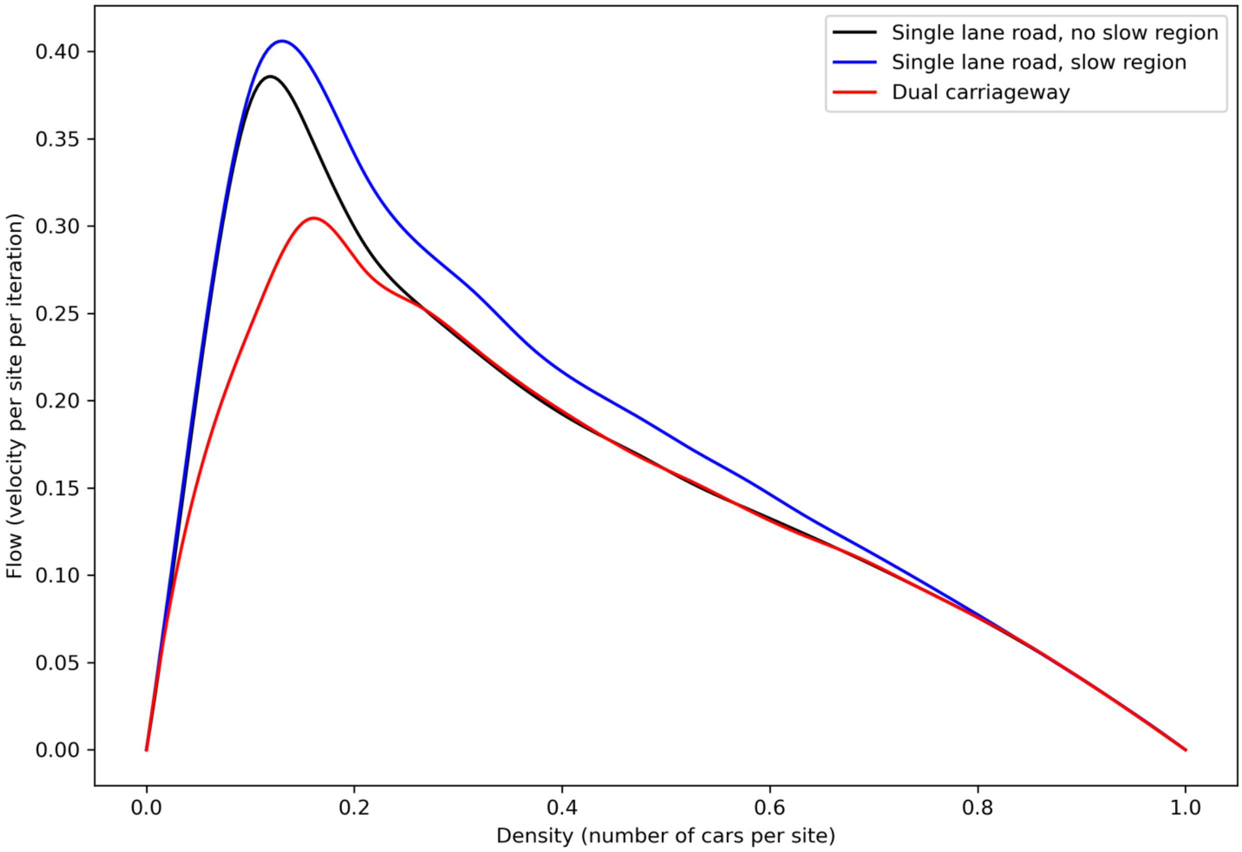

Scientific Computing Project Report – Traffic Flow

SAMUEL GABE

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0   [0000000000..........................................................................................]
1   [0000000000..........................................................................................]
2   [0000000000..........................................................................................]
3   [0000000000..........................................................................................]
4   [000000000.1.........................................................................................]
5   [000000000..1........................................................................................]
.
.
145 [5......4........4...................5......5...........5....................000.1...................]
146 [.....5.....4........4...................4......4............5...............00.1..2.................]
147 [..........5....4.........5..................4......4.............5..........0.1.1...2...............]
148 [..............4.....5........4...................5.....4..............5.....0.0..1....2.............]
149 [..................4......5........5..................4......5.............4.0.0...1.....2...........]
150 [......................4.......5........5.................4.......5.........10..1....2.....2.........]
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Figure 1: Reproducing the test case. This shows the first five and last six iterations of the model using the test case given in the project documentation. For this model, I modelled the road using a NumPy array. Where there is a car, the value of the array element is the velocity of the car; where there isn't a car, the value is -1. To produce this plot, I formatted each array, first converting it to a string, then replacing '-1' with a full stop and removing the spaces. Initially, the values of the array didn't align, due to having both one- and three-digit numbers. To fix this, I added extra spaces in each row depending on the number of digits in the iteration number. The final row here, row 150, is the same as the line given in the documentation, and I created a unit test to verify this.

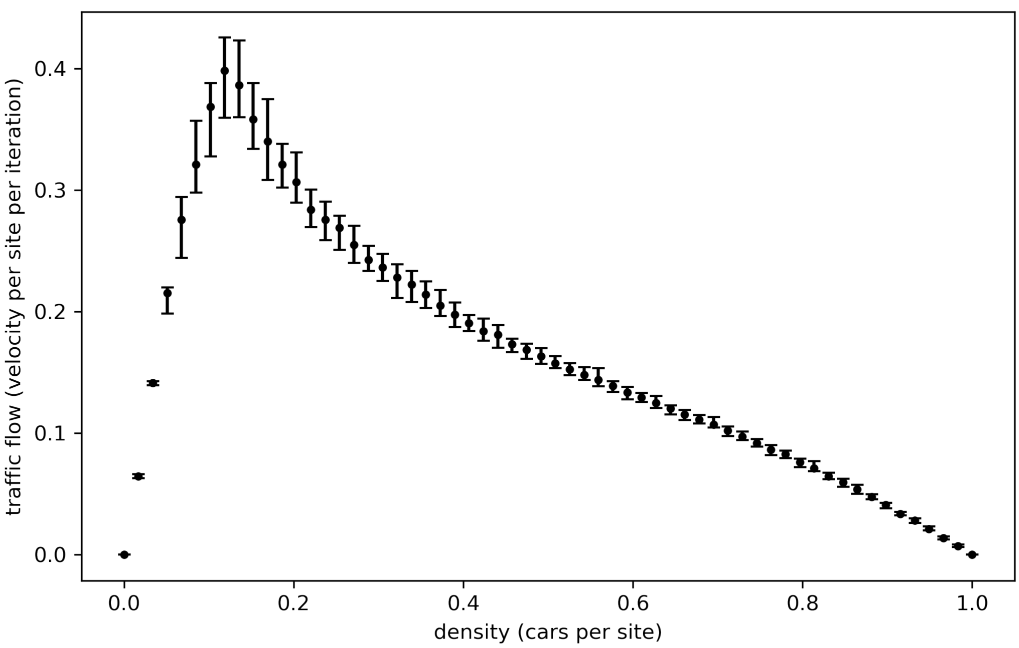

Figure 2: flow-density diagram with uncertainties. The graph has 60 points. L = 400, vmax = 5, p_slowdown = 0.6, 50 iterations for each point. The code was run for 20 different random seeds to get the errors. The points in the middle of the error bars show the mean traffic flows across all seeds. The traffic flow is calculated by finding the average velocity per site per iteration, excluding the first iteration (because cars in my program start off with maximum velocity and can slow down very quickly, which is not representative of real life). The maximum value for traffic flow was 0.40 ± 0.05 units of velocity per site per iteration, which occurred at density=0.12 cars per site. At first, the traffic flow increases, since the cars are so spread out that they do not encounter other cars and therefore do not need to brake. For this part of the graph, flow is directly proportional to the cars. However, as the number of cars increases, the traffic flow decreases, as cars need to brake more often. This decrease happens until density = 1.0, where every site is filled and therefore no cars can accelerate. This decrease is like what is seen in the reference document and in experimental data.

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0   [.......5....5.......5.....5......5..00.1......5...]
1   [4..........4....4........5.....5...200...2........]
2   [....4..........4....4.........5...300.1.....3.....]
3   [.........5........3.....4........3000..1.......3..]
4   [3...........4........4.....4....000.1...2........]
5   [....4.............5........5....400.1..2...2......]
6   [.........5...........4........4000...2..2....3...]
7   [............4.............5...000.1...1....3....3]
8   [..3..............4...........2.000..1....2.....3..]
9   [3....3...............4........100.1..1.....2......]
10  [....4....4...............4....00.1.1..1.......3...]
11  [4.......4.....5.............3.0.1.1.1..1..........]
12  [.....5......4.....4..........10..10...2.1.........]
13  [.........4......4.....4......00..0.1...1.1........]
14  [............4.......5.....5.00..0..1...1..2......]
15  [.................4.......4..10.1..1...2..1...2....]
16  [.....................4....1.00...2..2..1..1....2..]
17  [........................3.0.0.1...1..1..1...2....2]
18  [.2......................10.0..1...1..1...2....3..]
19  [....3...................00.0...1...1..1.....3...2]
20  [..3.....4...............00.0.....2...2.1.......3.]
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Figure 3: Traffic jam. Here there are some slower cars toward the right side of the road. As a car approaches the slow cars, it must brake. Then, when it reaches the front of the traffic jam, it is free to accelerate again. The traffic jam propagates backwards, which is seen in real life and in the model in the reference paper.

```
0   [5.......5.......5.......5.......5.......5.......5.......5.......5.......5.......5.......5.......5.......5...]
1   [.....5......4........5.......5.......5...1.......1...........5.....4.......4........5......4......3]
2   [..3.......5.....4........4........5....2...2......1.............4.......5.......5........5.....4...]
3   [.5...3........4......5.......4.......3..1....2......2................5......4........5........5....]
4   [5...3...3.........4.......5.......5...1...2...1.......2..................4......4........4........]
5   [..2....3...3..........5.......5....2..1....2..1........2.....................4......4........4.....]
6   [....2.....3...3...........4.......4.1..1....1..1.........2.........................5.......5......5]
7   [...4..2.....2.....3.............5...1.1...2...1...2........1..........................4.......5....]
8   [.....2..2.....2......4............30..1....2...2..1........1...............................5......4]
9   [...4...2..2......3.......4.........00...1.....2..1...2........2.................................5..]
10  [.4...2...2...3.......4.......4....00.....2.....2.1...1..........3.................................]
11  [....3...3...3....3........4.......4.00......1.....1..2..1............3.............................]
12  [......2...2...2....3..........5..0.00........2....1...2.1.............3...........................]
13  [........2...2...2......4.........20.0.1........1....1...0..1................3......................]
14  [..........3..2....3.......4....00..1..2.......1.....2.1..1.................3.......................]
15  [............2..2.....3.......3.00...1...2.......1....0...2..2...................3..................]
16  [..............1....3.....3....0.0.1...1...1.......1...0.....2..2....................3..............]
17  [...............1.......4.....40..1..2..1....2......1..0.......2..2......................4..........]
18  [.................2..........500....2..2.1.....1......1..1........2...2........................4....]
19  [...................2........000.....1..1.1.....2......2..2.......1....3.........................4..]
20  [.....................2......000.......2.1..2....1......1..1........1.......4.........................4]
21  [....5.................2.....000.......0..1...2...1......2.1........2..........5....................]
22  [.........5..............2...00.1......0....2...2..1......0..1..........3..........4................]
23  [............4............1.0.1..2.....1.....2...2.1.....1..1...........3...........4..............]
24  [.................4.........1.1..2..2.....2.....2.0..1......1..1...............4..........4.........]
25  [......................5.....1.1..1...2....1....0..1..1......2.1....................5...........5....]
26  [..........................4.0..1..1....2...1....0....2..2.....1.1.....................4..........4]
27  [....5.....................1.1..1..1....1...1..0.....1...2....1..2......................5.........]
28  [........4...................1..2.1...1.....2...20.......1...1....1...2..........................5...]
29  [.5...........5................20...1...2....1..00........1...1.....2....3.........................]
30  [......5..........4............00....1...1.....200.........2...2.....2.....3.....................]
31  [..........4..........4........00.....2...1.....00.1...........2...2.....2.....3.......................]
32  [...............5..........5...0.1.....1..1...0.1..2............3...3...2........4...................]
33  [...................4........2.0....2....1..1...0..1..1..............2...3...3..........5.............]
34  [.......................4.....1.1.....3..1..1...1...2..2.............2....3...3...........4.........]
35  [...........................5.1.1.....1..1...2.1...1...2.............2.......4...3............4......]
36  [............................1.1..2.....2..2.0...2..1...1..............2.......2....4............4..]
37  [..5.........................0..1...2.....20.0....1..1...1..............2.......2.......5..........]
38  [......4.....................0...1....2...00.0.....1...2..1.................3......2..........5.....]
39  [...........5................0.....2...1..0.10......1...1...2.................4.....3............4.]
40  [...5..........4.............0........3..20.00........1...1....2...................4....3..........]
41  [........5..........4........1........1.00.0.1........2..1....2...................4...3..........]
42  [............4..........5.....1......0.00.0..1.........2..2.....3......................3...3.....]
43  [.................5.........4...1.....0.0.1.1..1..........1....3.......4....................2....3..]
44  [.4..................4........2..1.....0.0...1..2.1..........1.......4........5...................2.....]
45  [.....4...................4.....1...2....1.1...2.1.1...........1............5.......4................3..]
46  [.4.......4...................4..1....2...0..1....1.1..2..........2.............4.......5..........]
47  [......5......4..................1..1...1.0....2.0..1..1..........2...................5.......4........]
48  [...........5......5.............1..1...10......10...1..1............3...................4.......4.....]
49  [.................5.....4.........1..1...00.....00....1..1................3...................5.....4..]
50  [.4...................5....4.......1..1..0.1....00.......2.1.................4..................4.....]
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Figure 4: Traffic flow with a slow patch in the middle. Here, L = 100 and when a car is between 0.4L and 0.6L, v_max decreases from 5 to 2. This causes traffic jams to occur around this area. These traffic jams propagate backwards as expected, moving outside the range where cars slow down. This obstacle could represent a flooded road where cars must slow down to move through the flooded section. One would expect traffic jams to lead up to the flooded section and not be restricted to the region where the flooding is taking place. One can clearly see that this happens between iterations 8 and 22.

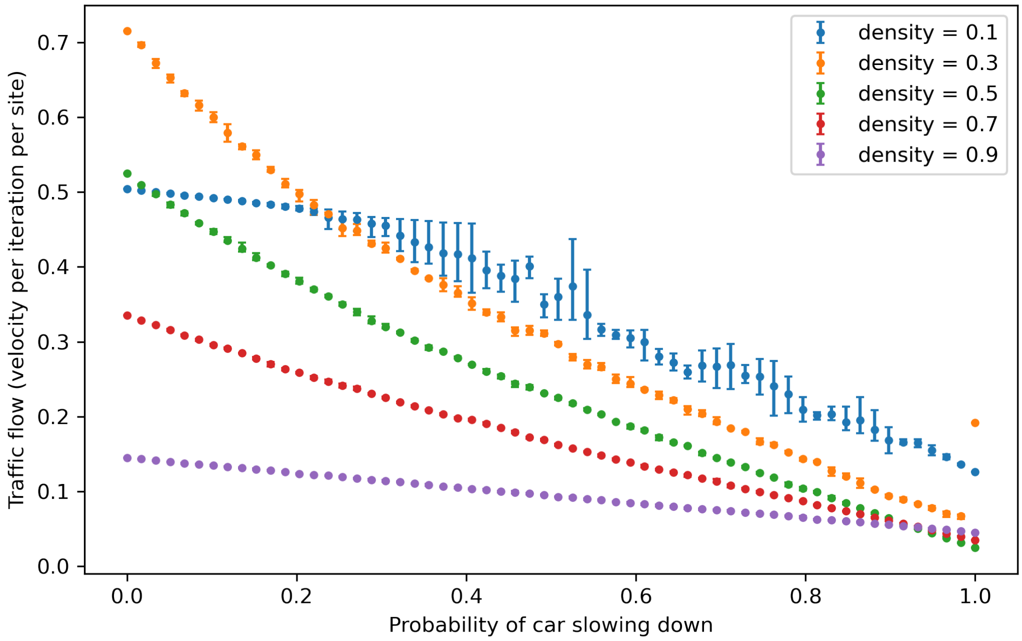

Figure 5: How traffic flow varies when the probability a car will slow down is changed. If cars have a higher probability of slowing down per iteration, this will cause traffic build-up, so traffic flow is reduced. This model could be thought of as a road with lots of bends: the more bends a road has, the more likely cars will be to slow down.

Note on point where p_slowdown = 1.0, density = 0.3: this is because the probability of a car accelerating is very low but not zero. If a car accelerates, on the next iteration it will have to brake due to the car in front. Additionally, it will almost certainly slow down due to randomization. The car has accelerated a value of 1, then decelerated a value of 2, so the car is slower. It is then very unlikely to ever speed up again. The slower car will cause other cars to slow down. However, if p_slowdown = 1, this will never happen, so cars stay at a constant velocity.

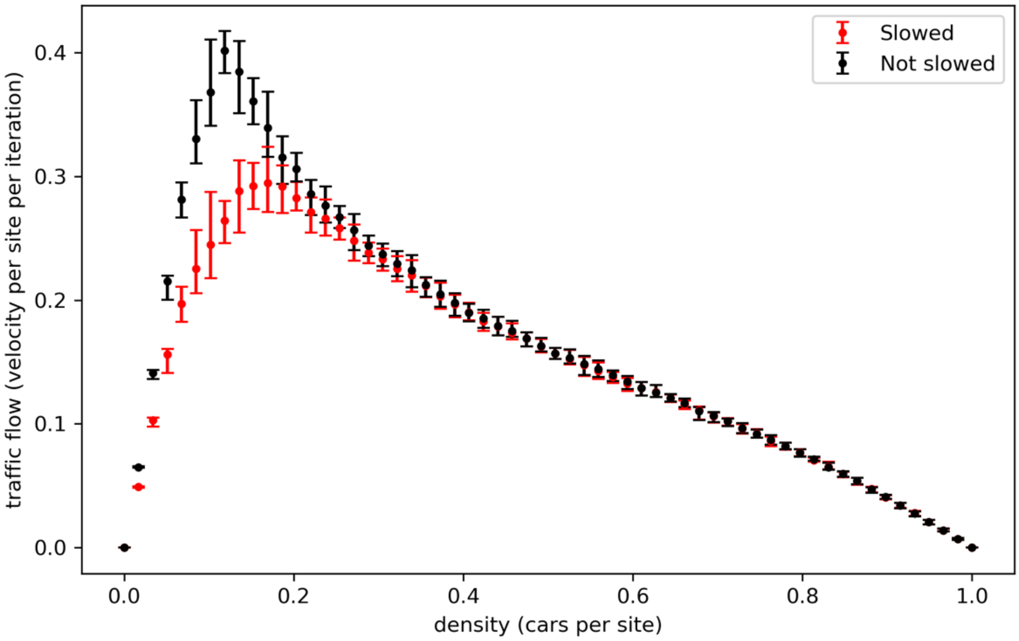

Figure 6: How the flow varies when an obstacle is added. The maximum traffic flow when slowed was 0.30 ± 0.03 units of velocity per site per iteration. This is a 25 ± 15% reduction in flow from when there is no slowing occurring (0.40 ± 0.05). Maximum traffic flow occurs at density=0.17, which is higher than the density for the maximum flow when there is no slow patch (0.12). The explanation for this is that cars will increase until the space between each car is roughly equal to the velocity of each car. Since the average velocity is slower when there is a slower region, the space between each car can be slower, therefore the density of peak traffic flow is higher.

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0   [.........5..5.......5.....5......5..20.1......5...]
    [......5...........................................]

1   [.5.........2.....5.......5.....5......1..2........]
    [...........5.........................15...........]

2   [......5.......3.......5.......5.....5...2...3.....]
    [................5....................0.....5......]

3   [...........5......4........5.......5...3...3....4.]
    [.....................5................1.........5.]

4   [...5............5......5........5.....3...3....4..]
    [...5......................5.............2.........]

5   [..5.....5............5......5........5...3....4...]
    [........5......................5...........3......]
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Figure 7: How traffic behaves when lanes are introduced. To implement lanes, I created a 2D array with two cars at each site, each car being in a different lane. All the same rules from the single lane road still hold; however, if a car needs to brake, it now has the option to move into the other lane. The car can change lane if some conditions are met. The conditions are as follows: the car will not be overtaken this iteration; there is no car in the other lane next to the current car; the car ahead in the other lane is further than the car ahead in the current lane. If the car needs to slow down and all the conditions are met, the car can now move into the other lane. In this model, cars stay in their lane until they need to slow down. This is not representative of how people drive in Europe: in real life, people will move to the outside lane if they are not actively overtaking another vehicle, and undertaking isn't allowed (in my

model, it is). However, in other parts of the world (e.g. USA), people stay in the same lane, as is the case in my model.

Note that on the first iteration, two cars move into the bottom lane as it is preferable to do so. Note also that on the first iteration, it is preferable for the left-most car in the top lane to move into the bottom lane so it can overtake the next car with velocity 2; however, it will be overtaken this iteration by the left-most car in the bottom lane, so it is forbidden from changing lanes.

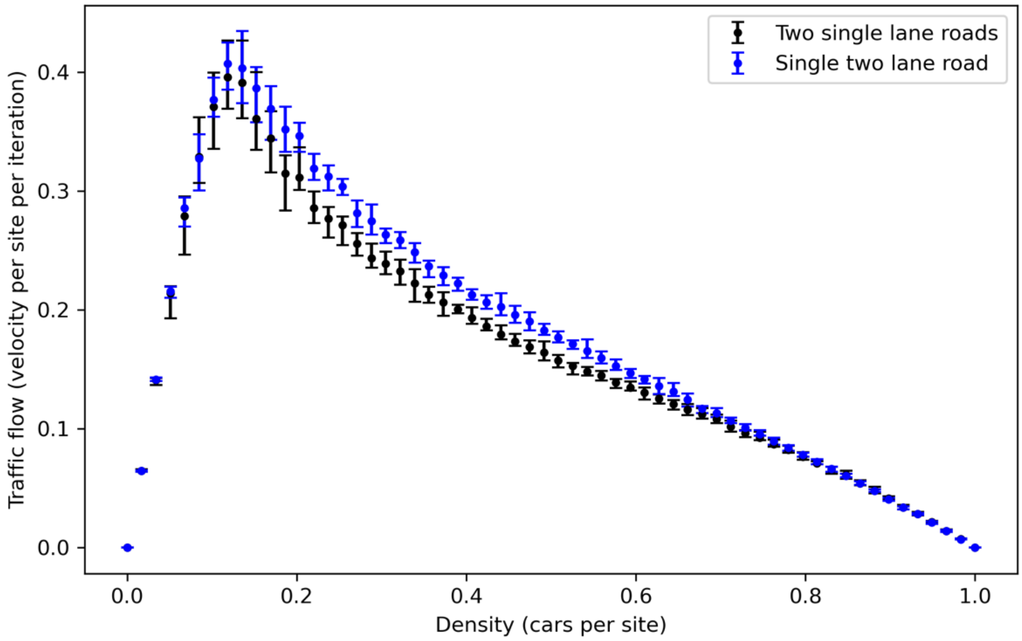

Figure 8: The traffic flow of a single two-lane road compared to two single-lane roads. The maximum traffic flow for a dual carriageway is 0.41 ± 0.02 units of velocity per site per iteration. On average, traffic flow is higher by 6.3% for a single two-lane road than two single-lane roads.