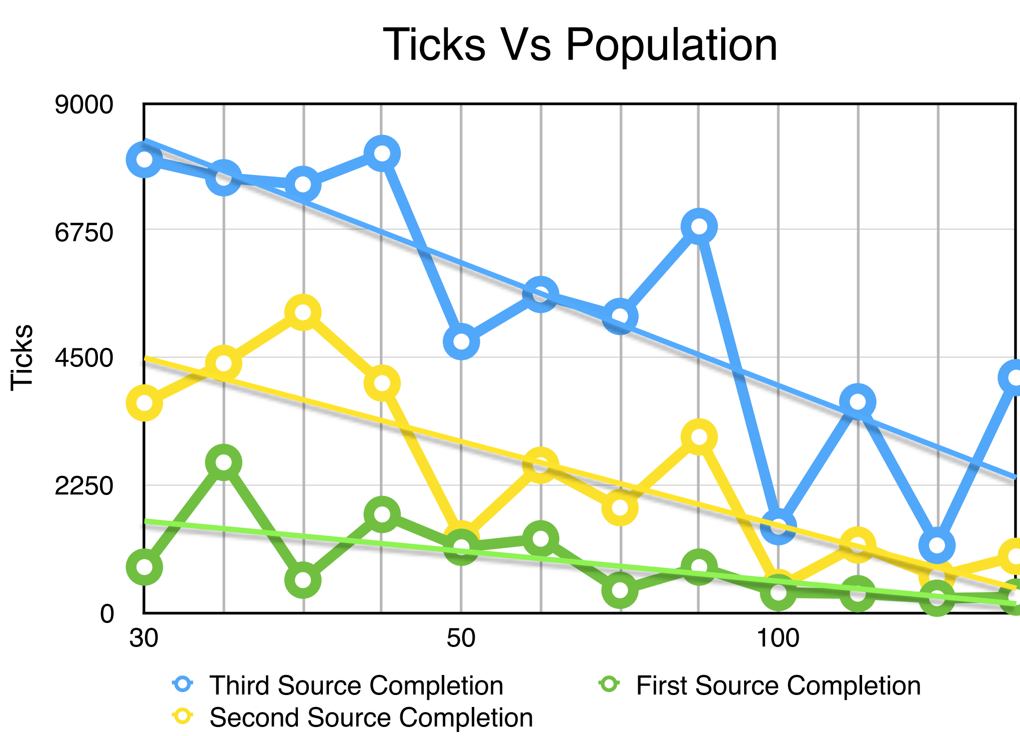
Question 2

Part A

Population	Diffusion-Rate	Evaporation-Rate	Total Tick Count	First Source Completion	Second Source Completion	Third Source Completion
30	40	10	8001	800	3700	8000
30	40	20	7679	2650	4400	7600
30	80	10	7562	570	5300	7500
30	80	20	8109	1730	4050	8100
50	40	10	4784	1150	1300	4700
50	40	20	5617	1300	2600	5600
50	80	10	5229	390	1850	5200
50	80	20	6819	800	3100	6800
100	40	10	1514	350	440	1500
100	40	20	3721	330	1190	3700
100	80	10	1183	250	630	1100
100	80	20	4147	270	990	4100



The strongest trend that can be observed from the data collected using the NetLogo Application is that as the population is increased, the total time taken for all sources to be depleted steadily decreased. As can be seen from the trend-lines, all sources decreased in time to depletion as the population increased.

More specifically, the variance between values of the same population was due to both the diffusion-rate, and evaporation-rate. It can also be seen that the lower value of both rates allowed for a better completion time. Therefore, as population increased, and both the diffusion-rate and evaporation-rate were maintained at their lower values, the best result was produced. This can be seen with the following data:

Population	Diffusion-Rate	Evaporation-Rate	Total Tick Count	First Source Completion	Second Source Completion	Third Source Completion
100	40	10	1514	350	440	1500
100	80	10	1183	250	630	1100

This data proves that with the highest population, and with the lowest evaporation-rate, the best results of the total experiment were found. The lowest amount of time seen throughout this experiment was an outlier to other results as it required the higher diffusion-rate. The reason for this is due to the larger population of ants converging on the source due to more ants being able to follow the path of the pheromone before it evaporated.

Part B

Online Pheromone Update

Pheromone Persistence Constant	State Transition Control Parameter (Alpha, Beta)	Population	Path	Cost
0.6	(1,5)	25	[18, 15, 22, 7, 26, 23, 0, 27, 11, 5, 8, 2, 28, 25, 4, 20, 1, 19, 9, 12, 6, 24, 10, 16, 21, 13, 17, 14, 3]	10,997.863632
0.3	(1,5)	25	[2, 28, 25, 8, 4, 20, 1, 19, 9, 3, 14, 10, 16, 21, 13, 17, 12, 15, 18, 24, 6, 22, 7, 26, 23, 0, 27, 11, 5]	10,034.402988
0.1	(1,5)	25	[11, 8, 4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 13, 17, 16, 21, 10, 18, 24, 6, 22, 15, 23, 26, 7, 0, 27, 5]	9,624.4763775
0.1	(1,1)	25	[8, 2, 28, 25, 4, 20, 1, 19, 9, 3, 12, 15, 10, 16, 21, 13, 17, 14, 18, 24, 6, 22, 26, 7, 23, 0, 27, 11, 5]	9,878.1927142
0.1	(5,1)	25	[22, 6, 24, 10, 14, 3, 18, 15, 20, 1, 25, 4, 12, 16, 13, 17, 21, 19, 9, 23, 0, 27, 5, 8, 11, 28, 2, 26, 7]	15,270.334241
0.1	(3,5)	25	[17, 13, 21, 16, 10, 18, 15, 12, 9, 19, 1, 20, 4, 8, 25, 28, 2, 5, 11, 27, 0, 23, 26, 7, 22, 6, 24, 3, 14]	10,160.535973
0.1	(1,5)	20	[14, 18, 24, 6, 22, 15, 23, 26, 7, 27, 0, 20, 4, 8, 5, 11, 25, 28, 2, 1, 19, 9, 12, 3, 17, 13, 21, 16, 10]	9,837.6530038
0.1	(1,5)	15	[27, 5, 11, 8, 25, 28, 2, 1, 20, 4, 12, 9, 19, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15, 26, 7, 23, 0]	10,250.094233

NOTE: Each set of parameters ran three times before the cost was averaged, and the path was taken from the lowest cost experiment, hence why same paths may not produce same cost.

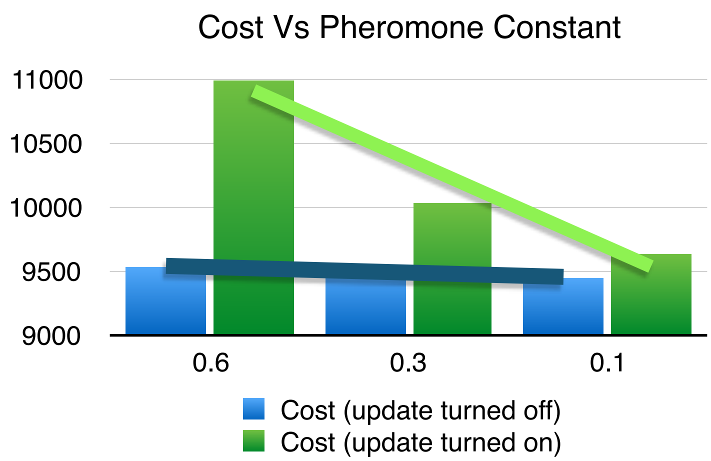
Online Pheromone Update Turned Off

Pheromone Persistence Constant	State Transition Control Parameter (Alpha, Beta)	Population	Path	Cost
0.6	(1,5)	25	[26, 7, 23, 0, 27, 5, 11, 8, 4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15]	9,533.1404742
0.3	(1,5)	25	[4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15, 26, 7, 23, 0, 27, 5, 11, 8]	9,504.4960731
0.1	(1,5)	25	[26, 7, 23, 0, 27, 5, 11, 8, 4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15]	9,447.383335
0.1	(1,1)	25	[13, 21, 16, 10, 18, 24, 6, 22, 26, 7, 23, 0, 27, 5, 11, 8, 4, 25, 28, 2, 1, 20, 12, 15, 19, 9, 3, 14, 17]	9,850.1566379
0.1	(5,1)	25	[0, 27, 5, 11, 8, 4, 25, 28, 2, 20, 1, 19, 9, 12, 3, 14, 10, 21, 16, 13, 17, 18, 24, 6, 22, 15, 26, 7, 23]	10,046.718758
0.1	(3,5)	25	[26, 7, 23, 0, 27, 5, 11, 8, 4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15]	9,953.082002
0.1	(1,5)	20	[2, 28, 25, 4, 20, 1, 19, 9, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 15, 12, 23, 26, 7, 0, 27, 5, 11, 8]	9,536.1074166
0.1	(1,5)	15	[8, 4, 25, 28, 2, 1, 20, 19, 9, 3, 14, 17, 13, 21, 16, 10, 18, 24, 6, 22, 26, 7, 15, 12, 23, 0, 27, 5, 11]	9,764.4295967

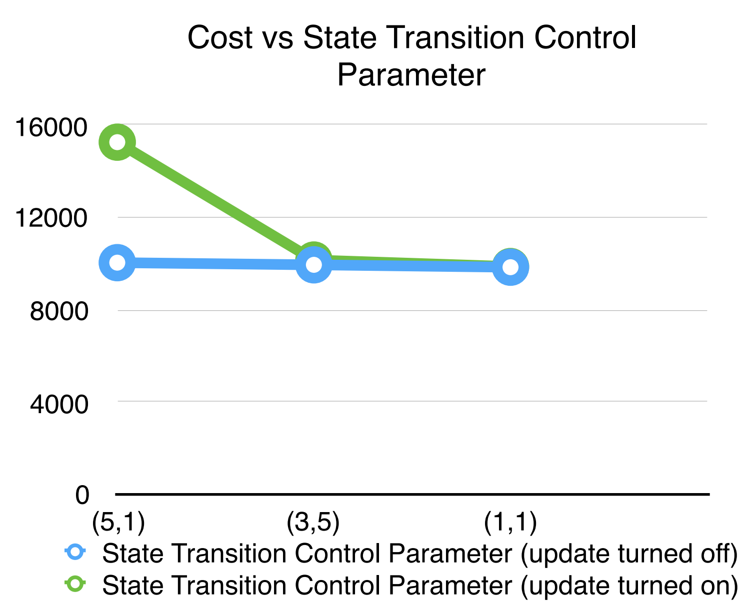
NOTE: Each set of parameters ran three times before the cost was averaged, and the path was taken from the lowest cost experiment, hence why same paths may not produce same cost.

Observations & Conclusion

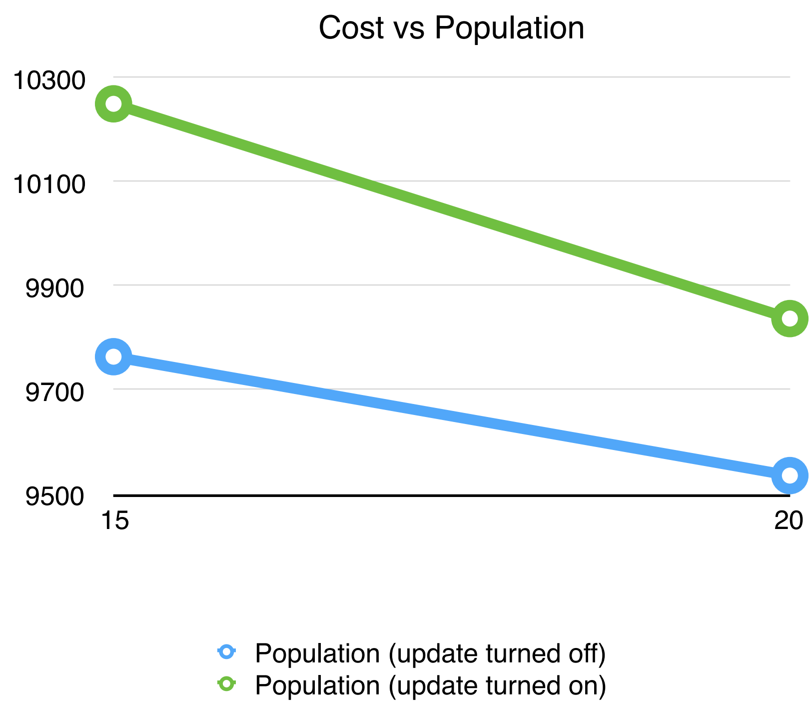
Considering the pheromone persistence constant, it was observed through both online and offline pheromone update that as the constant decreased, a lower cost solution was found. This can be seen in an example of the algorithm where the evaporation rate does not exist. In this example, the paths chosen by the first ants would excessively attract other ants. Hence, by lowering the evaporation rate to almost zero, more ants are able to follow that same path, providing consistently lower cost solutions.



Secondly, when analyzing the state transition control parameter, the impact of a lower alpha had a stronger impact when compared to a higher beta. From the results, decreasing the alpha value allowed a trend to occur that lowered the cost. With more results, the trend could be further analyzed to find the perfect ratio for optimal results. Overall, the distance was more valuable than pheromones on a path for producing a lower cost.



Lastly, when analyzing the importance of population, it was clear that an increased population allowed a solution to occur with a lower cost. This can be simply explained with more ants travelling different paths allowing a more optimal solution to be found. With different path traversals done, the likelihood of an optimal path is increased with a higher population.



In conclusion, many optimizations can be done varying by problem to allow an optimal solution with a low cost to be found. In this TSP, it is seen that with 29 cities, the best solution found was with update turned on and the following parameters:

Pheromone Persistence Constant	State Transition Control Parameter (Alpha, Beta)	Population	Path	Cost
0.1	(1,5)	25	[11, 8, 4, 25, 28, 2, 1, 20, 12, 9, 19, 3, 14, 13, 17, 16, 21, 10, 18, 24, 6, 22, 15, 23, 26, 7, 0, 27, 5]	9382.2836111

While generally optimal results were found when the update was turned off, this solution provided the lowest cost.