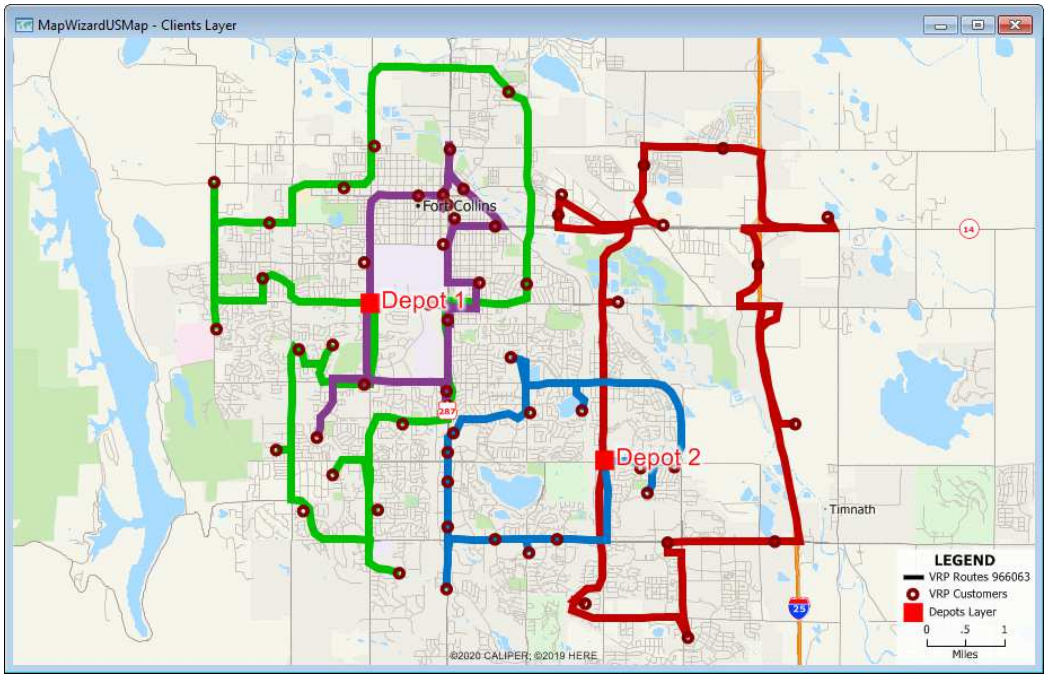
Routing Deliveries & Pickups Add-in

Many businesses and government agencies transport goods from one or more central locations to a set of destinations. It is important to manage these operations efficiently, both to reduce operating costs and to ensure that pickups and deliveries adhere to reasonable service standards.

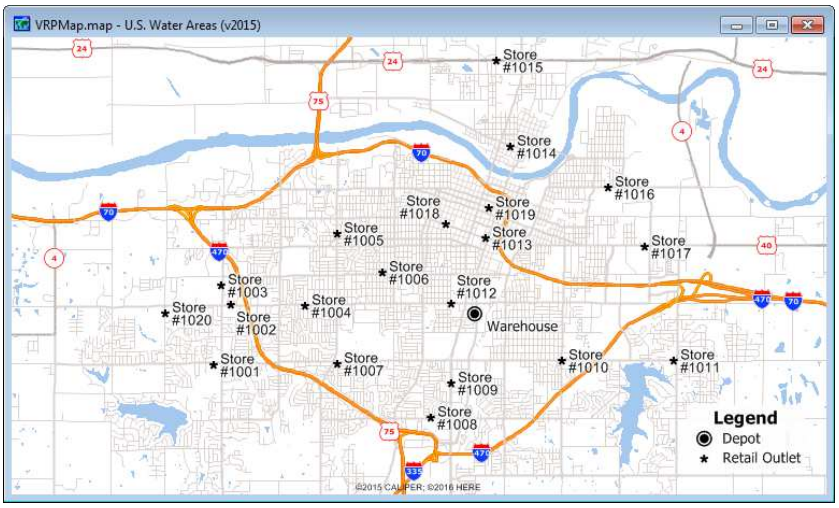
This general problem is known as the **vehicle routing problem**. Solving the vehicle routing problem involves determining how many vehicles are required to service the destinations, and developing a route and schedule for each one. Because there are many variations of the problem, it can be very difficult to solve. Maptitude provides a rich set of vehicle routing tools that solve various types of routing problems.



In This Guide

Introduction to Vehicle Routing

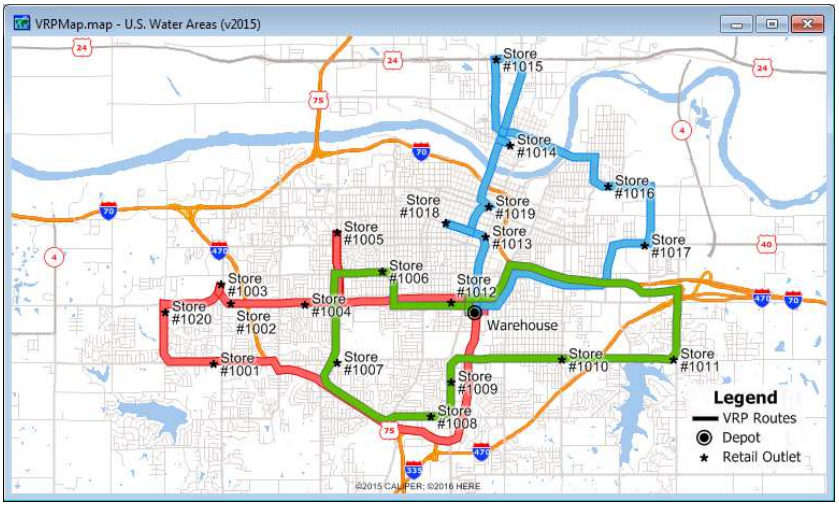
The best way to introduce the vehicle routing problem is to give an example. Imagine a company that has one warehouse that supplies goods to 20 retail stores in various locations, as shown in the map below.



Each day, trucks must deliver goods from the warehouse to each of the retail stores, and then return to the warehouse. Each depot has a fixed number of trucks, and each truck has a fixed capacity, which is a limit on the weight or volume of the goods that the truck can carry. Each retail store has some demand, which is the weight or volume of goods that must be delivered each day. In the simplest version of the vehicle routing problem, the company must determine the number of trucks that are needed to meet the demand at each store, and find cost-efficient routes for each truck.

The starting points for each route (such as the warehouse in the above example) are known as **depots**, and the points to be visited are known as **stops**. A vehicle route starts at a depot, visits one or more stops, and may or may not return to the depot.

The goal of the procedure is to obtain a set of routes that optimize the total time or distance traveled by the entire fleet of vehicles. The procedure considers the number of vehicles of various capacities and the cost to operate them when determining a solution.



There are many factors that can make a vehicle routing problem more complex. The list below shows some common situations that are easily handled by the Routing Deliveries & Pickups Add-in:

- There is more than one warehouse location, and stores can be serviced by trucks from any one of these warehouses. This kind of a problem is known as a **multiple-depot problem**.
- There are time restrictions on when deliveries can be made to some or all of the stores. For example, a particular store might require that goods be delivered between 5:00AM and 7:00AM, before the store opens at 8:00AM. This type of restriction is known as a **time window**.
- Each stop requires a certain amount of time to service. In most cases, each stop has a **fixed service time** that is independent of demand. For example, it takes time to pull a truck into a loading dock and check in with the receiver. There is also a **per-unit service time** that depends upon the demand at that stop. For example, the time it takes to move boxes from the truck onto the loading dock varies depending on how many boxes there are to move.
- There is a time restriction on **total route length,** or **route duration**. For example, when delivering take-out food, it may be desirable that the full route length is not more than an hour.
- There are **backhaul stops**. For example, vehicles may need to pick up empty containers at the end of their delivery trip. Backhaul stops can only be visited after all delivery stops are visited in a route.
- A vehicle route may contain mixed pickup and delivery stops, where the pickups and deliveries do not need to correspond to each other. A stop may require either a pickup, a delivery, or both services.
- A route does not need to end at the depot. In other words, the route does not contain the return trip from the last stop to the depot. This is often referred as an open-ended route instead of a closed tour. For example, a driver may want to drive home directly from the last stop of the day instead of returning to the depot. Another example is when the route duration constraint is effective only to the point of the last stop, such as in fresh goods delivery services.
- There is a need to balance the routes based on either the number of stops, or the distance traveled, or the total time traveled.

The Routing Deliveries & Pickups Add-in uses general-purpose methods that are appropriate for a fairly broad class of problems. There are some variations of the vehicle routing problem not handled directly within the Routing Deliveries & Pickups Add-in. Here are a few examples:

- Mixed products – Several different products must be delivered in the same vehicle, but some vehicles have restrictions on the goods that can be carried
- Partially pre-ordered routes – Certain stops must be visited in an exact order
- Other constraints – There are work rules or regulations that impose other types of constraints on the routes to be developed

Custom solutions for many of these variations on the vehicle routing problem are available from Caliper Corporation. In addition, the general-purpose methods that are included with Maptitude can be modified to handle special restrictions or to improve performance for some types of problems. Please contact Caliper Corporation for more information.

Preparing Data for Vehicle Routing

The Routing Deliveries and Pickups add-in requires the following:

- A point layer with the location of depots (the "depot layer") that includes the times that vehicles can be dispatched.
- A point layer with the location of stops (the "stop layer") that includes the times that the stops can be serviced, the unit demand, and both service and per-unit times
- Information on the availability of vehicles, their capacity, and their cost at each depot. This can be in a table (the "vehicle table") or entered and saved when using the Routing Deliveries and Pickups add-in.

Depot and Stop Layers

To solve a vehicle routing problem, you must first prepare layers that contain the point locations of the depots and stops. The depots and stops can be either in the same layer, or in different layers.

If you use a single layer for both depots and stops, or if your layers contain extra points other than stops and depots, you must create a depot selection set and a stop selection set. You can create selection sets of stops and depots using any of the Maptitude selection commands and tools. For more information on selection sets, see *Queries and Selection Sets*, in the Maptitude Help.

If you already have a point layer or layers for the depots and stops but some of the required fields are missing, you can add them using the ***Dataview>Table>Modify*** command, or create a joined view using the ***Dataview>Table>Join*** command. For more information, see *Working with Tables, Databases, & Charts*, in the Maptitude Help**.**

Depot Layer Fields

The depot layer must contain certain fields that are used in vehicle routing:

Field	Type	Contents
ID	integer	A number that uniquely identifies the depot
Name	string	A name that is used to identify a depot in the route reports
Open Time	integer	The earliest time, in military format (e.g. 1700 for 5:00pm), that vehicles can be dispatched from the depot
Close Time	integer	The latest time, in military format, that vehicles can return to the depot

The fields do not need to have the exact names indicated above, although using these names may make it easier for you to use the routing procedures.

The Open Time and Close Time fields define the time window from which vehicles may be dispatched. For more information on time window inputs, see "Time Windows" below.

Stop Layer Fields

The stop layer must have the following fields:

Field	Type	Contents
Name	string	A name that is used to identify a stop in the route reports
Open Time	integer	The earliest time, in military format (e.g. 1700 for 5:00pm), that vehicles can be serviced; See "Time Windows" below for more information; See "Time Windows" below for more information
Close Time	integer	The latest time, in military format, that a stop can be serviced; See "Time Windows" below for more information
Service Time	numeric	The minimum time required to service a stop (in minutes); See "Service Times" below for more information
Per Unit Time	numeric	The service time required for each unit of demand (in minutes); See "Service Times" below for more information
Delivery Demand	numeric	The delivery demand at a stop (not required for Pickup mode) defined as units, volume, or weight and must match the units used to define the capacity of vehicles
Pickup Demand	numeric	The pickup demand at a stop (not required for Delivery mode) defined as units, volume, or weight and must match the units used to define the capacity of vehicles

If you are routing from multiple depots, you have the option to pre-assign any number of stops to depots. To pre-assign stops to depots, the stop layer must include a field containing the ID numbers of the depots to which each stop is assigned:

Field	Type	Contents
Depot Assigned	integer	The ID of the specific depot which services a stop. Maptitude will use the assigned depot when present and will choose the nearest depot when this value is blank. If a depot has excessive demand over its total vehicle capacity, some stops may be assigned to the second nearest depot.

The Routing Deliveries and Pickups add-in will also let you specify additional fields that you may want included in the vehicle reports (e.g., address, contact name, drop-off instructions).

Time Windows

In both the depot and the stop layers, the Open Time and Close Time fields use military format, so 8:30AM should be written as 830, while 6:30PM should be written as 1830. Times beyond midnight are written as numbers over 2400; for example, 12:30AM should be written as 2430. Here are some examples:

Open Time	Close Time	Comments
500	830	Stop must be made in the early morning
1200	1245	A very small time window for making the stop
700	1900	There is essentially no restriction on servicing this stop
2200	2500	Stop must be made between 10:00PM and 1:00AM
1200	1100	This time window is invalid, and would cause an error

In general, as the time windows become more and more restrictive, the number of vehicles that are required to service the stops increases. If you do not need time window restrictions, you can simply set the open time to 0 and the close time to a large number (e.g., >2400).

A stop can also have multiple time windows. For example, a stop may accept deliveries from 10:00AM to noon and again from 2PM to 5PM. In this case, you will need separate fields in the stop layer for each of the time windows (e.g., OpenTime1, CloseTime1, OpenTime2, CloseTime2).

Service Times

NOTE:
Certain combinations of time windows and service times may make it infeasible to service some stops.

The Routing Deliveries & Pickups Add-in accounts for the time required to service each stop when calculating routes. The service time can have a fixed component and a variable component that is demand dependent (time per unit). Both of these components can vary from stop to stop. The fixed time, for example, at one stop may take longer if it is difficult to park there or if it lacks a loading dock. Likewise, the per-unit time may be longer at a stop that requires delivery to an upper floor.

The amount of time it takes to service a stop is as follows:

service time = (fixed time) + (number of units) * (time per unit)

Vehicle Data

NOTE:
Capacity can be defined as a number of units, volume, or weight, but must match the units used to define demand in the stop layer. See page 4 for more information on stop layers.

Vehicle information can be entered manually while performing vehicle routing or imported from a vehicle table. For each depot, you must specify the types of vehicles available. For each vehicle type, you must specify:

- A unique ID for the vehicle, such as VIN, license plate, etc.
- The capacity of the vehicle, which must match in units the demand at the stops
- The purchase/operating/rental cost

If you are importing the vehicle information from a table, it must contain the following fields:

Field	Type	Contents
Depot ID	Integer	The ID corresponding to the depot ID in the depot layer
Vehicle ID	String	The ID corresponding to the vehicle
Type	String	Descriptive text describing the vehicle
Capacity	Real	The capacity of the vehicle, which must match in units the demand at the stops
Cost	Real	The purchase/operating/rental cost of each vehicle type

Solving the Vehicle Routing Problem

The Routing Deliveries and Pickups add-in solves complex routing problems with time window, heterogeneous fleet, backhaul, mixed pickup and delivery, and route length constraints. It can handle multiple depots and open-ended routing problems. Additionally, you can choose to balance routes based on any of three different criteria: time, distance, or the number of stops.

In addition, if some stops are not visited due to any restriction (such as vehicle capacity or time windows), a selection set named "Unserviced" will be created on the stop layer.

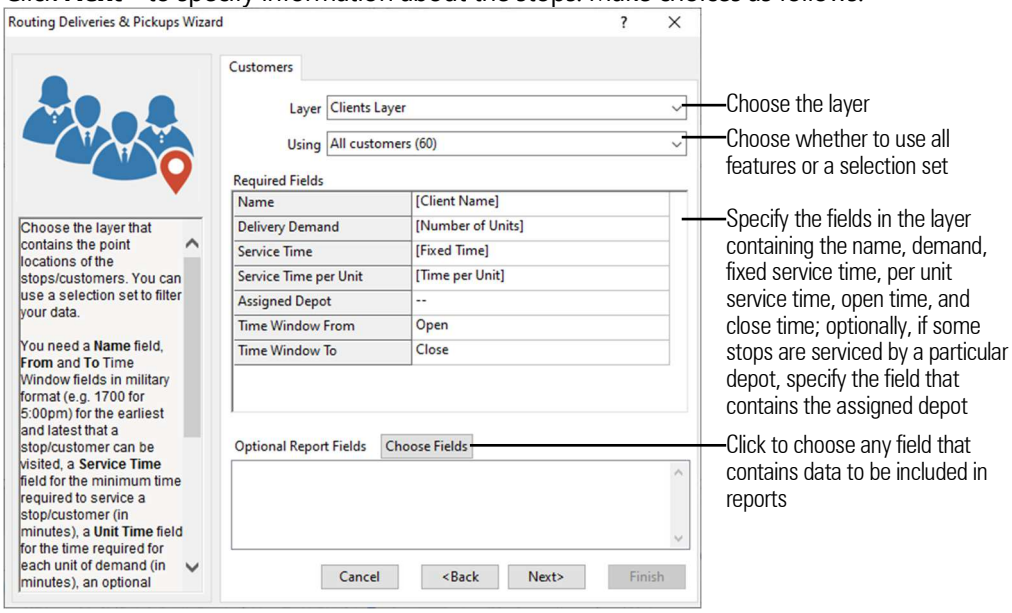
▶To Solve the Vehicle Routing Problem

1. Open a workspace with a map that contains a depot layer and a stop layer.
2. Choose ***Tools>GIS Developer's Kit>Add-Ins>Routing Deliveries & Pickups*** to start the Routing Deliveries & Pickups Wizard.
3. Choose the **Create New Vehicle Routes** option from the radio list.
4. From the Operation Mode drop-down list, make choices as follows:

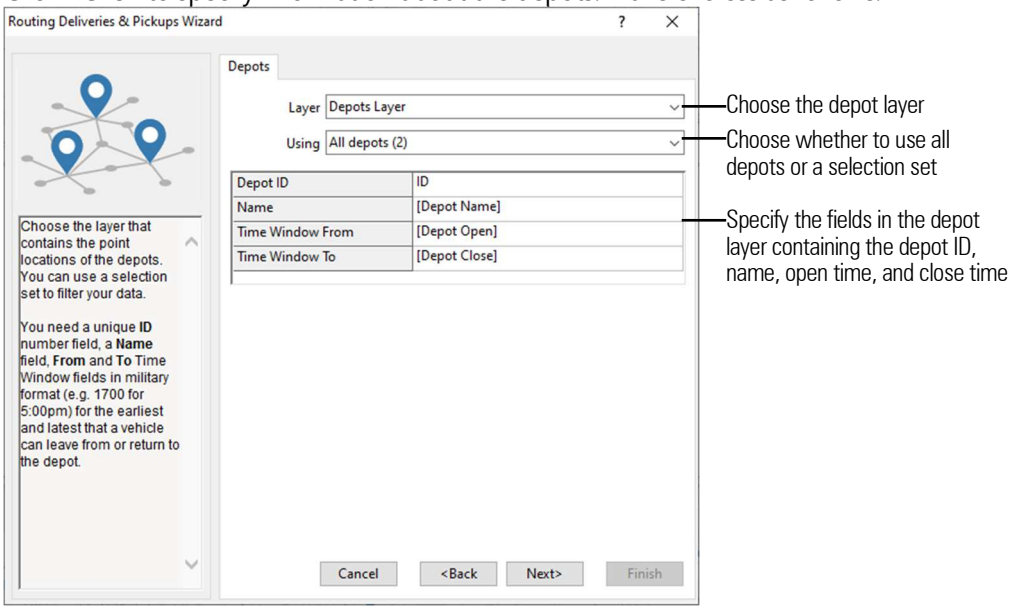
Option	When to use it…
Delivery	Vehicles from the depots will only be delivering units to the stops
Pickup	Vehicles from the depots will only be picking up units from the stops
Mixed Pickup & Delivery	Vehicles from the depots may be picking up or delivering units
Backhaul	Vehicles need to pick up empty containers at the end of their delivery trip

5. If your stop layer contains records with multiple time windows, specify the maximum number of time windows.

6. Click **Next>** to specify information about the stops. Make choices as follows:



7. Click **Next>** to specify information about the depots. Make choices as follows:

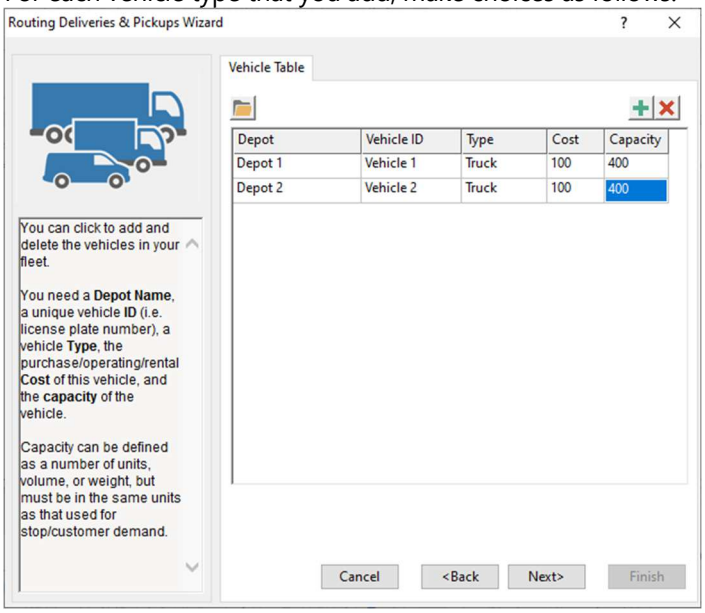


8. Click **Next>** to specify information about the vehicles.

9. To manually specify the available vehicles, click  to add a vehicle type.

   If you have a vehicle table, click  , choose a file type, browse for the table, and click Open to display the Load Vehicle Table dialog box. Verify that the correct fields are chosen for Depot ID, Type, Cost, Number of Vehicles, and Capacity, and click **OK**.

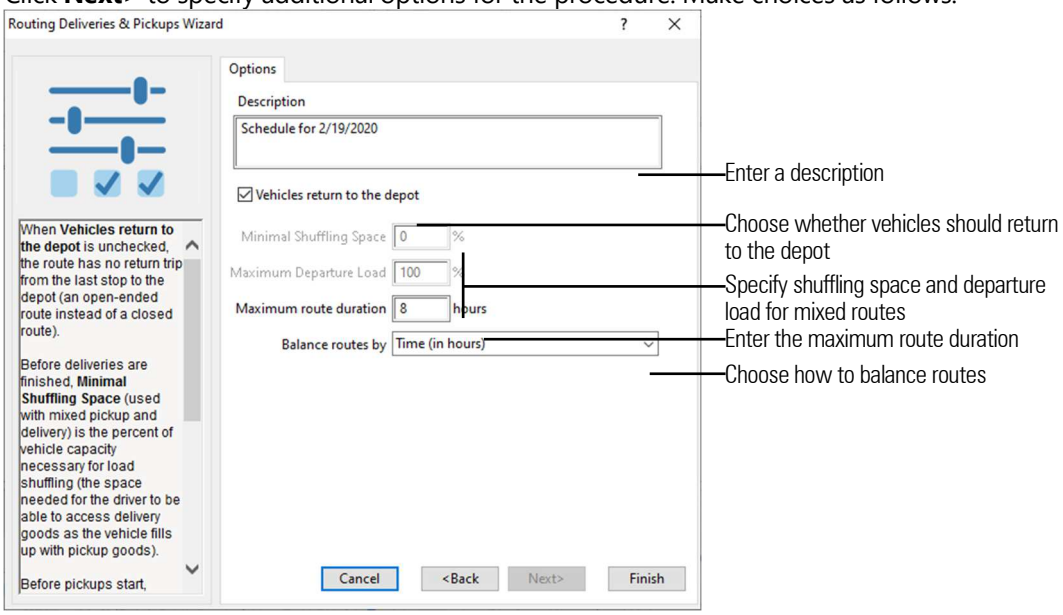
10. For each vehicle type that you add, make choices as follows:



- Choose the depot to which the vehicle belongs from the drop-down list in the Depot column
- Enter the ID, license plate tag, or other vehicle identifier in the Vehicle ID column
- Enter the type of vehicle in the Type column
- Enter the purchase/operating/rental cost in the Cost column
- Enter the capacity of the vehicle, using the same units as stop layer demand, in the Capacity column

Repeat steps 9 and 10 until you have defined all of the vehicles available at each depot.

11. Click **Next>** to specify additional options for the procedure. Make choices as follows:

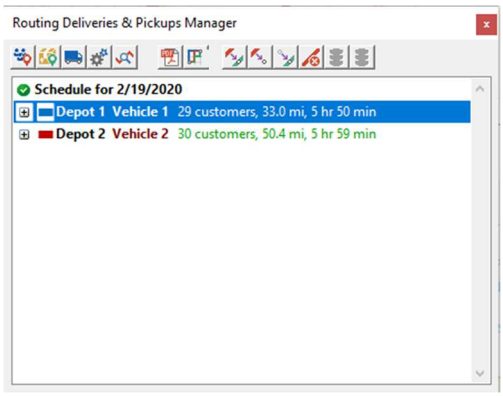


12. Click **Finish**.
13. Browse for a folder in which to save the results and click **Select Folder**.

Maptitude solves the vehicle routing procedure, displays the routes on the map, and opens the Routing Deliveries & Pickups Manager.

▶To View Details About One or More Routes

1. You can view details about routes, display a map of a single route, and create reports with detailed information about the routes using tools in the Routing Deliveries & Pickups Manager as follows:



To do this...	Do this...
See the list of stops for a route	Click ⊞ next to the route to see the arrival and departure time at the stop and the pickup and demand load
Display a single route on the map	Double click a route in the list, right-click on a route in the list and choose ***Display Route [Route Name]***, or highlight a route in the list and click
Display all routes on the map	Right-click on the description at the top of the list and choose ***Display Route***, or highlight the description at the top of the list and click
Generate an itinerary report for a route	Right-click on a route in the list and choose ***Create Report for [Route Name]***, or highlight a route and click
Generate an itinerary report for all routes	Right-click on the description at the top of the list and choose ***Create Report***, or highlight the description at the top of the list and click

▶To Load Existing Routes onto a Map

1. Open a map that contains a depot layer and a stop layer.
2. Choose ***Tools>GIS Developer's Kit>Add-Ins >Routing Deliveries & Pickups*** to start the Routing Deliveries & Pickups Wizard.
3. Choose the **Load Existing Vehicle Routes** option from the radio list.
4. Browse for the Vehicle Routing Configuration file (.VRPConfig) and click Open.
5. Click Next to display the Customers page.
6. The customer layer and fields are loaded from the previous run of the procedure. Make any changes and click Next to display the Depots page.
7. The depot layer and fields are loaded from the previous run of the procedure. Make any changes and click Next to display the Vehicles page.
8. The vehicles used from the previous run of the procedure are displayed. Make any changes to the vehicles and click Next.
9. The options used from the previous run of the procedure are displayed. Make any changes to the options and click Finish.

Maptitude solves the vehicle routing procedure, displays the routes on the map, and opens the Routing Deliveries & Pickups Manager.

Try it Yourself … A 60-Second Tutorial: Solving a Vehicle Routing Problem

1. Choose ***File>New Workspace***, chose **New map of my data/table/spreadsheet** from the frist scroll list, and cilck **OK**.
2. In the Tutorial folder, open the Excel spreadsheet with logistics data for your country (e.g., Logistics Australia.xlsx, Logistics United States.xlsx, etc.).
3. Choose the **Depots** sheet and click **OK**. Maptitude displays Create-a-Map Wizard.
4. Click **Next>**, choose the first "Locate" option in the scroll list, and click **Finish**. Maptitude locates the two depots. Click **OK** to close the Results dialog box.
5. In the Display Manager, click the style sample next to the Depots Layer to display the Style dialog box. Change the size to 16pt, change the color, change the icon to a solid square, and click **OK**.
6. Choose ***Map>Add Table/Spreadsheet to a Map*** and choose the same logistics Excel file in the Tutorial folder.
7. Choose the **Clients** sheet and click **OK**. Maptitude displays Create-a-Map Wizard.
8. Click **Next>**, choose the first "Locate" option in the scroll list, and click **Finish**. Maptitude locates the clients. Click **OK** to close the Results dialog box.
9. Choose ***Tools>GIS Developer's Kit>Add-Ins >Routing Deliveries & Pickups*** to display the Routing Deliveries & Pickups Wizard.
10. Click the **Create New Vehicle Routes** radio button, verify that **Delivery** is chosen from the Operation Mode drop-down list, and click **Next>** to display the Customers page.
11. Notice that the Routing Deliveries & Pickups Add-in already has chosen to use all features in the Clients layer and has found the fields for name, service time, and time window. Choose **[Number of Units]** for the Delivery Demand and click **Next>** to display the Depots page.
12. Notice that the Routing Deliveries & Pickups Add-in already has chosen to use all features in the Depots layer and has found the fields for name, open time, and close time. Click **Next>** to display the Vehicles page.
13. Click  four times to add 4 vehicles.
14. Click and drag to highlight all of the cells in the Cost column and type **100** to set the costs for all four vehicles.
15. Click and drag to highlight all of the cells in the Capacity column and type **250** to set the capacities for all four vehicles.
16. Choose **Depot 1** from the drop-down list in the Depot column for two of the vehicles, and **Depot 2** for the other two vehicles.
17. Click **Next>** to display the Options page.
18. Enter **8** in the Maximum Route Duration box, choose **Time (in hours)** from the Balance Routes By drop-down list, and click **Finish**. Maptitude displays the Save Vehicle Routing Results In dialog box.
19. Right-click in the dialog box, choose ***New> Folder***, name the folder **My VRP Results**, and click Select Folder.
20. Click  next to a route to see the stops that route services.
21. Right-click the itinerary description at the top of the list and choose ***Create Report***. Maptitude creates a PDF report. Scroll through the PDF to see the itinerary for each route. Close the report when you are done.
22. Choose ***File>Close Workspace*** and click **Don't Save** to close the workspace without saving changes to the map.

Editing Vehicle Routes

Once you have created vehicle routes, you can use the Routing Deliveries & Pickups Manager to modify routes.

Sometimes there will be stops that were not assigned to any route in the initial solution, or that are removed from routes by you. These stops are referred to as **unserviced customers**. The Routing Deliveries & Pickups Manager lets you handle unserviced customers in several ways:

- You can modify the settings that were used to produce the routes and rerun the procedure. For example, you could modify the number of trucks available or change the balancing method, then rerun the procedure to see if there are fewer unserviced customers.
- You can use the tools to manually move stops from one route to another, add unserviced customers to a route, or remove stops from a route. Changes you make to the routes are automatically updated on the map and in the Routing Deliveries & Pickups Manager.

▶To Modify the Customers Serviced

1. Click  to display the Customers portion of the Routing Deliveries & Pickups Wizard.
2. Make any changes to the customers, such as the layer and/or selection set to use, and click OK.
3. Click  to run the vehicle routing procedure again with the changes to the customers.

▶To Modify the Depots Serviced

1. Click  to display the Depots portion of the Routing Deliveries & Pickups Wizard.
2. Make any changes to the depots, such as the layer and/or selection set to use, and click OK.
3. Click  to run the vehicle routing procedure again with the changes to the depots.

▶To Modify the Available Vehicles

1. Click  to display the Vehicles portion of the Routing Deliveries & Pickups Wizard.
2. Make any changes to the vehicles available at each depot and click OK.
3. Click  to run the vehicle routing procedure again with the changes to the vehicles.

▶To Modify the Route Duration, Route Balancing, and Other Settings

1. Click  to display the Options portion of the Routing Deliveries & Pickups Wizard.
2. Make any changes to the options and click OK.
3. Click  to run the vehicle routing procedure again with the changes to the options.

▶To Move a Stop to a Different Route

1. Click  in the Routing Deliveries & Pickups Manager to activate the Move a Stop tool.
2. Click on a stop, then click on the route to which you wish to add the stop. Where you click on the route will determine the sequence in which the stops are serviced. Stops earlier in the route will be unchanged; stops later in the route will be serviced after the inserted stop. You will be warned if moving a stop violates time window or vehicle capacity constraints.
3. If you click a location where there is more than one route, Maptitude displays the Pick Destination Route dialog box. Choose the route you wish to move the stop to and click OK.

4. The stop is removed from the sequence of stops in the initial route, and inserted into the new route. Maptitude recalculates the changed routes, highlights them on the map, and shows detailed information about the change in the Routing Deliveries & Pickups Manager.
5. Click  to save the changes or click  to cancel the changes.

If you save the changes, Maptitude updates the changed routes and redraws the map.

▶To Add an Unserviced Customer to a Route

1. Click  in the Routing Deliveries & Pickups Manager to activate the Add an unserviced customer to a route tool.
2. Click on an unserviced customer, then click on the route at the location where you would like to move the stop. Where you click on the route will determine the sequence in which the stops are serviced. Stops earlier in the route will be unchanged; stops later in the route will be serviced after the inserted stop. You will be warned if moving a stop violates time window or vehicle capacity constraints.
3. If you click a location where there is more than one route, Maptitude displays the Pick Destination Route dialog box. Choose the route you wish to add the unserviced customer to and click OK.
4. Maptitude recalculates the route with the new stop, highlights the new route on the map, and shows detailed information about the new route sequence in the Vehicle Route Editing toolbox. Any stops that violate time window constraints are shown in red in the scroll list.
5. Click  to save the changes or click  to cancel the changes.

If you save the changes, Maptitude inserts the unserviced customer into the route, and redraws the map with the new route.

▶To Remove a Stop from a Route

1. Click  in the Routing Deliveries & Pickups Manager to activate the Remove a Stop tool.
2. Click on the stop you wish to remove from a route.
3. Maptitude recalculates the route without the stop, highlights the new route on the map, and shows detailed information about the new route sequence in the Vehicle Route Editing toolbox. Any stops that violate time window constraints are shown in red in the scroll list.
4. Click  to save the changes or click  to cancel the changes.

If you save the changes, Maptitude removes the stop from the route and adds it to the unserviced selection set.

▶To Delete a Route

1. Click  in the Routing Deliveries & Pickups Manager to activate the Delete a Route tool.
2. Click on the route you wish to remove.
3. If you click a location where there is more than one route, Maptitude displays the Pick Destination Route dialog box. Choose the route you wish to delete and click OK.
4. Maptitude highlights the route on the map.
5. Click  to save the changes or click  to cancel the changes.

If you save the changes, Maptitude deletes the route, makes all of the stops along the route unserviced, and adds them to the unserviced selection set.