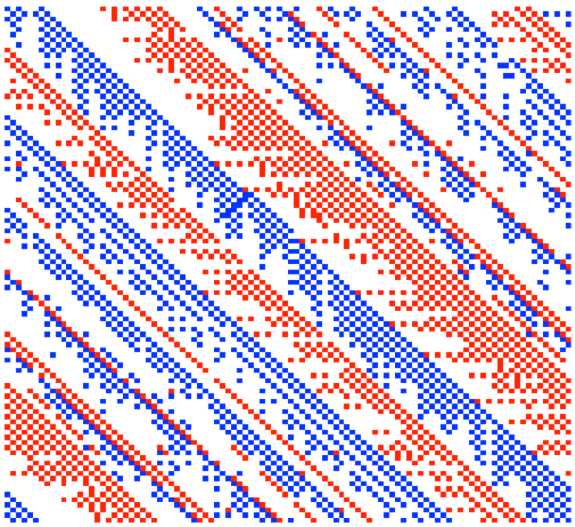
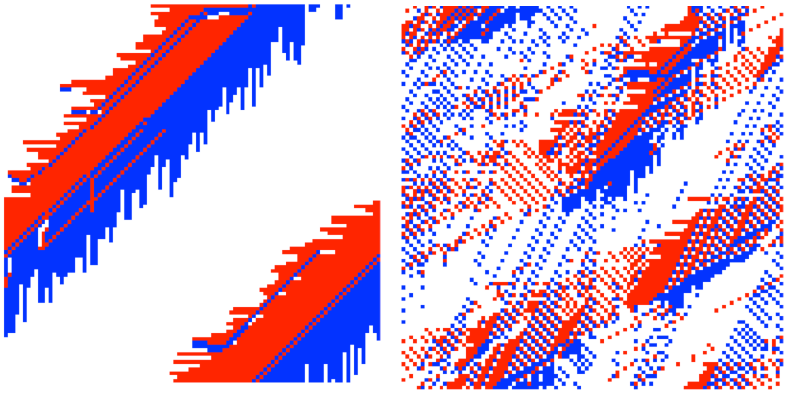
(1) For what values of p, the density of the grid, did you find free flowing traffic and traffic jams? Did you find any cases of a mixture of jams and free flowing traffic?

In my simulation, I found that when p >= 0.45, the traffic jams come very quickly, examples are p = 0.45 and p = 0.7; for p <= 0.3, the traffic jams do not happen at least within 2000 iterations. The mixture phase happens when 0.3 < p < 0.45. Typically in my simulations, I examined p = 0.42 and p = 0.4 many times to confirm my idea.



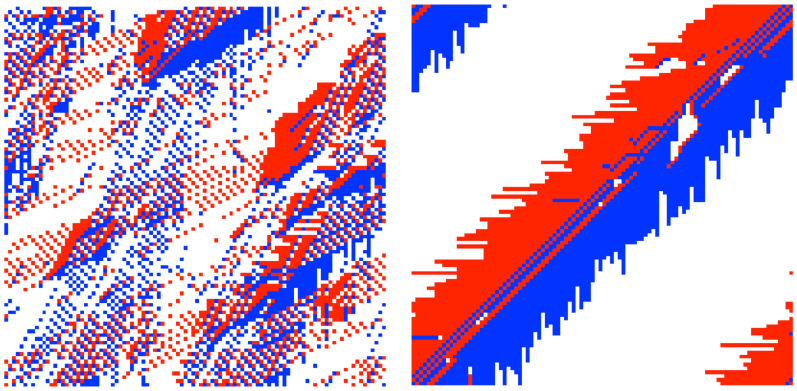
```
> bml.sim(100, 100, 0.3)
[1] "So far so good! No deadlock for 2000 iterations!"
```

Figure 1. *p = 0.3, 100*100 size*. No deadlocks within 2000 iterations. Single phase without any partial traffic observed. The car flows pretty smoothly.



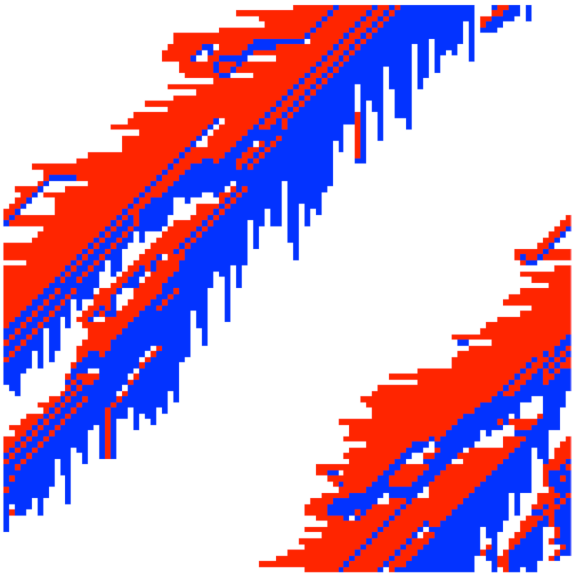
```
> bml.sim(100, 100, 0.4)
Deadlock at 523th iteration
> bml.sim(100, 100, 0.4)
Deadlock at 1376th iteration
> bml.sim(100, 100, 0.4)
[1] "So far so good! No deadlock for 2000 iterations!"
```

Figure 2. *p = 0.4, 100*100 size*. Deadlocks happen after 523 and 1376 iterations for the first two simulations, but no deadlocks happen for the third simulation within 2000 iterations. Pictures (from left to right) is from the second case and the third case. Even for the no deadlock case, we can clearly see some partial traffic in the picture, which is a mixture of both phases.



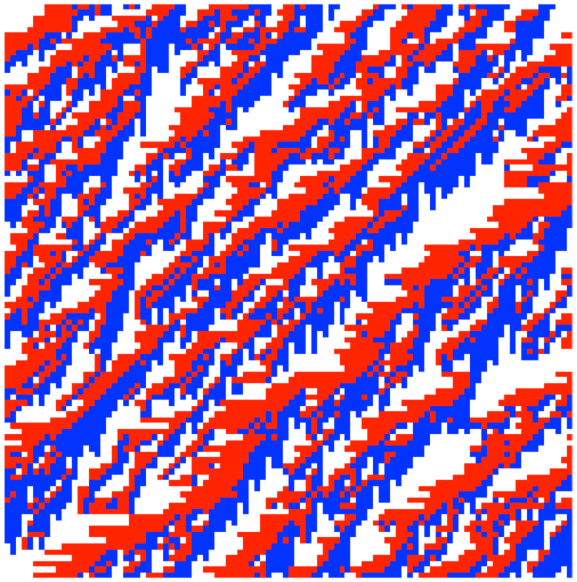
```
> bml.sim(100, 100, 0.42)
[1] "So far so good! No deadlock for 2000 iterations!"
> bml.sim(100, 100, 0.42)
[1] "So far so good! No deadlock for 2000 iterations!"
> bml.sim(100, 100, 0.42)
Deadlock at 1503th iteration
> bml.sim(100, 100, 0.42)
Deadlock at 399th iteration
```

Figure 3. *p = 0.42, 100*100 size*. No deadlock within 2000 iterations for two simulations, but deadlock happens for the third and fourth case. Pictures (from left to right) is from the first case and the third case. Even for the no deadlock case, we can clearly see some partial traffic in the picture, which is a mixture of both phases.



```
> bml.sim(100, 100, 0.45)
Deadlock at 379th iteration
> bml.sim(100, 100, 0.45)
Deadlock at 714th iteration
> bml.sim(100, 100, 0.45)
Deadlock at 584th iteration
> bml.sim(100, 100, 0.45)
Deadlock at 401th iteration
```

Figure 4. *p = 0.45, 100*100 size*. Deadlock happens after 379, 714, 584 and 401 iterations. Picture is from the second case.



```
> bml.sim(100, 100, 0.7)
Deadlock at 173th iteration
```

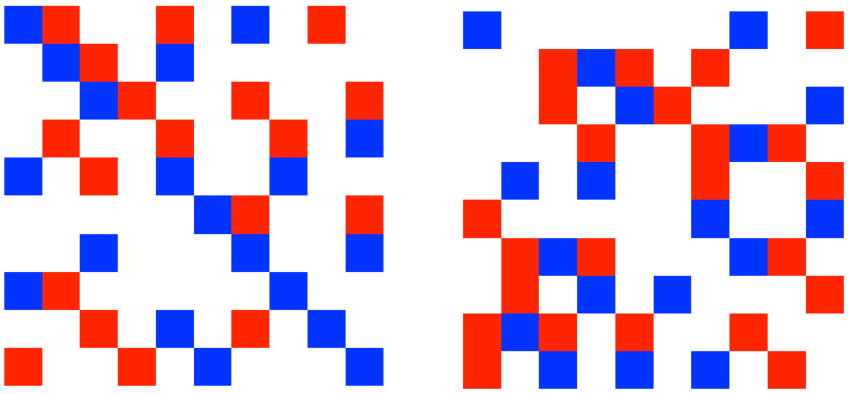
Figure 5. *p = 0.7, 100*100 size*. Deadlock happens after 173 iterations. Picture is from the first case. This phase is a single traffic phase. Very obvious to see.

(2) How many simulation steps did you need to run before observing this behavior?

The iterations are recorded and shown in each figure listed above. I chose the maximum iterations to be 2000 for the sake of computation ability on my laptop.

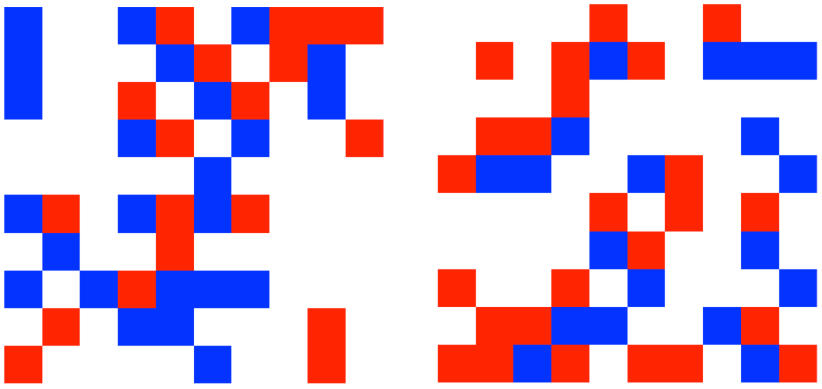
(3) Does the transition depend on the size or shape of the grid?

The answer is yes. I used different size of grid, with same p, smaller size has a better chance to avoid traffic within 2000 iterations. The example is when p = 0.45. I used 10*10, 30*30 and even 50*50, and at last 100*100. When the size gets larger, the traffic is easier to appear within 2000 iterations. As illustrated below.



```
> bml.sim(10, 10, 0.4)
[1] "So far so good! No deadlock for 2000 iterations!"
> bml.sim(10, 10, 0.4)
[1] "So far so good! No deadlock for 2000 iterations!"
```

Figure 6. *p = 0.4, 10*10 size*. No deadlocks happen within 2000 iterations. Compare this with Figure 2 with size 100*100.



```
> bml.sim(10, 10, 0.45)
[1] "So far so good! No deadlock for 2000 iterations!"
> bml.sim(10, 10, 0.45)
[1] "So far so good! No deadlock for 2000 iterations!"
> bml.sim(10, 10, 0.45)
[1] "So far so good! No deadlock for 2000 iterations!"
```

Figure 7. *p = 0.45, 10*10 size*. No deadlocks happen in 2000 iterations for 3 simulations. Compare this with Figure 4 with size 100*100. This is a more obvious contrast since in Figure 4, all 4 simulations result in traffic phase.