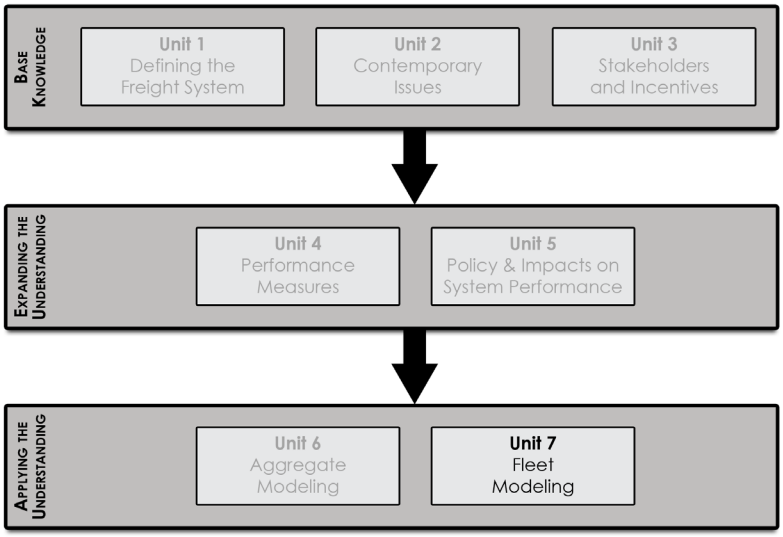
BEFORE CLASS

Connection	Activity Overview	Required Resources	Pre-Class Preparation
Review to see how this activity fits as part of the course and Unit 7.	Read to learn more about the content of the activity.	Review to make sure you have the materials you need for this activity.	Read to prepare for what you will do in class during the activity.

CONNECTION

Activity #10 is the only assignment within Unit 7: Fleet Modeling. This activity introduces students to the needs, motivations, and limitations within fleet modeling and to methods of solving vehicle routing problems.

In Activity #10, students are introduced to the Vehicle Routing Problem (VRP) and fleet modeling through the use of a previously developed model, which allows for exploration of the relationships between costs, emissions, and customer service.



Unit 7: Fleet Modeling

- L Fleet Modeling
- A **Fleet Modeling**

ACTIVITY OVERVIEW

Activity #10 follows a lecture on the concepts and theory regarding fleet modeling, and consists of an in-class component. During the in-class activity students are asked to complete a tutorial which walks students through the use of a vehicle routing problem (VRP) based on grocery delivery in the Seattle area. In this activity, students are provided with a version of the vehicle routing model (a macro-enabled excel file) and will determine routing and scheduling for a particular fleet and customer demands. Using information about time windows, customers' demand, and fleet characteristics, students will calculate the routing and scheduling for a subset of this company's customers and observe how changes in inputs alter outcomes.

The **learning objectives** for Activity #10 include:

- To understand the basic concept of vehicle routing and the VRP.
- To be introduced to and use a modeling tool.
- To identify tradeoffs between costs, emissions, and customer service within fleet routing.

Required Resources

You will need the following material for this activity:

- Activity #10 text
- Excel files (Activity Base Case.xlsm and new_time_windows.xlsx)
- Computer lab (one computer per student)

Pre-Class Preparation

For the instructor:

- Review the Connection, the Essay, the Required Resources, the Script, and the Solution and Notes.

For the student:

- The pre-class component should be comfortable with the information presented in the Fleet Modeling lecture.

DURING CLASS

Agenda	Instructor Notes	Common Questions	Discussion Notes and Ideas
Review with the students to show them what tasks will be completed during class and the approximate time for each task.	Use this to remind you of the information that you need to remember and the sequence that you will follow during class.	Keep these in mind! They are what students have asked about this activity in the past.	Keep these in mind for possible use during class or to update the activity in the future

Agenda

- Activity #10 (approximately 80 minutes)
- The instructor is to facilitate the activity by answering questions regarding the tutorial.
- Students will work independently but are encouraged to consult with other students regarding concerns.
- During the session, the instructor should observe students, noting problems and addressing concerns.

Instructor Notes

The instructor is to facilitate the activity by observing students, noting problems and addressing concerns and/or questions.

Common Questions/Concerns

Students may not initially understand how ordering of vehicles (within the model input) effects the results. Within the model, vehicles are assigned in the order which they are input into the model.

Students must remember to enable the macro in order to use the model.

When the model is run an output file is created. Unless that file is saved under a different name, it will be overwritten when the model is run again.

Discussion Notes/Ideas

Additional questions which could be asked during the activity session:

- How can you determine vehicle utilization using the output data?
- Do cost and emissions increase or decrease when time windows are narrowed? widened?
- (prior to running the model) How do you expect cost and emissions, and emissions and customer service to be related?
- How many routes/vehicles are used to service all the customers?
- What is the total cost and total emissions produced to service all customers?
- What time does the second truck leave the depot and what time does the second truck return to the depot?
- Which route is the most expensive?
- Which route has the highest CO_2 emissions?
- What is the first customer visited in the third route?

AFTER CLASS

Answers and Notes	Activity Assessment	Next Steps
Use the information here to help you evaluate student performance.	Use this space to take notes regarding the implementation and facilitation of the activity which can be used to make any necessary adjustments to the activity.	This is a reminder of what comes next, including any homework or preparation that students need to complete for the next class or activity.

Answers and Notes

Tutorial questions (with answers):

QUESTIONS 1.2

How far does a vehicle have to travel to get from customer 18 to customer 47? What about when the vehicle travels from customer 47 to customer 18? Why might these distances be different?

5.85 miles/5.40 miles

The distances may differ due to considerations such as one-way street and on/off-ramps.

Between what times customer 10 can be served?

2:30 am – 6 am (150-360 minutes after midnight)

How much time is needed to deliver customer 14's totes?

8.4 minutes

What are the capacities of each individual vehicle in the fleet?

90 totes

What are the emissions factors for the vehicles in the fleet?

0.7 kg/mi @ 15mph; 0.4 kg/mi @ 45mph

Do the vehicles in the fleet produce more emissions when driving fast or slow?

slow

Based on the capacities and emissions factors for the fleet, do you think this is a homogenous or heterogeneous fleet?

Homogenous – all trucks have the same capacities and emissions factors

What is the total cost if TRUCK 1 drives 10 miles in 15 minutes?

*10mi*0.2$/mi + 15min*0.3$/min = $6.50*

QUESTIONS 1.4

How many routes/vehicles are used to service all the customers?

4

What is the total cost and total emissions produced to service all customers? (Also fill this information into the chart on the last page of this activity)

$176.80; 45.96 kg CO2

What time does the second truck leave the depot and what time does the second truck return to the depot?

Leaves at 150 min after midnight (2:30am) and returns at 305 minutes after midnight (5:05am)

Which route is the most expensive?

Route 3 ($56)

Which route has the highest CO_2 emissions?

Route 3 (158 kg CO2)

What is the first customer visited in the third route?

#58

QUESTIONS 2.4

Are more or less trucks needed in this scenario when compared to the base case? Why?

More, because of truck capacity. The first 3 trucks are small within this scenario.

Are the total emissions higher or lower than the base case emissions? Why?

Lower. The large vehicles do not travel as far in this scenario.

Why do the costs per minute values not change?

They represent the hourly pay rate of the driver, which does not change between scenarios.

QUESTIONS 2.9

Summarize the differences in the results using the two different heterogeneous fleet orderings. Compare number of vehicles used, emissions, and cost.

Fleet 1: 5 vehicles, 45.31 kg CO2, and $168.80 to serve all customers

Fleet 2: 3 vehicles, 52.69 kg CO2, and $173.60 to serve all customers

Are the previous results what you would expect? Explain how the ordering of vehicles impacts overall cost and emissions.

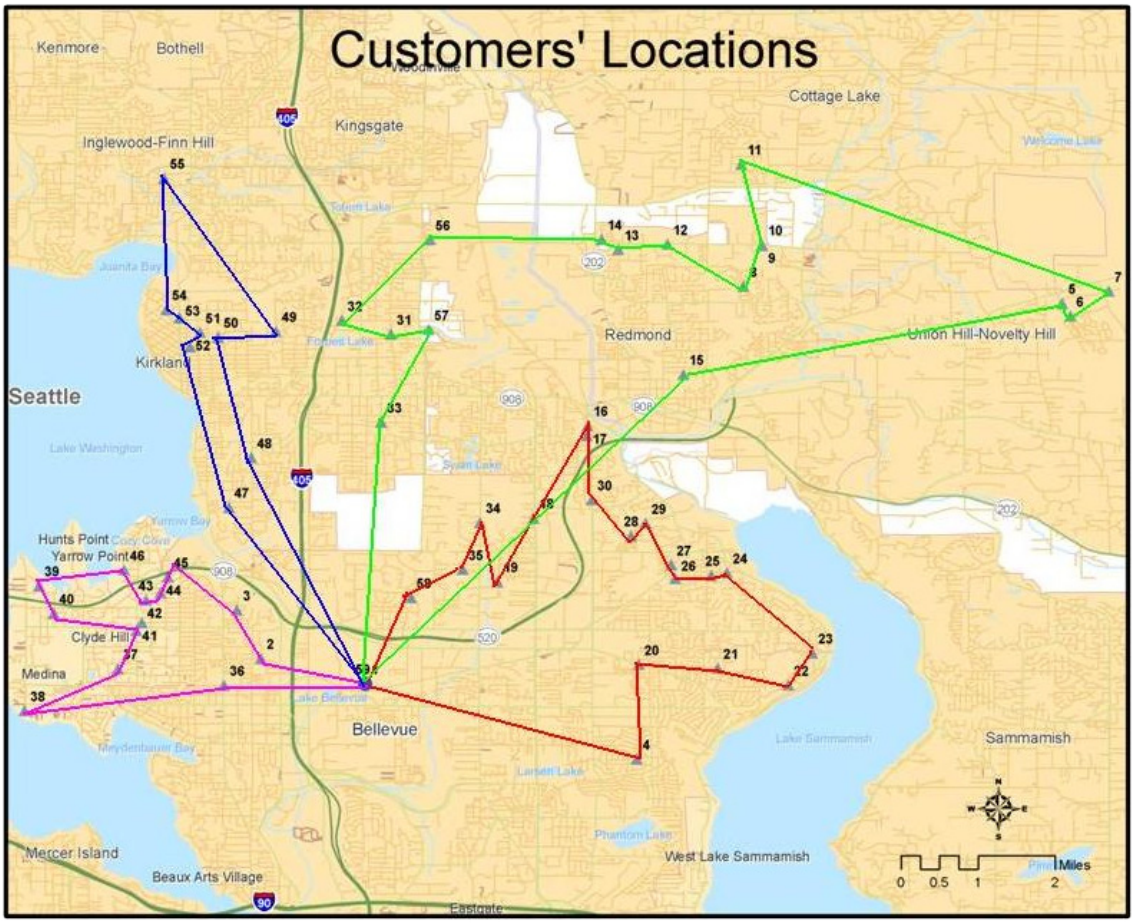
We are often lead to believe that due to economies of scale, larger trucks are better. But, ordering the higher capacity/higher cost vehicles first results in fewer trucks being used but the total costs and emissions increase.

Based on the results of each scenario, if a fleet manager has a heterogeneous fleet and wanted to minimize emissions, how would you tell him/her to order trucks? Does this order also minimize cost?

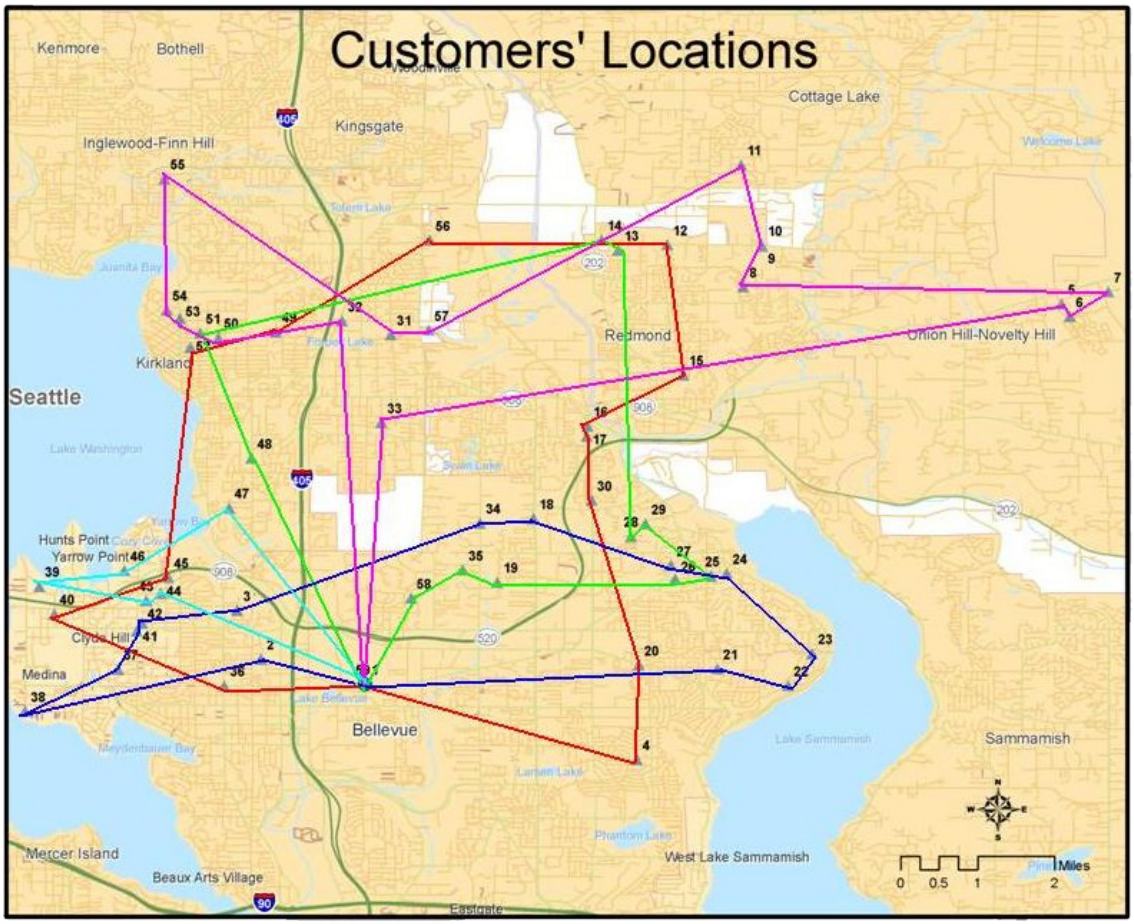
Utilize the lower emissions trucks first, ordering second on lower cost per mile to minimize emissions first and cost second. The most fuel efficient trucks should travel the farthest.

QUESTIONS 3.8

The maps below show representations of the two time window scenarios modeled above (note that the routes shown in the maps are not the actual routing solutions determined by the model). Identify which map represents which scenario (1) customers get to choose within what time window their delivery occurs or (2) customers are assigned to a time window based on their location.



Scenario 2 Assigned time windows



Scenario 1 Customer chosen time windows

What is the trade-off in terms of cost and emissions between each of the scenarios modeled?

When customers are given the ability to select their own delivery time, coordination of deliveries becomes more difficult and both cost and emissions increase because more driving and time if often required. Customers choose a delivery time that is best for the individually, but not necessarily best for the system.

What is the trade-off in terms of customer service between each of the scenarios modeled?

Customer service is lowered if delivery time is determined for the customer rather than allowing them to decide because the delivery time might not fit the customers' schedule. However, good customer service can be maintained in both scenarios by if deliveries are made on time.

Final Comparison

Complete the table below with the activity results.

	Base Case	Heterogeneous Fleet 1	Heterogeneous Fleet 2	Time Window 1	Time Window 2
Total Cost	$176.80	$168.80	$173.60	$208.10	$182.40
Total Emissions	45.96	45.31	52.69	53.53	46.82

Using the data and results of this activity, make 3 conclusions regarding urban vehicle routing?

Using smaller vehicles is cheaper and better for the environment

Having a mix of vehicles (big/small) can be better than just a single type

Assigning time windows for deliveries will be better for a business but may not be for the customers

When customers choose delivery times, total costs and emissions will typically rise

When selecting fleet vehicles to implement, choose lower capacity trucks first, that are cheaper to run per mile.

When possible use a heterogeneous fleet, as it allows you to be more adaptable to delivery needs, thus lowering your overall cost.

Vehicle capacity has a large impact on efficiency and bigger is not always the most ideal.

When delivery companies are allowed to plan their own routes and schedule they are ultimately more efficient, costing lost and having less emissions.

More delivery vehicles or routes could allow a company to become even more efficient if smaller but more fuel efficient vehicles are used.

Activity Assessment

Next Steps

This activity is the last within the course module.

