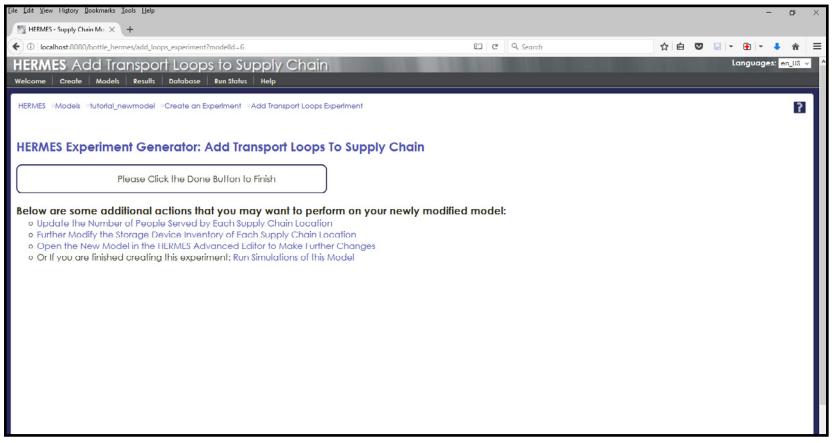
18. Click **"Save"**. The truck you just created is now available in the table. Make sure that it is selected by clicking on it.



18. Click **"Save"**. The truck you just created is now available in the table. Make sure that it is selected by clicking on it.

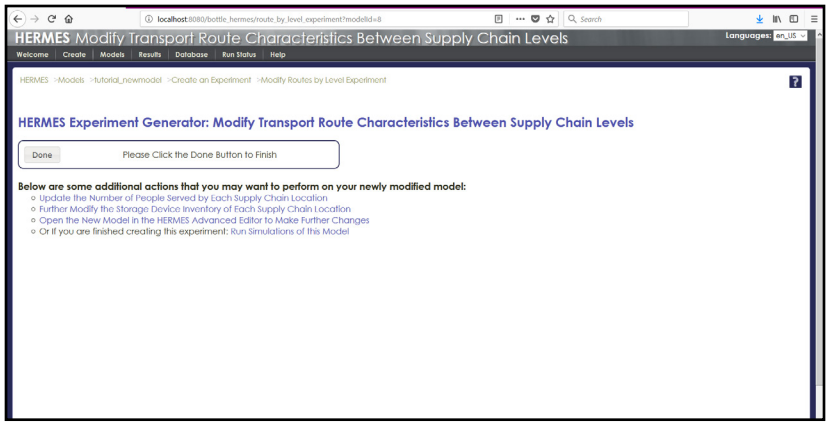


19. Click **"Next"** to get a summary page. If one of your parameters looks wrong, you can always use the Back button to fix it before changing the model.

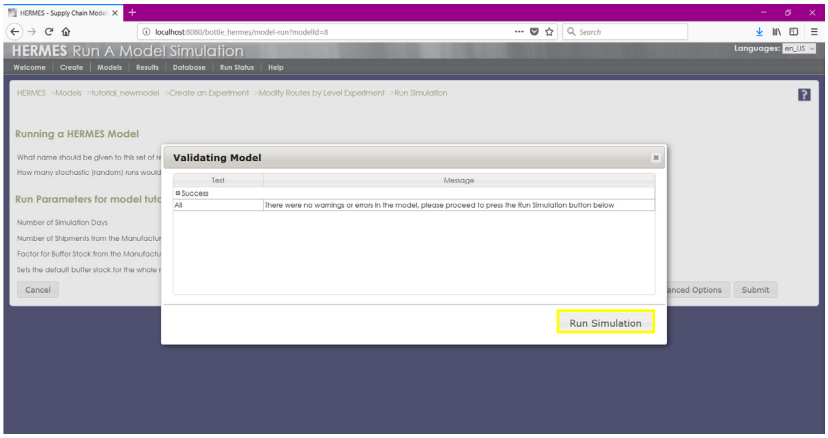


21. When the model has been adjusted, the page will update with further options.

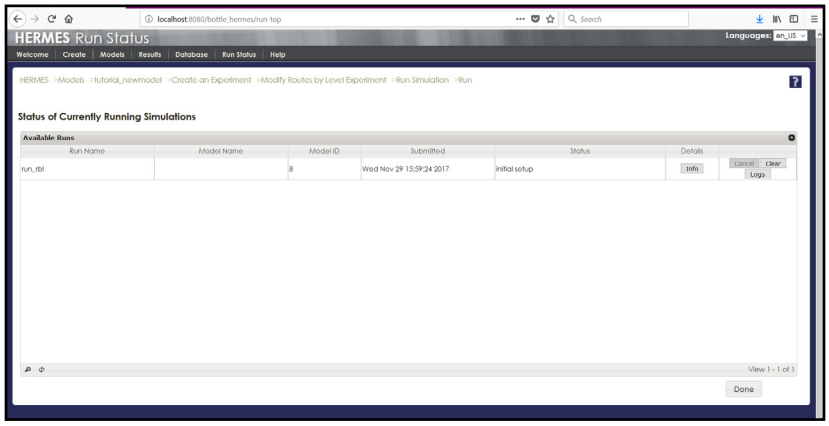
Run Simulation



22. Click **"Run Simulations of this Model"** in the last line of text.



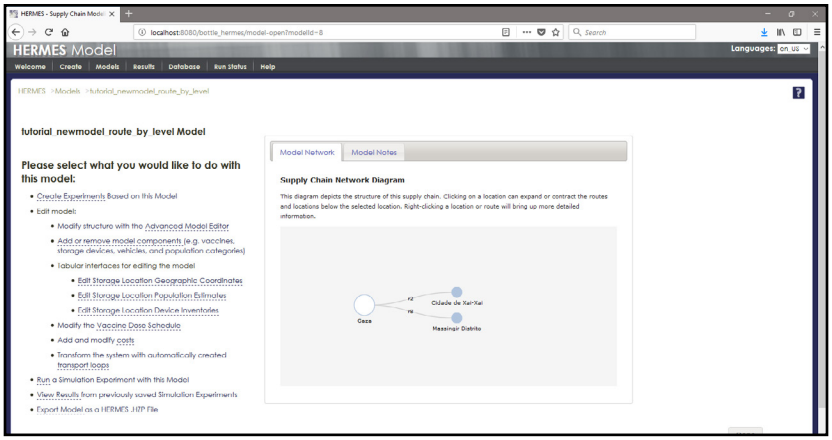
23. Type a name for your run and click **"Submit"**. There should be no errors in the model. (*Note: If there are errors, please see the Troubleshooting section to fix*).



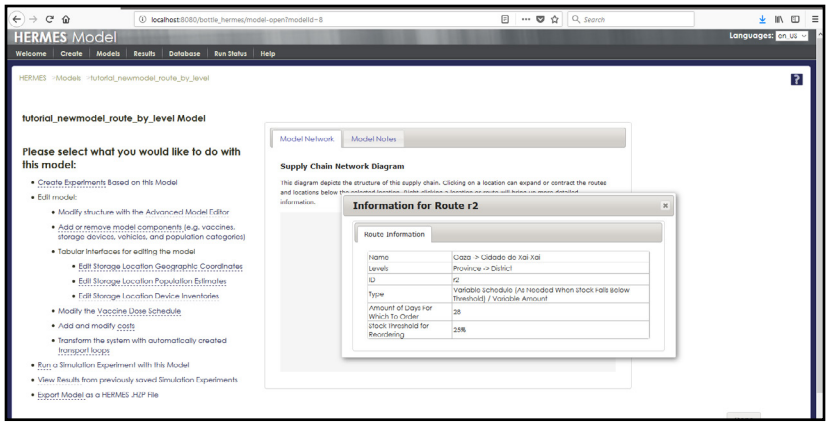
24. Click **"Run Simulation".** The run status page will open and you can watch the progress of your run.

View Changes in the Model

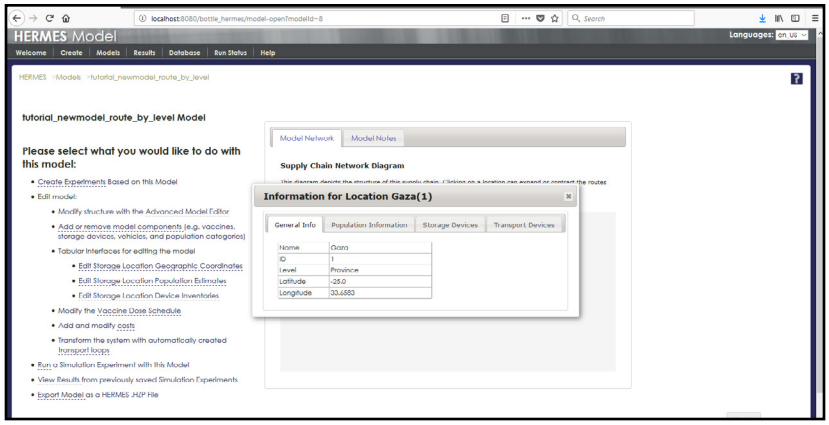
While waiting for the simulation to finish running, take a look at the changes in the model.



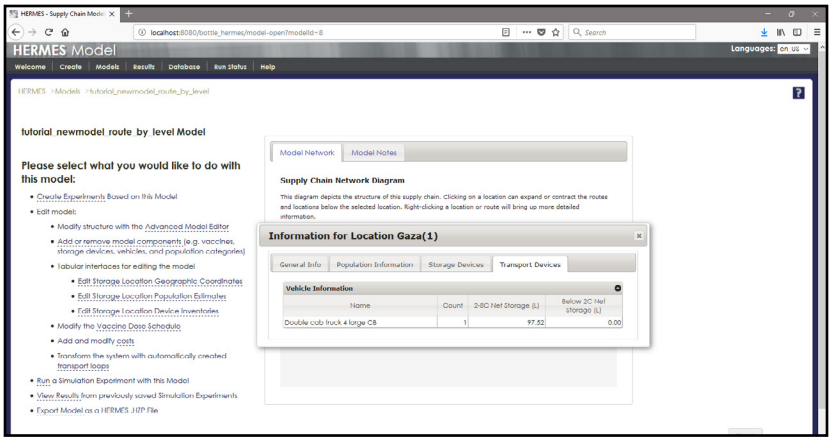
26. Open the model tutorial_ newmodel_route_by_level (*or whatever you named it in step XX*) by going to the models page and clicking **“Open” i**n the row of that name.



27. The structure of this model hasn’t changed, but the frequency and transport used for the routes from Gaza to its districts have. If you right click on either the r2 or r8 lines, you will see that the Type has changed from “Fixed Schedule / Variable Amount Based on Frequency“ to “Variable Schedule (*As Needed When Stock Falls Below Threshold*) / Variable Amount”



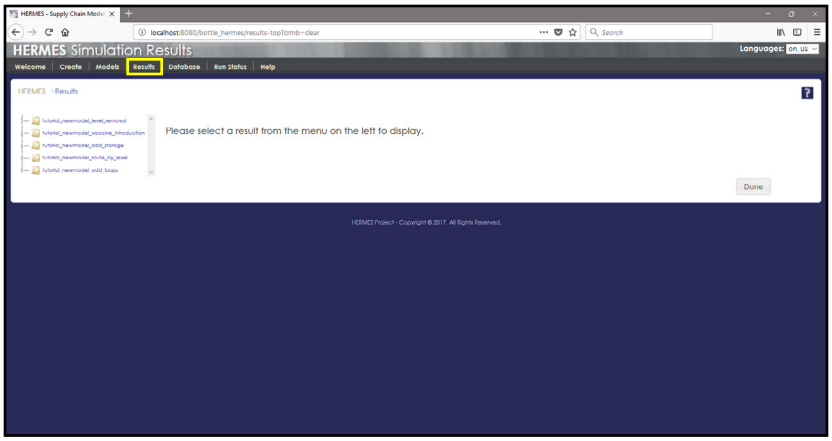
28. To see the change in transport type, first righ tclick on Gaza to show its location information.



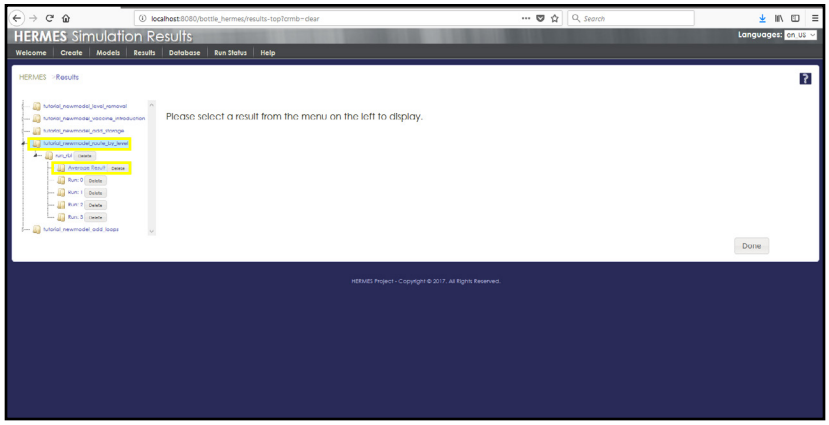
29. Then click on the **"Transport Devices"** tab. This will now show the infomation for the double cab truck 4 large CB that was added to replace the provincial Hilux which was originally there.

View Results

Once your run has finished you will want to look at the results and compare them to your original run.

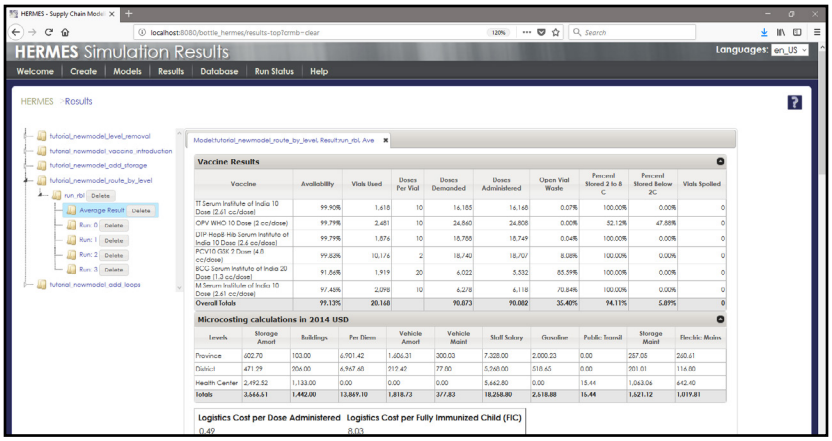


30. Click on the **“Results”** on the top menu bar to open the Results page.

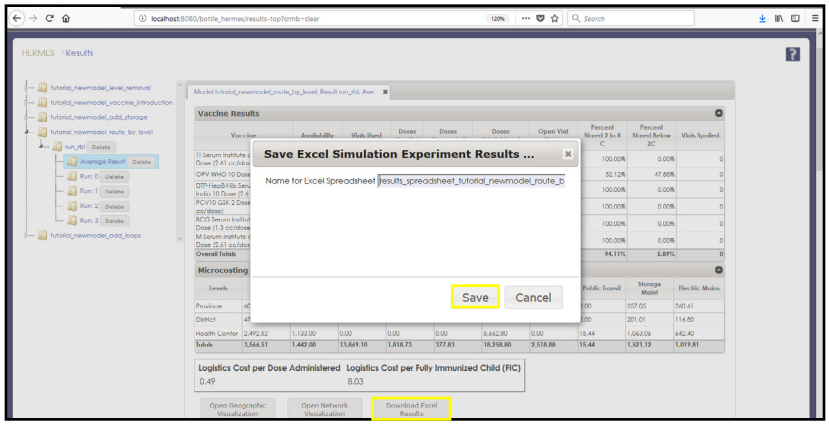


31. Expand the tutorial_ newmodel_route_by_level tree and select the **“Average**

Spreadsheet Costing Results



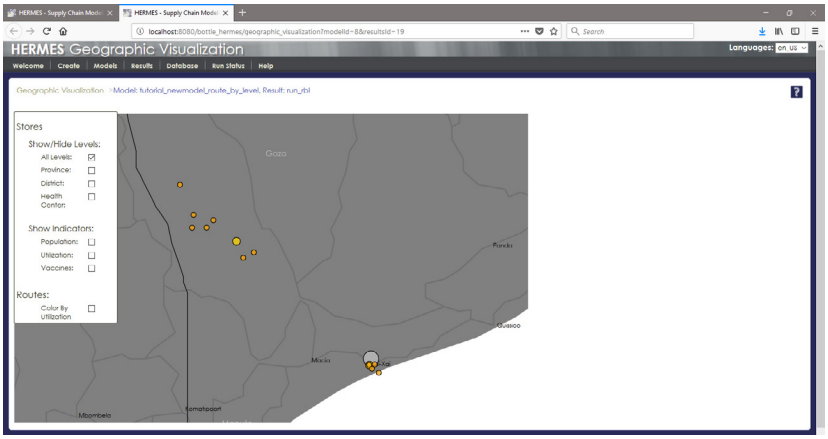
32. Spreadsheet costing results



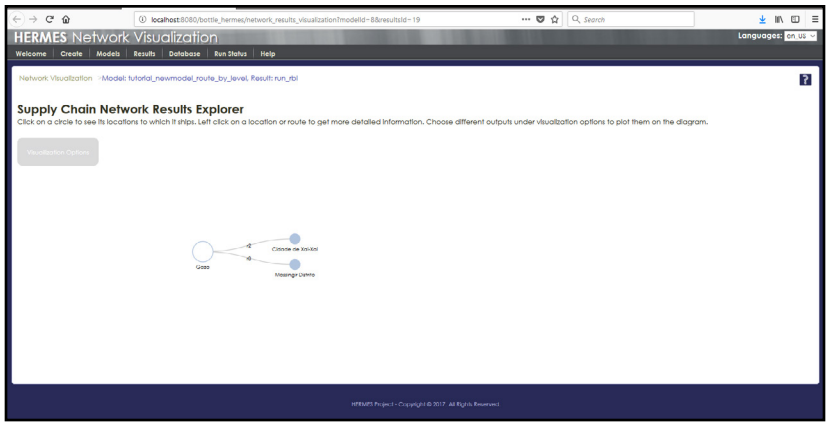
33. Click on the **"Download Excel Results"** Spreadsheet button below the tables to acquire a spreadsheet of results.

34. Click the "**Save**" button and then use the download dialog box to either open or save a copy.

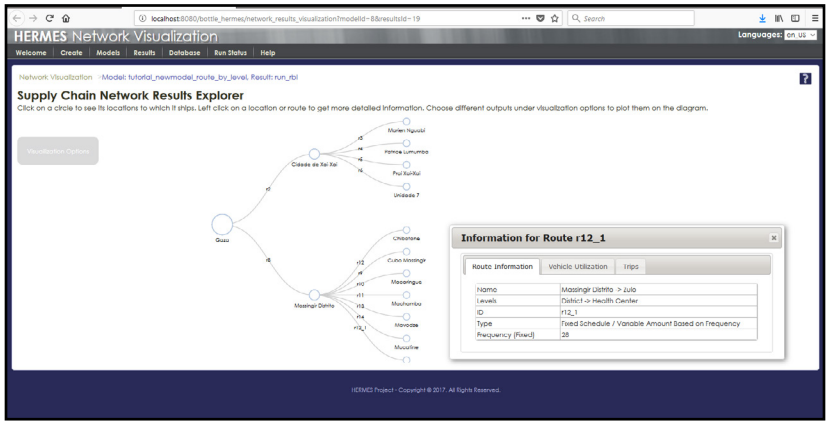
Visualization Buttons



35. Click the **"Open Geographic Visualization"** button. This page will open in a new window and can take some time to load.

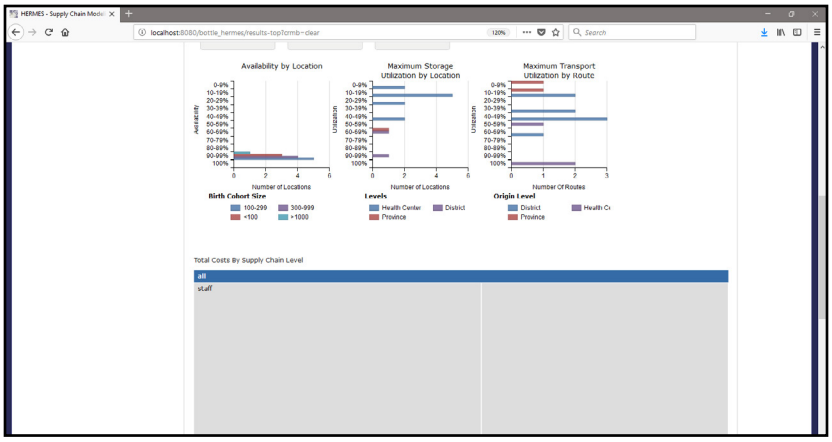


36. Back on the results window, click the **"Open Network Visualization"** button. This page will also open in a new window. A filled-in circle means there are locations below that one. This is the same diagram as you looked at from the model page.

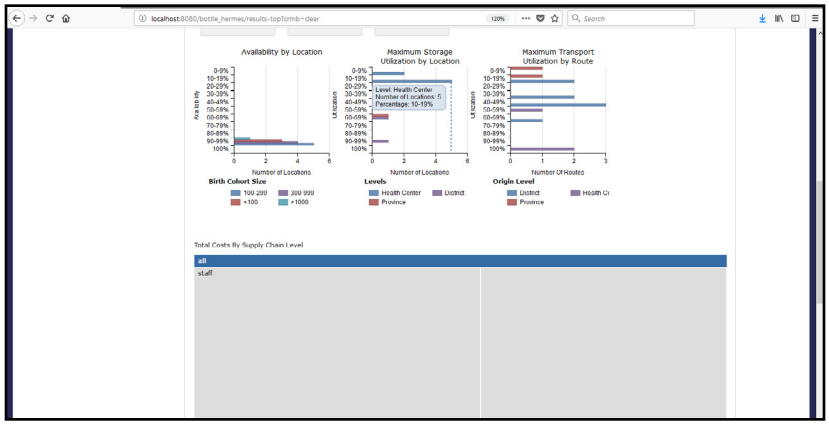


37. You can navigate this the same way you did on the models page; left click a circle to expand or contract locations; right click a circle or route to get information on that location or route.

Histograms

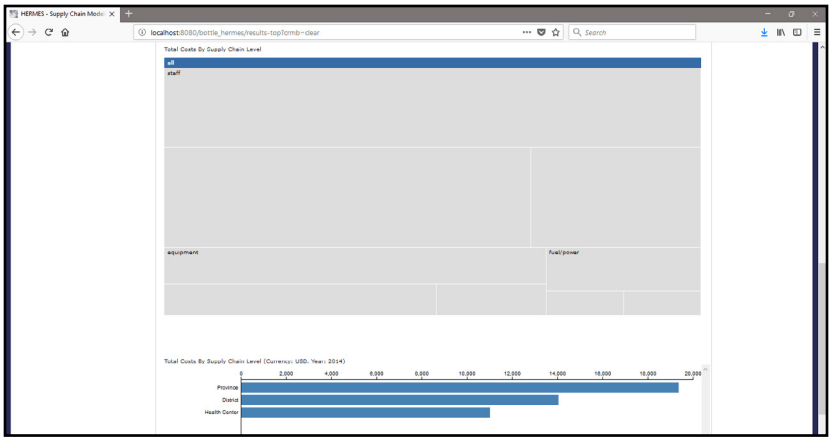


38. Look at the histograms.



39. Hovering your mouse over a bar will pop up more information about the bar (*see middle chart*).

Total Costs by Supply Chain Level



40. Total costs by supply chain level are represented by a treemap and bar chart, both of which are interactive.

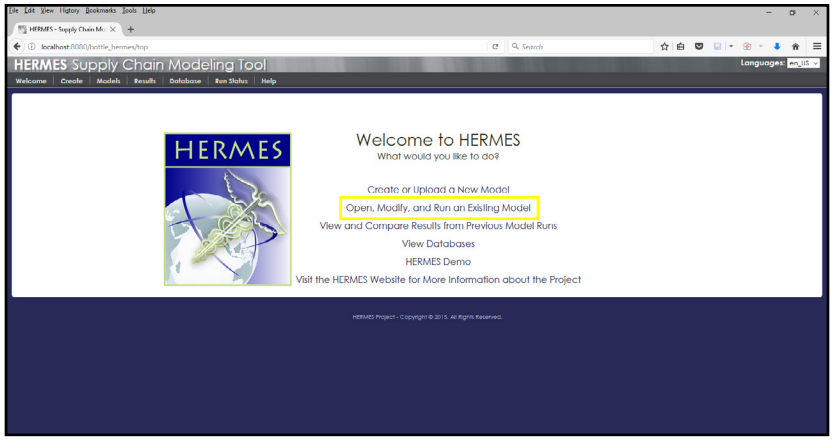
Tutorial 7 | Introduce Transport Loops

In this tutorial, you will alter the tutorial_newmodel you previously created by introducing transport loops.

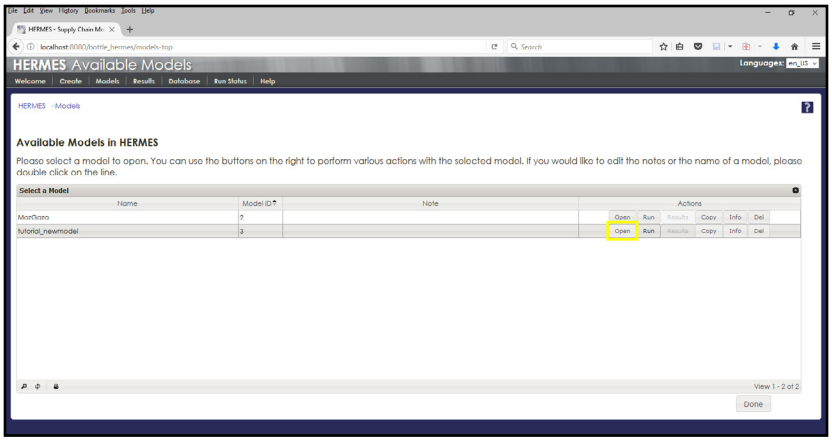
Many supply chains utilize transport routes that start at one location and visit multiple locations before returning to their origin. This type of shipping route is known as a "loop". Loops can be more efficient and provide more reliable shipping of products than delivering to locations one at a time because they require maintaining a smaller fleet of vehicles that can potentially travel shorter distances and provide a more regular shipping pattern. However, transport loops may also require larger vehicles with additional storage space which may be more costly to operate and maintain and may incur per diem costs as the routes become quite long. Modeling can help a user understand these tradeoffs and where and when transport loops may make sense for your supply chain.

This experiment will take you through a series of screens that will ask you between which supply chain levels you would like to create transport loops, the number of locations per transport loop and the vehicle that you would like to use for each loop. After you insert your parameters, HERMES will automatically create transport loops for the model based on shortest distance.

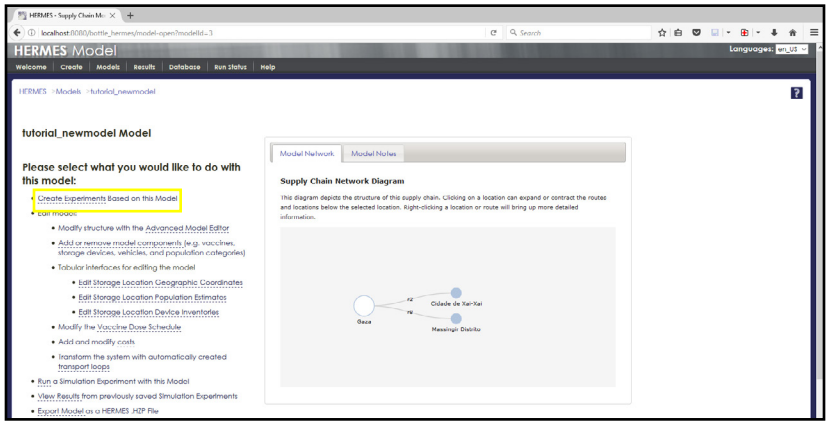
Open Model



1. On the Welcome Page, click **"Open, Modify and Run an Existing Model."**



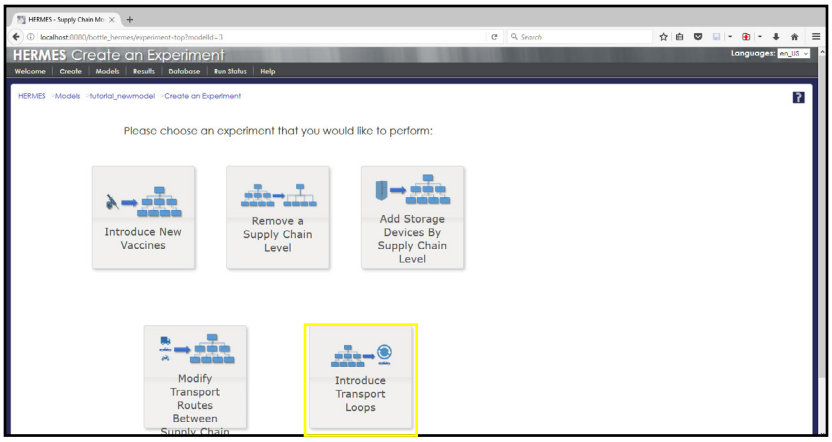
2. Click on the **"Open"** button in the tutorial_newmodel row.



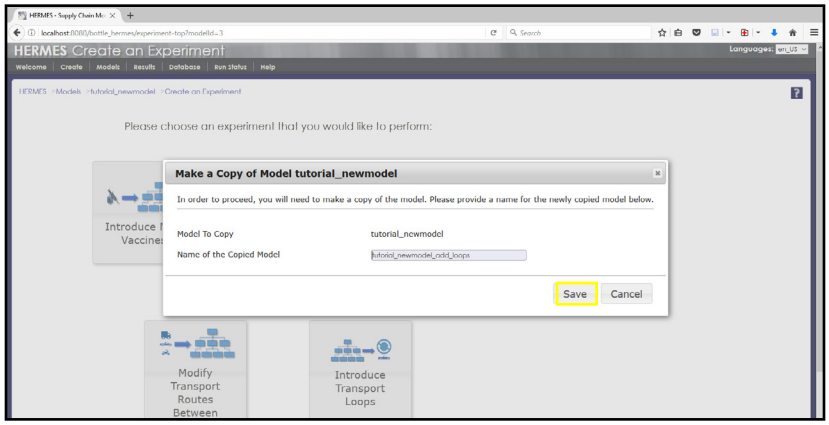
3. This opens the main model page.

4. Click on **"Create Experiments Based on this Model"**.

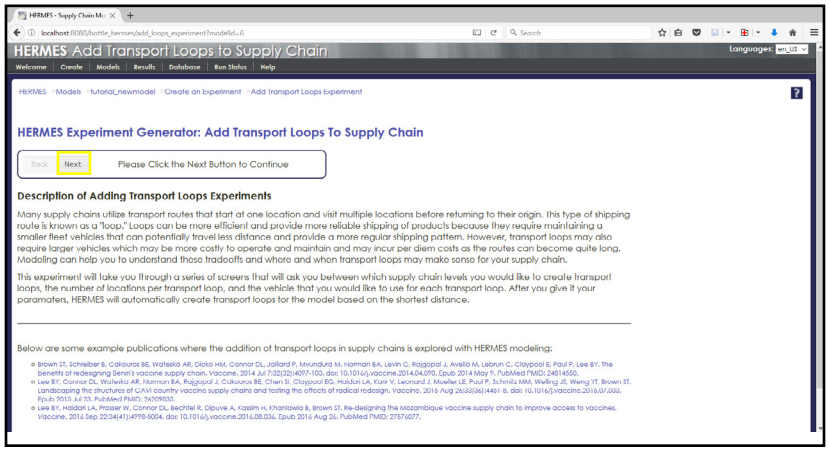
Start Experiment



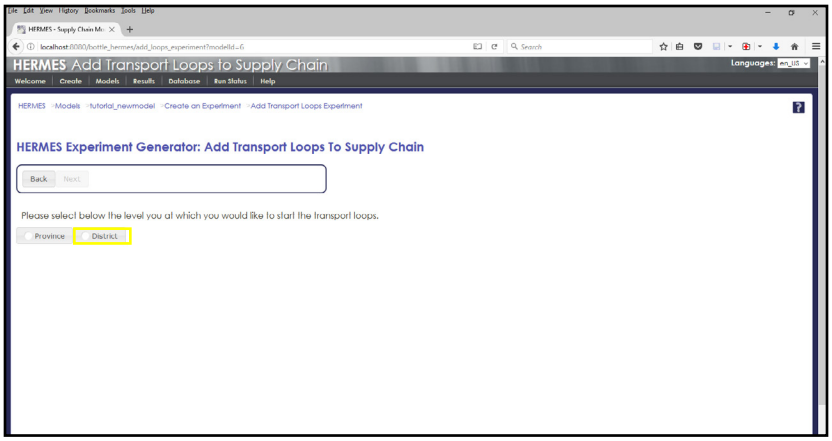
5. Click on the **"Introduce Transport Loops"** box. You will be prompted to create a copy of the model to run.



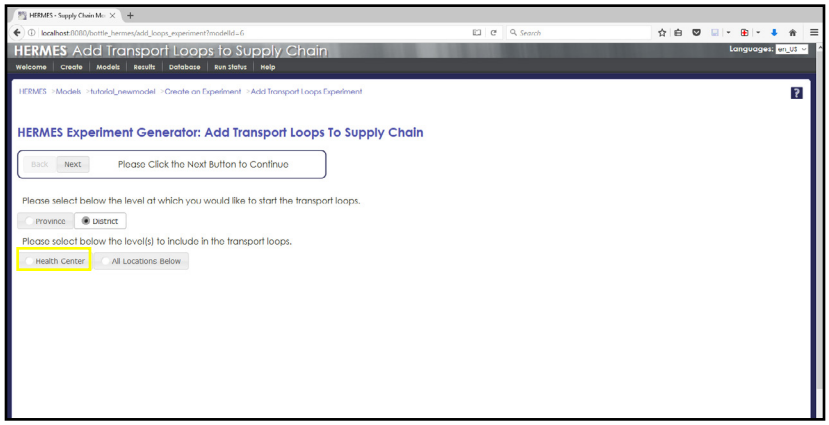
6. Click **"Save"**, unless you want to change the name of the copied model first. The next page has some text describing this type of experiment.



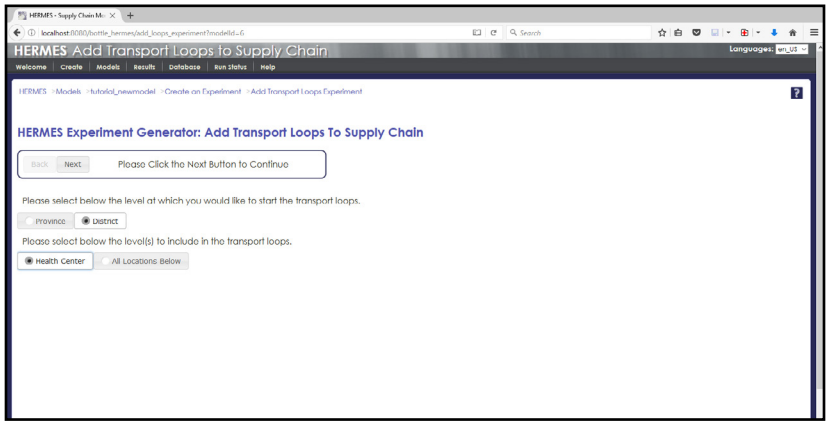
7. Click **"Next"**. This is the beginning of your choices for adding a transport loop.

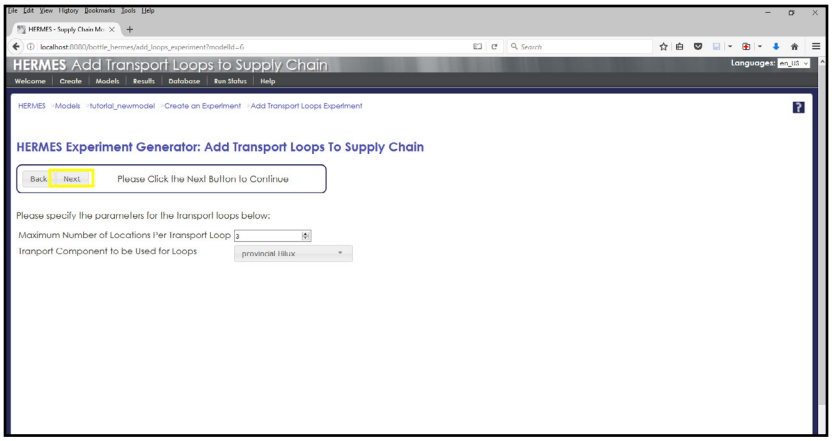


8. Select **"District"** as the level at which to start the loops. This will open another selection below.

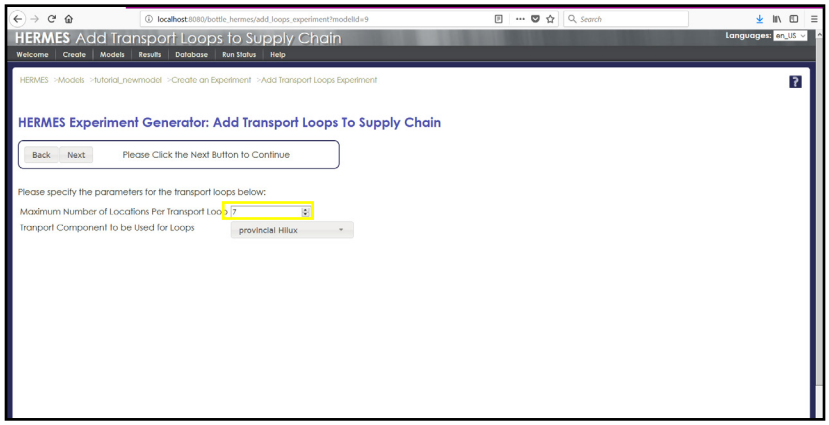


9. Now select **"Health Center"** as the level the loops will distribute to.

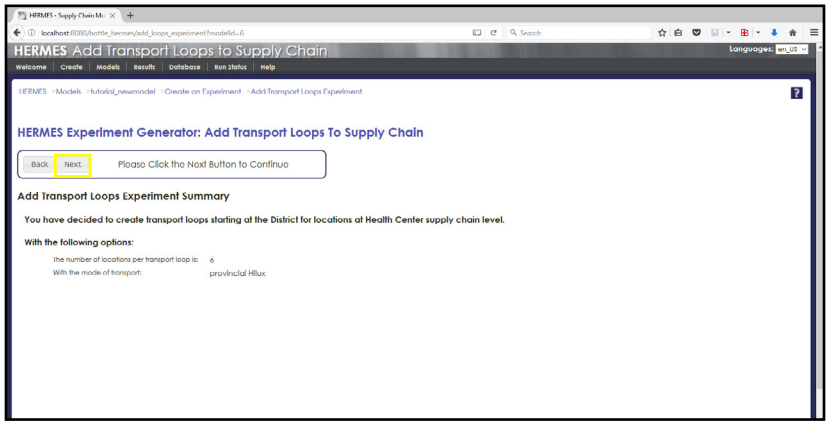




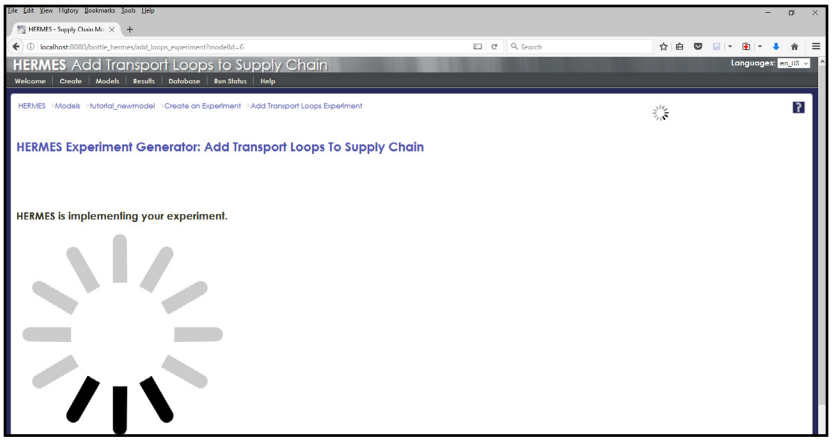
10. Click **"Next"** to add in some more parameters.



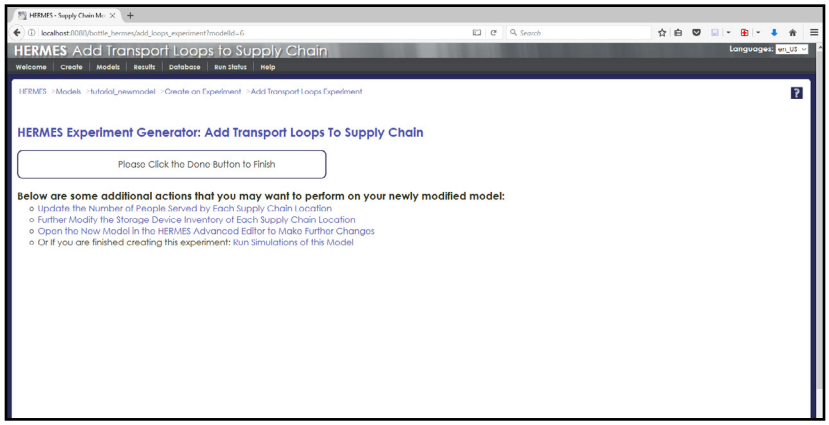
11. Change the Maximum Number of Locations Per Transport Loop to 7. Make sure the Transport Component is the provincial Hilux.



12. Click **"Next"** to get a summary page. If one of your parameters looks wrong, you can always use the Back button to fix it before changing the model.

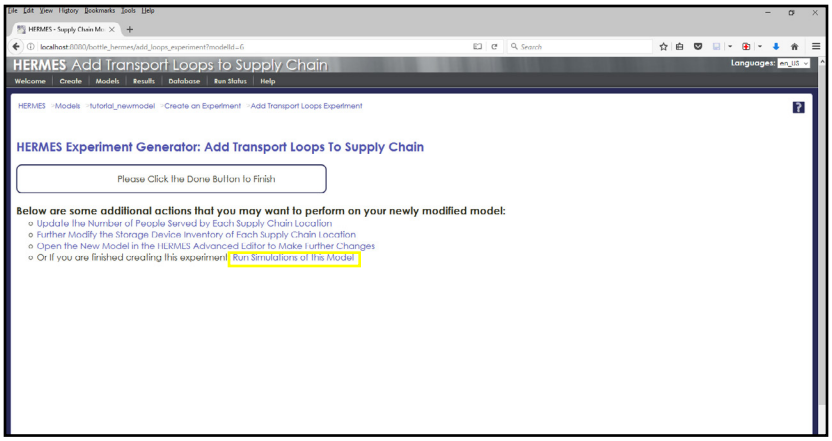


13. Click **"Next"** to have HERMES adjust the model by creating transport loops. This might take a few seconds or a few minutes depending on how large your model is. (*It shouldn't take more than 30 secs for this model.*)

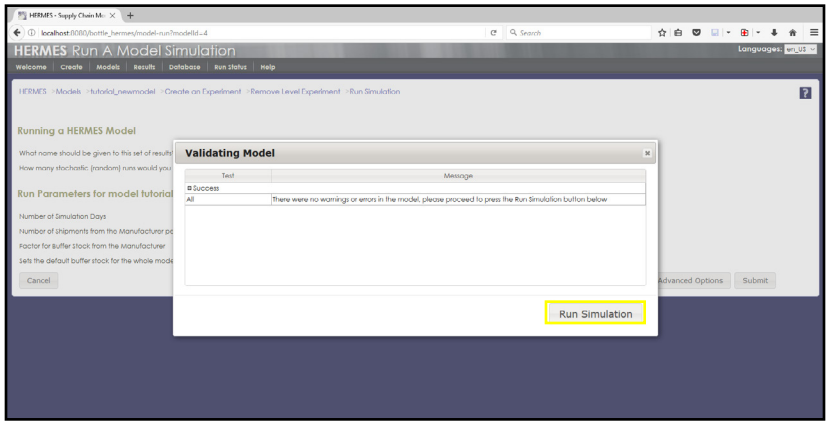


14. When the model has been adjusted, the page will update with some further options.

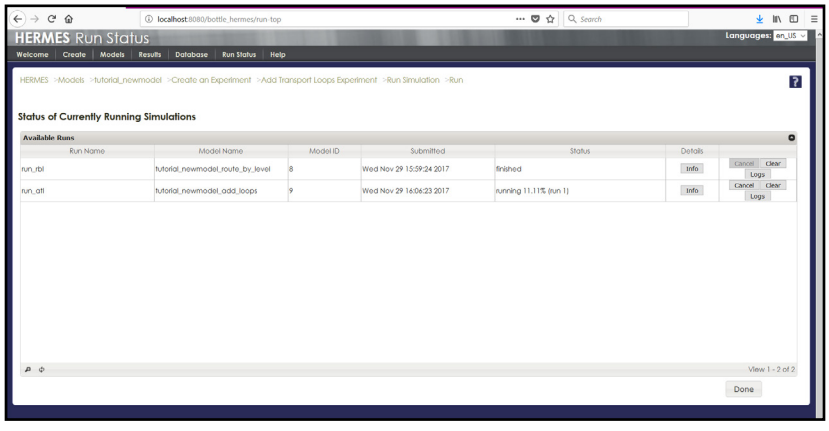
Run Simulation



15. Click **"Run Simulations of this Model"** (*in the last line of text*)



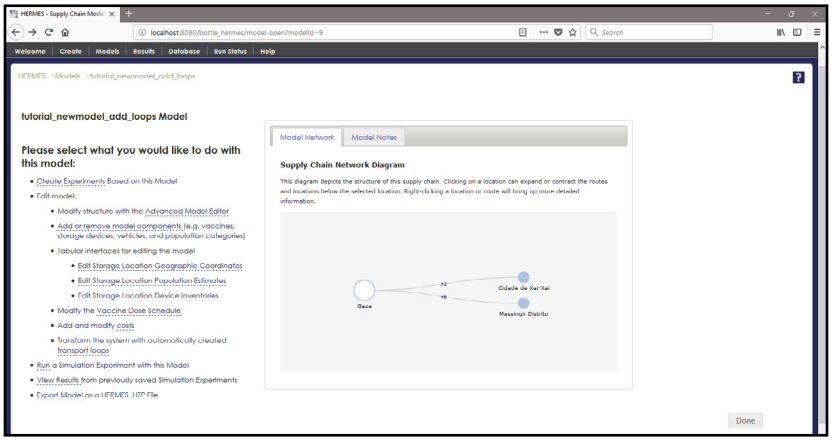
16. Type a name for your run and click the **"Submit"** button. There should be no errors in the model.



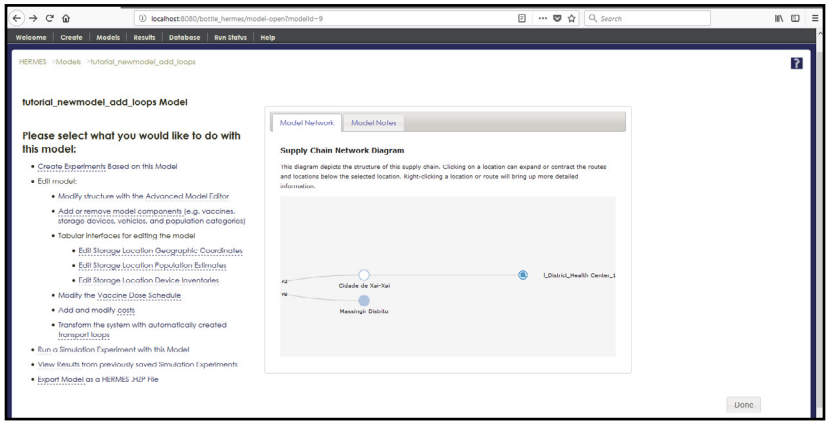
17. Click **"Run Simulation"**. The run status page will open and you can watch the progress of your run.

View Changes in Model

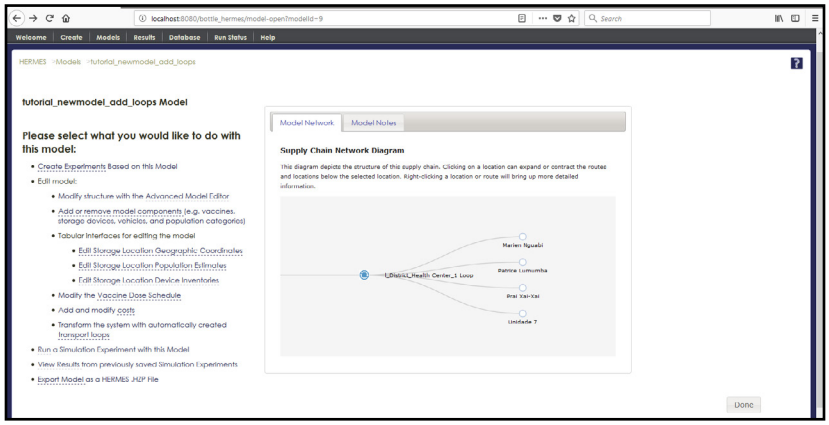
While waiting for the simulation to finish running, take a look at the changes in the model.



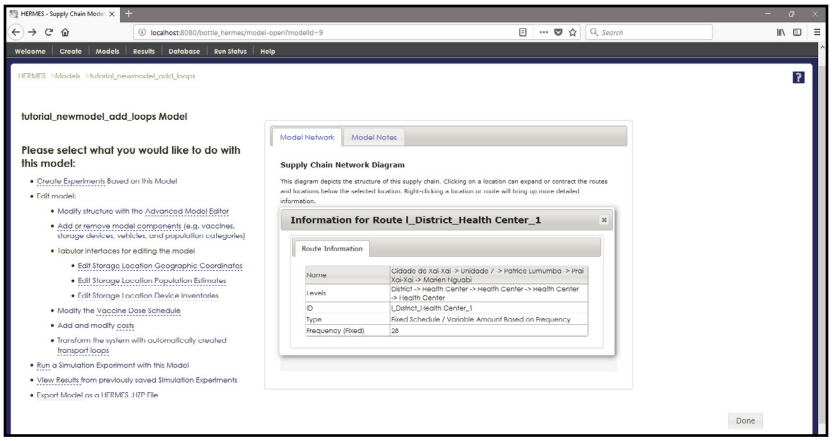
18. Open the model tutorial_newmodel_add_loops (*or whatever you named it in step XX*) by going to the Models page and clicking **"Open"** in the row of that name.



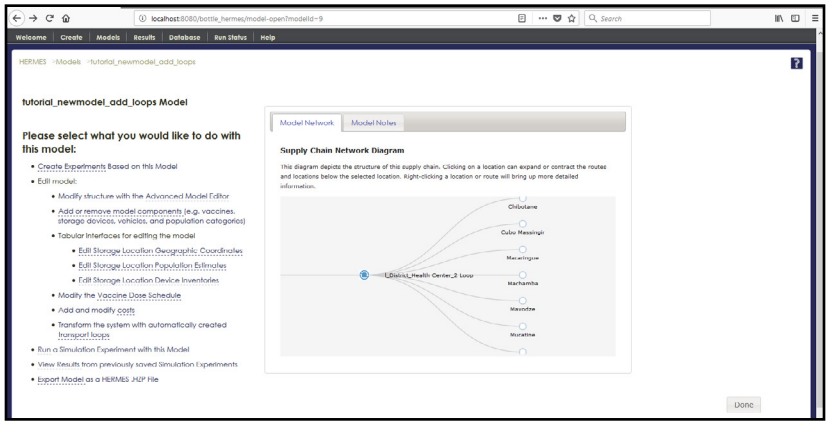
19. At the top level, this may look the same as the original tutorial_newmodel diagram. Click on **"Cidade de Xai-Xai"**. The blue circle with arrows indicate a loop has been formed and labeled as a loop.



20. Click on the blue circle with arrows. This shows you the locations included in the loop.



21. Although the locations are portrayed as separate routes listed in alphabetical order, right clicking on any of the lines emanating from the blue circle with arrows will give the same information about the looped route, including the looping order.

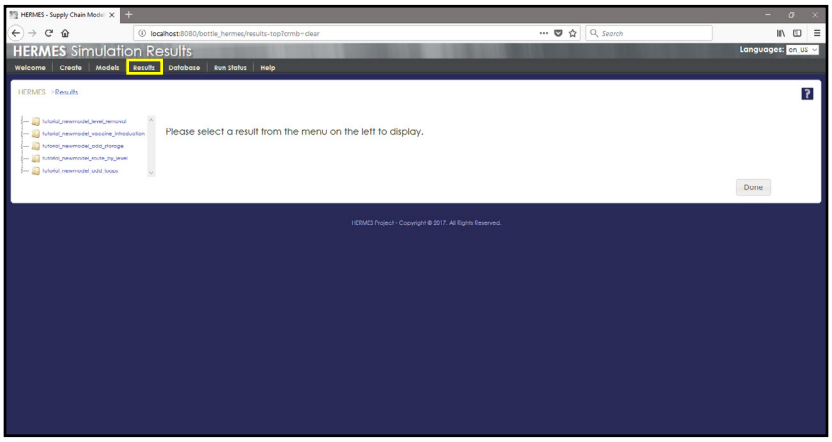


22. Similarly, clicking on **"Massingir Distrito"** and then the blue dot with arrows will show the loop that was created for that district.

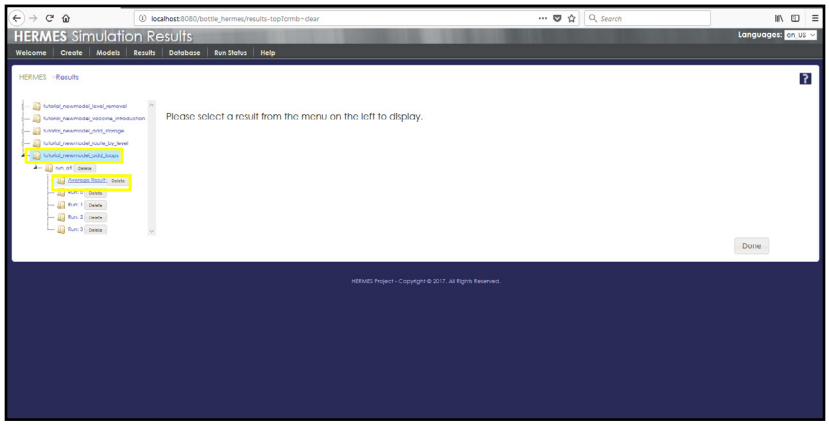
23. Spend a few minutes exploring the new structure and right clicking on the routes to see their descriptions.

View Results

Once your run has finished you will want to look at the results and compare them to your original run.

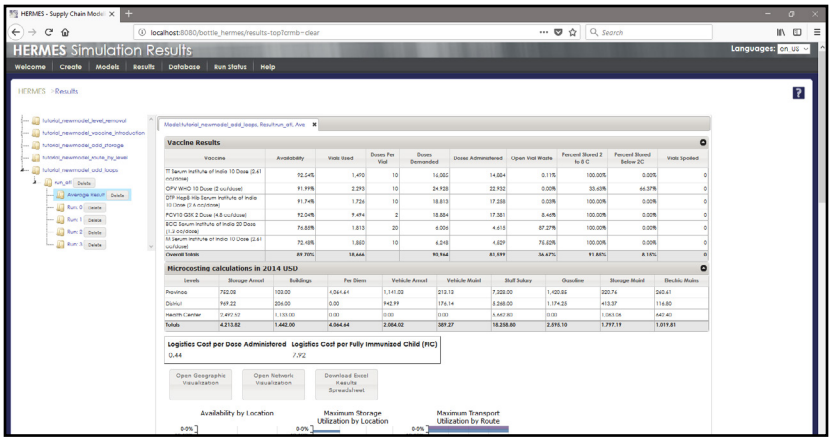


24. Click on **“Results”** on the top menu bar to open the Results page.

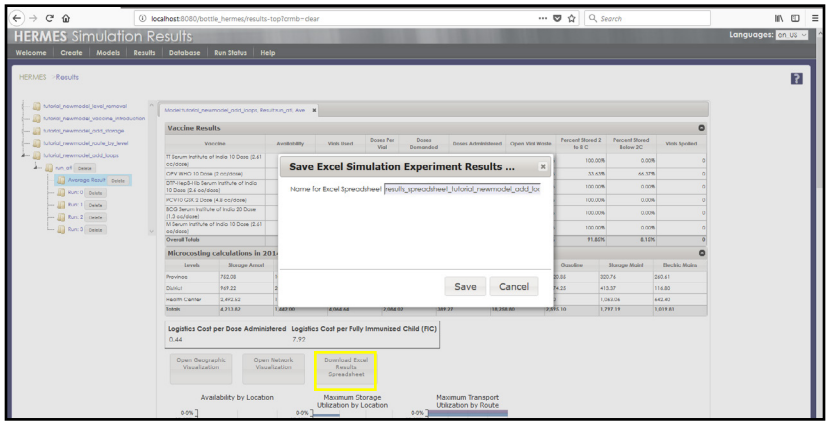


25. Expand the tutorial_ newmodel_add_loops tree and select the **“Average Results”**.

Spreadsheet Costing Results



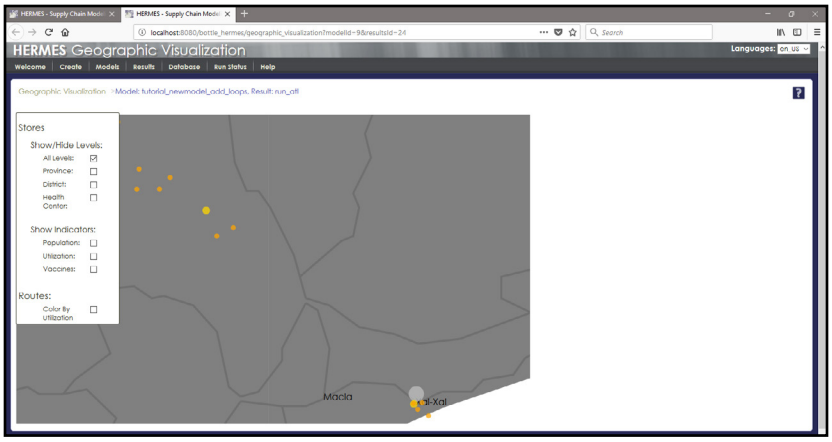
26. Spreadsheet costing results



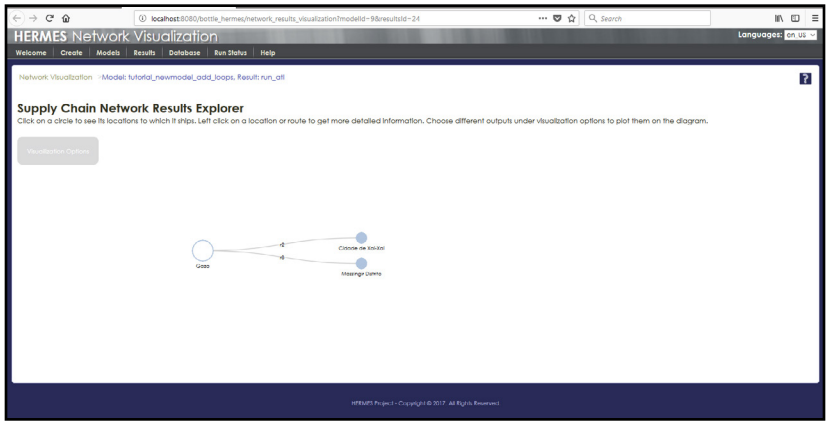
27. Click on the **"Download Excel Results Spreadsheet"** button below the tables to acquire a spreadsheet of the results.

28. Click the **"Save"** button and then use the download dialog box to either open or save a copy.

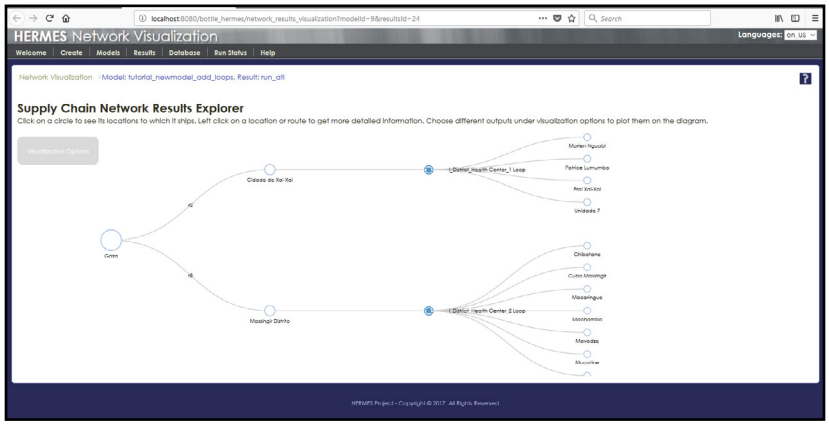
Visualization Buttons



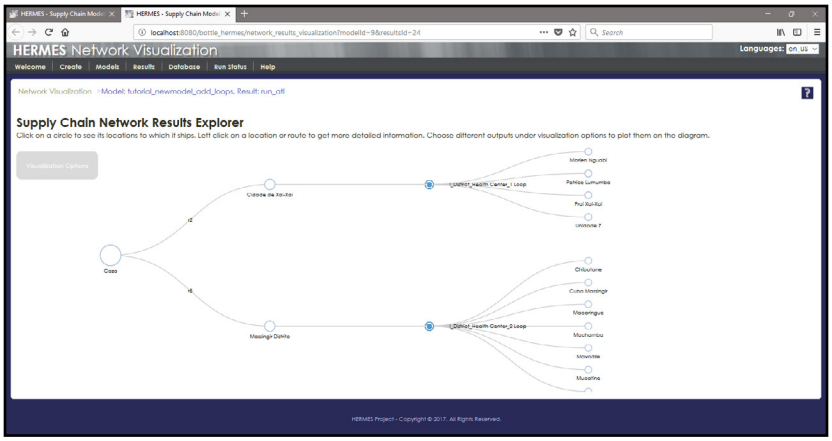
29. Click the **“Open Geographic Visualization”** button. This page will open in a new window and can take some time to load.



30. Click the **“Open Network Visualization”** button. This page will also open in a new window. A filled in circle means there are locations below that one. This is the same diagram as you looked at from the model page.

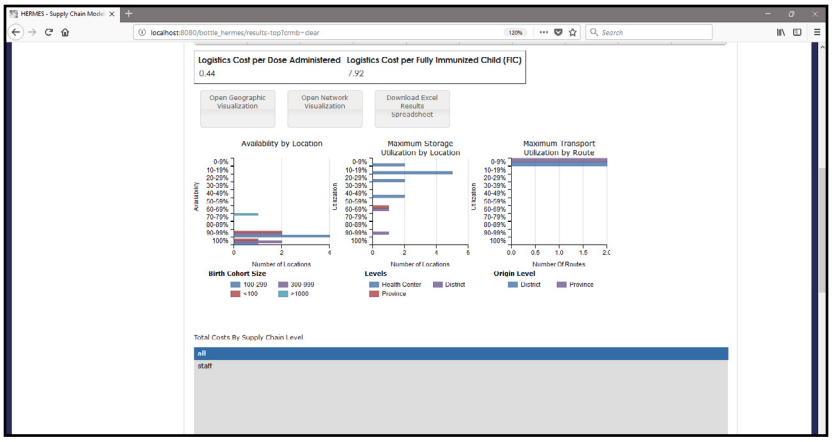


31. Left click on the **“Cidade de Xai-Xai”** circle to expand the locations below.

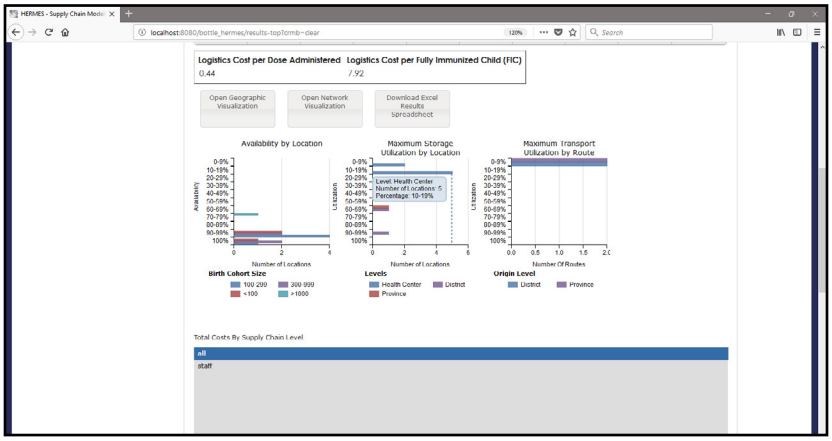


32. The diagram here shows the structure with all locations displayed (*any filled in circles were clicked*).

Histograms

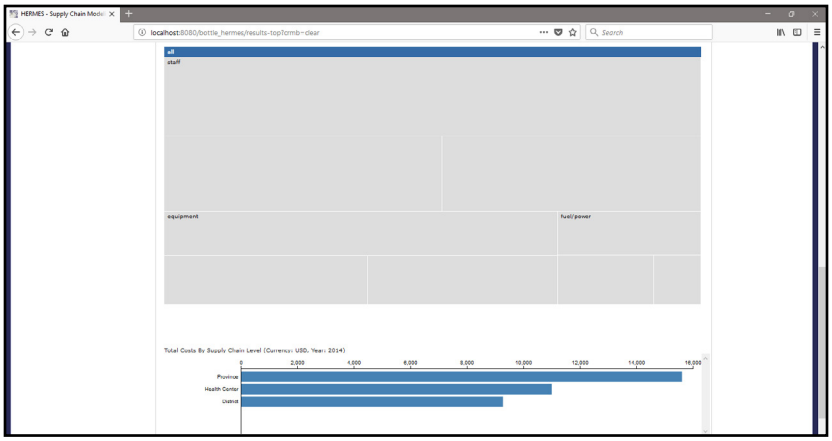


34. Look at the histograms.



35. Hovering your mouse over a bar will pop up more information about that bar (*see middle chart*).

Total Costs by Supply Chain Level



36. Total costs by supply chain level are represented by a treemap and bar chart, both of which are interactive.