Before Beginning

My expected learning outcome derives from the conversations concerning this project that we had in class; I know that the `CarWash` project makes use of queues in order to handle the waiting line and feed cars into the washing bay, and therefore I expect to build on previous knowledge acquired in `KQueue`. This project will put to the test my ability to implement an `LLQueue` and my abilities to properly enqueue and dequeue objects while simultaneously keeping track of other data.

After skimming through the project guidelines, I see that the project expects the programmers to have a full understanding of how queue processing works.

I am expecting to extend the Car class, writing `ArrivingCar`, `WaitingCar`, and `WashingCar`, which each have different states depending on their position in the washing process. I also expect to modify the `CarWashSimulation` and Application classes.

Problems may arise when moving cars in and out of the bay; shifting objects with each looped step can sometimes get confusing, and I'm likely at some point to get some form of an off-by-one error.

After Completion

My actual learning outcome was precisely what I expected; this project was just an extension of the `KQueue` minilab. I also learned (the hard way) that `ArrayLists` cannot hold primitives…more on that topic in the problems section. As I wrote before, the project does a good job in extending lessons learned in the `KQueue` minilab. Practice makes perfect, and this project forced some much needed practice.

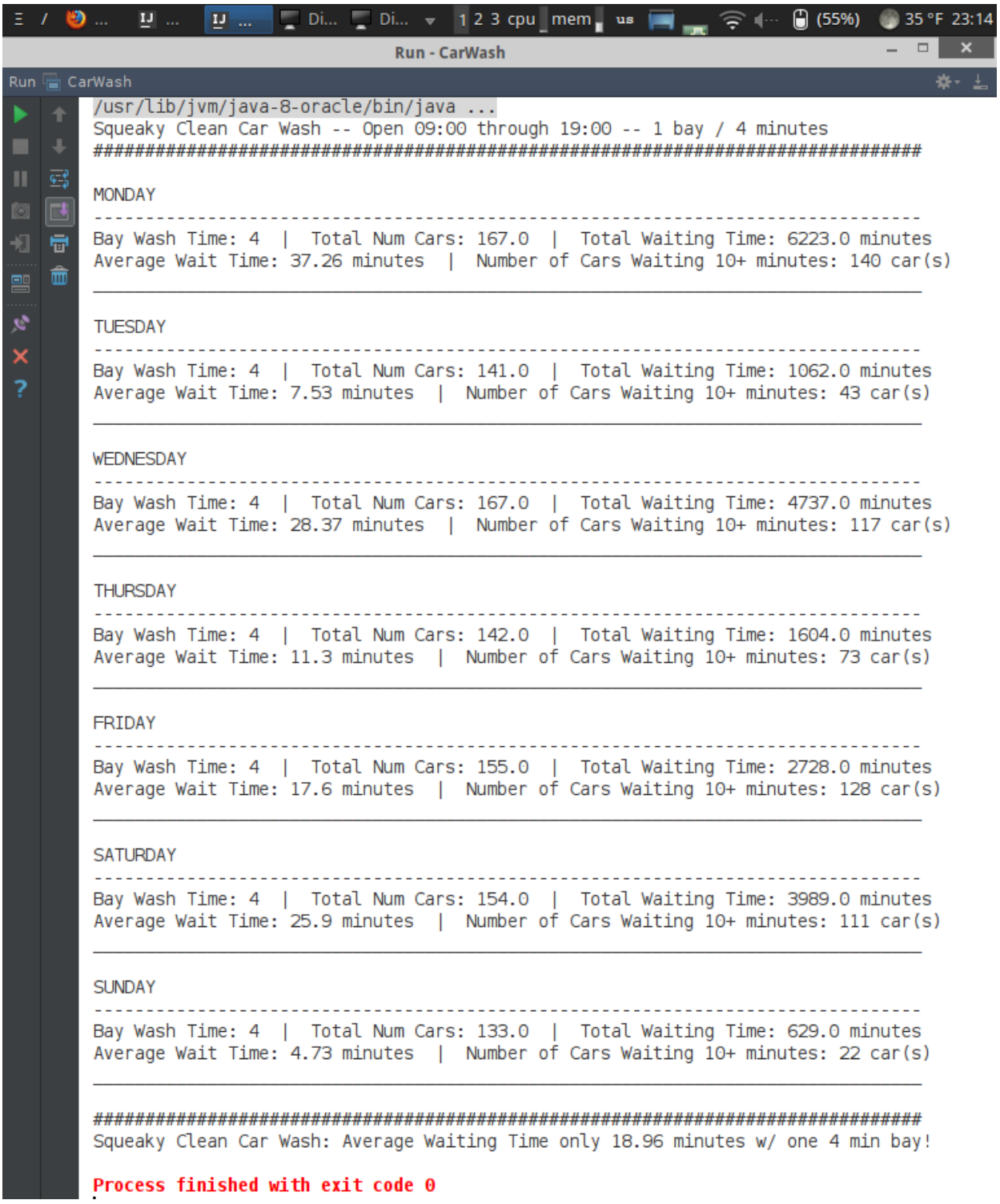
For some reason, even though `LLQueue` takes <T>, the `enqueue()` method can only enqueue Objects. Halfway through my project's completion, I realized that every time I enqueued a Car into the `waitingLine` queue, it was converted to just an Object and lost the reference to its arrival time. I had to solve this by casting the returned object of `dequeue()` as a Car. However, I quickly learned that the `ArrayList` which I hoped to use to store the extracted waiting times of the `dequeued` cars would not hold plain integers, leading to issues when mixing wrapped integer objects and integers primitives in my average waiting time calculations. Instead I rely on an array which is created at the program start with enough indices to accommodate the generated cars.

Analysis

Pictures of my output can be found both in the submitted folder as well as in the latter pages of this document. Please note that the output displayed in the pictures does not match the text file output, as the data were captured in two different runs of the simulation. Included on the following two pages are 7 day simulations of the Squeaky Clean Car Wash using the old 4 minute cycle bay (Bay(4)) and the proposed new 3 minute cycle bay (Bay(3)), respectively. When using Bay(4), the average wait time was 15.02 minutes, whereas the average wait time when using the proposed Bay(3) is only 2.28 minutes. This is an improvement of 84.82%, where usage of Bay(3) results in cars waiting only 15.18% of their average 4 minute wait time. Furthermore, an average of 78 cars waited 10 or more minutes per day for Bay(4), as opposed to the 3 cars which waited for 10 or minutes for Bay(3). Installing the 3 minute wash bay is therefore a good investment and should result in fewer lost customers to excessive wait times. The optional project extension—installing two or more bays—was not implemented.

```
Squeaky Clean Car Wash -- Open 09:00 through 19:00 -- 1 bay / 4 minutes
################################################################################

MONDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 143.0  |  Total Waiting Time: 894.0 minutes
Average Wait Time: 6.25 minutes  |  Number of Cars Waiting 10+ minutes: 36 car(s)
________________________________________________________________________________

TUESDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 144.0  |  Total Waiting Time: 2805.0 minutes
Average Wait Time: 19.48 minutes  |  Number of Cars Waiting 10+ minutes: 101 car(s)
________________________________________________________________________________

WEDNESDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 160.0  |  Total Waiting Time: 5444.0 minutes
Average Wait Time: 34.03 minutes  |  Number of Cars Waiting 10+ minutes: 120 car(s)
________________________________________________________________________________

THURSDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 139.0  |  Total Waiting Time: 1185.0 minutes
Average Wait Time: 8.53 minutes  |  Number of Cars Waiting 10+ minutes: 54 car(s)
________________________________________________________________________________

FRIDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 152.0  |  Total Waiting Time: 1983.0 minutes
Average Wait Time: 13.05 minutes  |  Number of Cars Waiting 10+ minutes: 74 car(s)
________________________________________________________________________________

SATURDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 153.0  |  Total Waiting Time: 2772.0 minutes
Average Wait Time: 18.12 minutes  |  Number of Cars Waiting 10+ minutes: 125 car(s)
________________________________________________________________________________

SUNDAY
--------------------------------------------------------------------------------
Bay Wash Time: 4  |  Total Num Cars: 133.0  |  Total Waiting Time: 757.0 minutes
Average Wait Time: 5.69 minutes  |  Number of Cars Waiting 10+ minutes: 34 car(s)
________________________________________________________________________________

################################################################################
Squeaky Clean Car Wash: Average Waiting Time only 15.02 minutes w/ one 4 min bay!
```

```
Squeaky Clean Car Wash -- Open 09:00 through 19:00 -- 1 bay / 3 minutes
################################################################################

MONDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 145.0  |  Total Waiting Time: 203.0 minutes
Average Wait Time: 1.4 minutes  |  Number of Cars Waiting 10+ minutes: 0 car(s)
________________________________________________________________________________

TUESDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 158.0  |  Total Waiting Time: 481.0 minutes
Average Wait Time: 3.04 minutes  |  Number of Cars Waiting 10+ minutes: 3 car(s)
________________________________________________________________________________

WEDNESDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 142.0  |  Total Waiting Time: 217.0 minutes
Average Wait Time: 1.53 minutes  |  Number of Cars Waiting 10+ minutes: 0 car(s)
________________________________________________________________________________

THURSDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 141.0  |  Total Waiting Time: 187.0 minutes
Average Wait Time: 1.33 minutes  |  Number of Cars Waiting 10+ minutes: 0 car(s)
________________________________________________________________________________

FRIDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 157.0  |  Total Waiting Time: 388.0 minutes
Average Wait Time: 2.47 minutes  |  Number of Cars Waiting 10+ minutes: 1 car(s)
________________________________________________________________________________

SATURDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 162.0  |  Total Waiting Time: 619.0 minutes
Average Wait Time: 3.82 minutes  |  Number of Cars Waiting 10+ minutes: 13 car(s)
________________________________________________________________________________

SUNDAY
--------------------------------------------------------------------------------
Bay Wash Time: 3  |  Total Num Cars: 157.0  |  Total Waiting Time: 368.0 minutes
Average Wait Time: 2.34 minutes  |  Number of Cars Waiting 10+ minutes: 3 car(s)
________________________________________________________________________________

################################################################################
Squeaky Clean Car Wash: Average Waiting Time only 2.28 minutes w/ one 3 min bay!
```


Run - CarWash
Run CarWash
/usr/lib/jvm/java-8-oracle/bin/java ...
Squeaky Clean Car Wash -- Open 09:00 through 19:00 -- 1 bay / 4 minutes
##
MONDAY

Bay Wash Time: 4 | Total Num Cars: 167.0 | Total Waiting Time: 6223.0 minutes
Average Wait Time: 37.26 minutes | Number of Cars Waiting 10+ minutes: 140 car(s)
TUESDAY

Bay Wash Time: 4 | Total Num Cars: 141.0 | Total Waiting Time: 1062.0 minutes
Average Wait Time: 7.53 minutes | Number of Cars Waiting 10+ minutes: 43 car(s)
WEDNESDAY

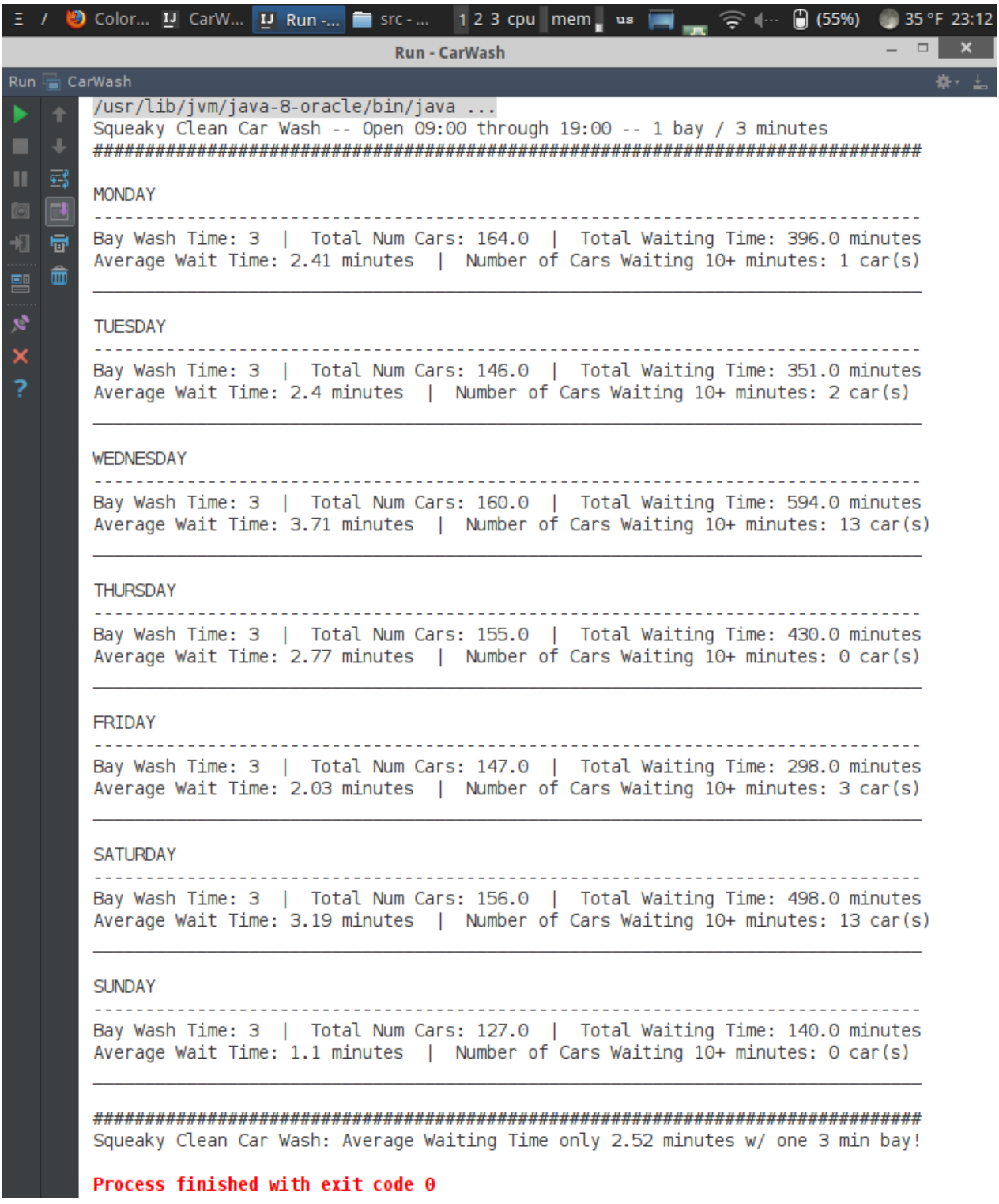
Bay Wash Time: 4 | Total Num Cars: 167.0 | Total Waiting Time: 4737.0 minutes
Average Wait Time: 28.37 minutes | Number of Cars Waiting 10+ minutes: 117 car(s)
THURSDAY

Bay Wash Time: 4 | Total Num Cars: 142.0 | Total Waiting Time: 1604.0 minutes
Average Wait Time: 11.3 minutes | Number of Cars Waiting 10+ minutes: 73 car(s)
FRIDAY

Bay Wash Time: 4 | Total Num Cars: 155.0 | Total Waiting Time: 2728.0 minutes
Average Wait Time: 17.6 minutes | Number of Cars Waiting 10+ minutes: 128 car(s)
SATURDAY

Bay Wash Time: 4 | Total Num Cars: 154.0 | Total Waiting Time: 3989.0 minutes
Average Wait Time: 25.9 minutes | Number of Cars Waiting 10+ minutes: 111 car(s)
SUNDAY

Bay Wash Time: 4 | Total Num Cars: 133.0 | Total Waiting Time: 629.0 minutes
Average Wait Time: 4.73 minutes | Number of Cars Waiting 10+ minutes: 22 car(s)
##
Squeaky Clean Car Wash: Average Waiting Time only 18.96 minutes w/ one 4 min bay!
Process finished with exit code 0


Run - CarWash
Run CarWash
/usr/lib/jvm/java-8-oracle/bin/java ...
Squeaky Clean Car Wash -- Open 09:00 through 19:00 -- 1 bay / 3 minutes
MONDAY
Bay Wash Time: 3 | Total Num Cars: 164.0 | Total Waiting Time: 396.0 minutes
Average Wait Time: 2.41 minutes | Number of Cars Waiting 10+ minutes: 1 car(s)
TUESDAY
Bay Wash Time: 3 | Total Num Cars: 146.0 | Total Waiting Time: 351.0 minutes
Average Wait Time: 2.4 minutes | Number of Cars Waiting 10+ minutes: 2 car(s)
WEDNESDAY
Bay Wash Time: 3 | Total Num Cars: 160.0 | Total Waiting Time: 594.0 minutes
Average Wait Time: 3.71 minutes | Number of Cars Waiting 10+ minutes: 13 car(s)
THURSDAY
Bay Wash Time: 3 | Total Num Cars: 155.0 | Total Waiting Time: 430.0 minutes
Average Wait Time: 2.77 minutes | Number of Cars Waiting 10+ minutes: 0 car(s)
FRIDAY
Bay Wash Time: 3 | Total Num Cars: 147.0 | Total Waiting Time: 298.0 minutes
Average Wait Time: 2.03 minutes | Number of Cars Waiting 10+ minutes: 3 car(s)
SATURDAY
Bay Wash Time: 3 | Total Num Cars: 156.0 | Total Waiting Time: 498.0 minutes
Average Wait Time: 3.19 minutes | Number of Cars Waiting 10+ minutes: 13 car(s)
SUNDAY
Bay Wash Time: 3 | Total Num Cars: 127.0 | Total Waiting Time: 140.0 minutes
Average Wait Time: 1.1 minutes | Number of Cars Waiting 10+ minutes: 0 car(s)
Squeaky Clean Car Wash: Average Waiting Time only 2.52 minutes w/ one 3 min bay!
Process finished with exit code 0