Methods:

The majority of this program was already setup. This simulation accepts command line in puts for the carwash arguments which is then used to when running the carwash simulation. The data in this case the length of the car line for the carwash is store in a Pandas data frame which will later be used to plot a graph using Matplotlib. The remainder of the implementation involved setting up the car arrival time to follow that of a Poisson distribution as well as adding randomness factor to the simulation.

Using a for loop the simulation is able to be run multiple times with each time a variable being altered. For the case of this simulation the variable being decremented is the number of machines in the car wash. The resulting car line length corresponding to the different number of machines available will be plot together on a graph via matplotlib for comparison and analysis.

Results:

Running the car wash simulation with one machine and then followed by running simulation 3 times decrementing number of machines from 3 to 1.

```
codewk2_simpy % python3 carwash.py -r 43 -m 1 -w 5 -t 7 -s 20
codewk2_simpy % python3 carwash.py -r 43 -m 3 -w 5 -t 7 -s 20
```

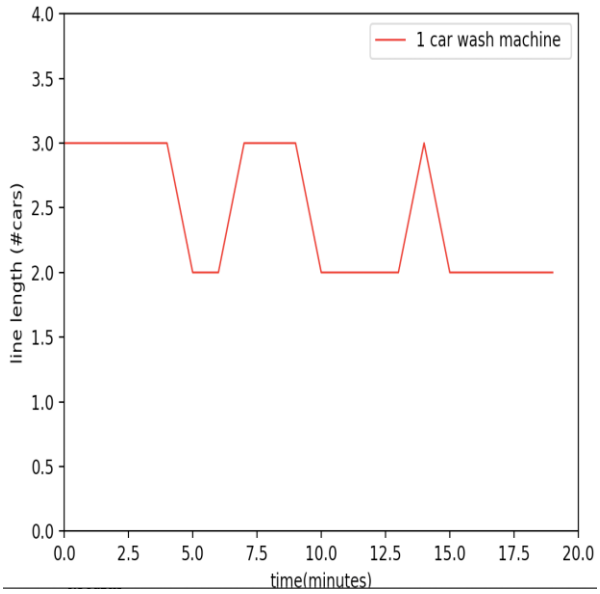

Figure 1

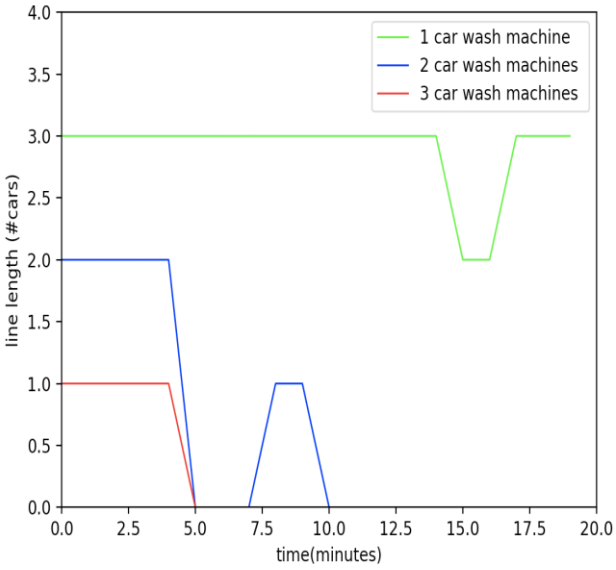

Figure 2

From these two figures, we can conclude that there is a negative correlation between the number of carwash machines and the length of the car line. If we examine figure 1 we can tell that the car line for the car wash is always maintained between 3 and 2 cars waiting to enter the car wash. With 4 cars line up to be washed at the start of the simulation the single car wash machine would only be able to finish washing one car every five minutes while the arrival time of new cars is every 7 minutes which will keep replenishing the line.

Looking at figure 2 it is evident that when there is more than a single machine at the carwash the size of the car line decreases dramatically. Looking at the blue line which represents the carwash operating with two machines we can see that having two machines the carwash is

able to operate on a rate of 2 car every 5 minutes. The extra machine allows the carwash to handle the load when considering cars needing to be serviced and cuts down on the length of the car line to 0 at 10 minutes into the simulation. If we look at the red line in Figure 2 which represents a carwash with 3 machines it is even more evident of how more machines decrease the length of car lines. With 3 machines this carwash is able to service 3 of the initial cars waiting at once and from there future cars arriving every 7 minutes will not have to even wait to be serviced.

Poisson Distribution:

Using the Simpy's random library, I was able to use a Poisson function within that library which would provide the cars with a Poisson distribution for their arrival times. The different arrival time were then stored into a list and ran with the simulation for 5 separate runs with each run using a different value for time between car arrivals or T_INTERVAL. The resulting car lines are then stored using the Pandas data frame and later graphed using matplotlib. For the sake of consistency each of these runs had the number of car wash machines fixed to 2.

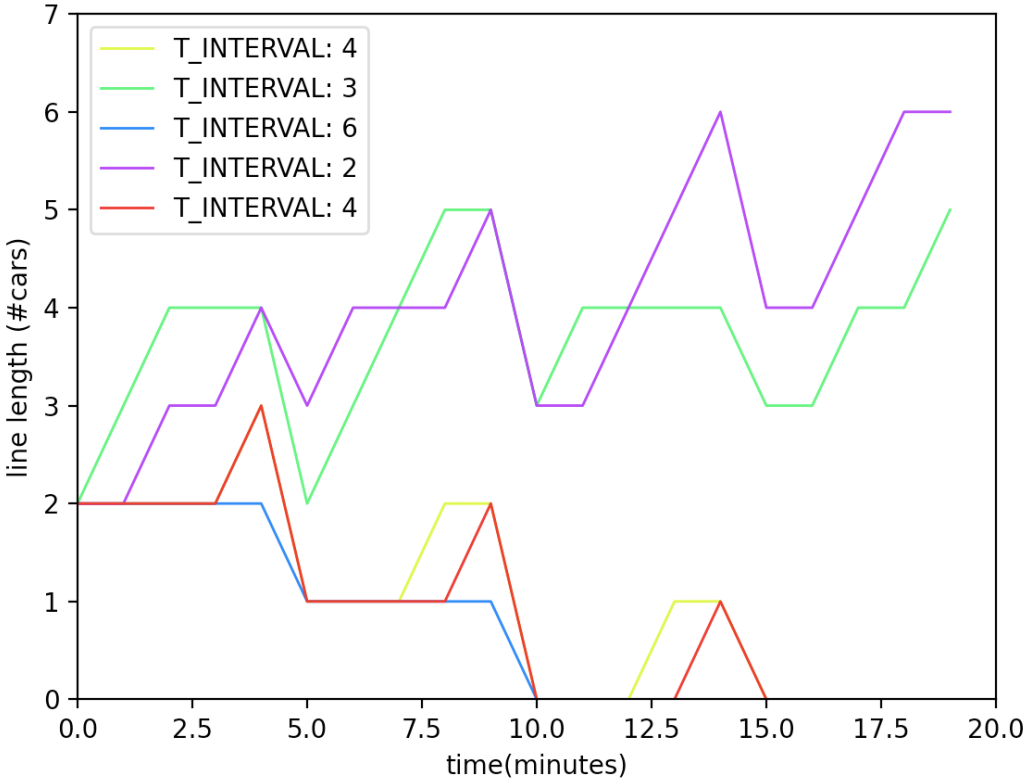

Figure 3

After examining figure 3, it is evident that there is once again a negative correlation between the car arrival time and the length of the car line. The longer it takes for cars to arrive at the car wash the more time the machines will have to wash the cars and shorten the line before it can lengthen. We can take a look at the purple line in Figure 2 which is the simulation running with cars arriving at the carwash every 2 minutes. With cars coming every 2 minutes and the car wash needing 5 minutes to wash 2 cars, the carwash does not have enough capacity nor time to work through the car line due to the frequency new cars are arriving. On the other hand, looking at the blue line representing the car arrival rate of one car every 6 minutes then the carwash has the capacity and enough time to handle the existing line and make room for cars coming in next.

At the 10-minute mark the car wash has already finished washing or is currently washing the 4 initial cars as well as the car that arrived at the 6-minute mark freeing up space for the next incoming car.

Something Interesting:
Which is more cost effective, add a single fast machine (Figure A) or 2 slower machines (Figure B).

```
codewk2_simpy % python3 carwash.py -r 43 -m 2 -w 6  -t 5 -s 20
```

```
codewk2_simpy % python3 carwash.py -r 43 -m 1 -w 3  -t 5 -s 20
```

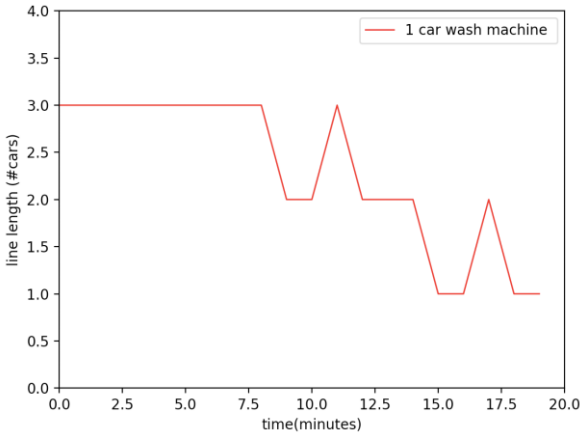

Figure A

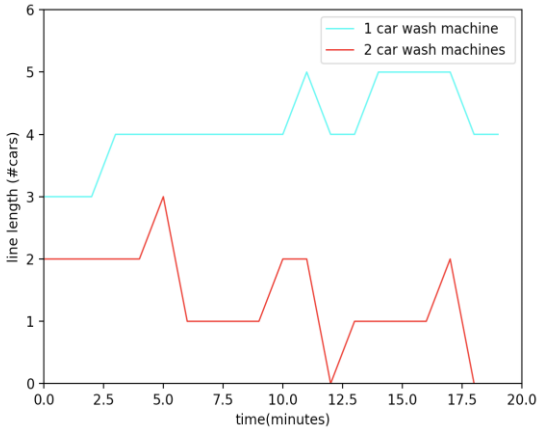

Figure B

For this question I equalized the efficiency of the two setups by having the faster machine wash a car at a rate of one car every 3 minutes while the 2 slower machines each wash a car at a rate of one car every 6 minutes. At first, I had assumed that the graphs would look similar since the rate at which they would wash a car would be equivalent. While the number of cars washed by the two different setups would be equal the length of the car line would be different.

By observing Figure A and Figure B we can see that the machine from A would vastly outperform machine B in a one on one contest in dwindling the car line however when two machine B are present the line size is actually overall smaller compared to that of Figure A. Due to having two machines as opposed to just one setup B is able to take two cars from the line at once while the setup in A can only handle the waiting cars one by one.

Now to answer the question, assuming that the two setups wash the same number of cars in the given time and that the cost of machine A is not more than that of 2 machine Bs then I would rule that having 2 slower machines would be more cost effective than 1 faster more expensive machine. This decision is based on notion that having two machines is more effective in reducing the size of the car line which would make the carwash more attractive to customers as compared to a carwash that has a very long line which may repelled some potential business from dirty car owners.