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Final Report and Software A3
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(Please note the section regarding experiments performed and results begin on page 3 and all other sections remain unchanged from the previous deliverable)

Simulation Software Motivation and Overview

The goal of my computer program model is to simulate the traffic intersection of 14th Street and Atlantic Drive. Specifically, I am interested in the wait times for vehicles in each of the four lanes of 14th Street and the two lanes of Atlantic Dr at this intersection. Currently, a vehicle can experience a lot of difficulty turning onto 14th Street from Atlantic Drive due to a limited sight distance, quick moving cars, and no traffic light. The end goal of my simulation is to determine the effect on the wait times for all lanes of traffic at this intersection with the introduction of a traffic light.

The overall structure of my simulation code involves modeling six conceptual resources wherein arrival actions happen on each of these resources. Rather than being based on the number of arrival events as seen in the airport simulation, my simulation runs for a set time duration. As long as the current time in the simulation is less than the set duration time for an experiment, arrivals continue to be scheduled.

The arrival action invocations are recursive in that once an arrival event occurs, that arrival event schedules another arrival action. I have implemented a function that randomly selects which resource is to receive a new arrival. Since the volume of traffic is much greater for 14th Street in both directions compared to Atlantic Drive, I have weighed the chance of an arrival event on 14th Street much higher than for an arrival event on Atlantic Drive (an arrival action being scheduled on any 14th Street lane has a 22.22% probability whereas an Atlantic Drive lane has a 4.71% probability).

The actual time for an arrival event to then be scheduled in the future event list is based on the same exponential distribution as found in the airport simulation provided to class. However, I have configured the mean arrival time to be shorter for the 14th Street lanes compared to the Atlantic Drive lanes to account for the higher volume of traffic on those lanes.

My event list data structure is a modified linked list wherein events are added in order according to the timestamp, but the event removed from the event list is always the event with the lowest timestamp. Please refer to *future_event_list.py* for my future event list implementation. Like the airport simulation program provided to the class, each event in my future event list class has a

timestamp, an enum for the event type, a callback function, and a reference to the next event in the future event list. Note, to provide a simpler interface with the future event list, I have abstracted my future event list as five methods of the *SimulationEngine* class in the *engine.py* file. The *SimulationEngine* class also has a method to get the current *Now* time.

A key component to the veracity of this simulation model concerns the notion of vehicles approaching the 14th Street/Atlantic Drive intersection and what different turns are possible, as well as the blocking effects these various turns can have on other vehicles wishing to cross the intersection. To be able to experiment on the addition of a traffic light at this intersection, I created 28 activities. Half of the 28 activities account for possible turns made at the intersection with a traffic light, and the other half of the 28 activities account for possible turns made at the intersection without the traffic light. Please refer to *Figure 1* in the Appendix below to help understand the different activities that will be talked about in brief.

Please note I have simplified my conceptual model compared to what I produced for the A1 milestone. I now realize how many activities can be involved in a simulation, and to account for the resource queues currently used (these are denoted by elongated hexagonal shapes in *Figure 1*) required a lot of work. So, to account for the various turn options in the intersection referred to in *Figure 1*, each 14th Street lane has two options, either straight and left or straight and right, depending on if the lane is closest to the median or to the sidewalk, respectively.

I have modeled the intersection itself of 14th and Atlantic by having a north, south, east, and west zone. At any time, any of the zones can be occupied, and therefore be set to *False*. If a car is making a turn that crosses a given zone, and the zone is already occupied (set to *False*), then the car will not be able to schedule the event to make the turn and will have to wait until that zone is clear. Once a vehicle finishes an event that would cause the zone to be occupied, the event then checks the various possible waiting lanes dependent on the zone just occupied (represented as queues in my simulation), to see if any vehicle is waiting. If a car is found to be waiting, the event then invokes the event to enable the turn and remove a vehicle from the respective queue.

Since 14th Street is the main thoroughfare, and since Atlantic Drive has stop signs on both north and south lanes, the vehicles on Atlantic Drive always will have to verify the intersection is free to cross.

With the presence of a traffic light, I assume cars will not turn right on red. Also, since it is likely that cars will accumulate in a queue, upon completion of an event, the event will check if other cars in the same resource are waiting, and schedule those waiting vehicles to make a turn out of the resource.

Verification and Validation

Regarding verification of the model, there were several bugs in my simulation that I worked out by using print statements and using the Python debugger, pdb. There was a problem that would occur wherein after a car passed through the intersection on the right of way and then check if vehicles were waiting. It would invoke the event to enable the vehicle to turn, but since it would always do so, the program would crash since the future event list would schedule an activity for a car that did not exist in the respective queue. To resolve this, I check at the beginning of turn activities if the queue has at least one vehicle. If not, then I break out of the event.

Regarding validation, I have run the simulation with different expected times of arrival for the 14th St lanes as well as the Atlantic Dr lanes. The shorter expected time of arrival increased the flow of traffic for a given set of lanes. Also, with the absence of a stop light, cars on Atlantic Drive have to on average wait longer in general than cars going along 14th Street.

When introducing a stop light, the average waiting time for cars on 14th Street lanes decreases as the red light time for the 14th Street lanes decreases in comparison to the green light time. This would suggest the logic for the stop light is able to approximate an intersection with a traffic light.

Experiments and Results

The main focus of my experiments were to evaluate the average wait time per car for each road segment at the intersection of 14 Street and Atlantic Drive. The variable parameters in the experiments were:

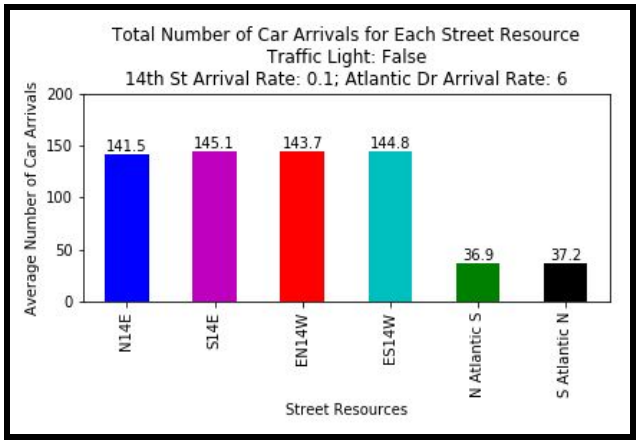
1) Presence or absence of a traffic light;
2) If traffic light was present, the time duration for the green and red lights on 14th Street (and as a consequence the time duration for the green and red lights on Atlantic Drive).

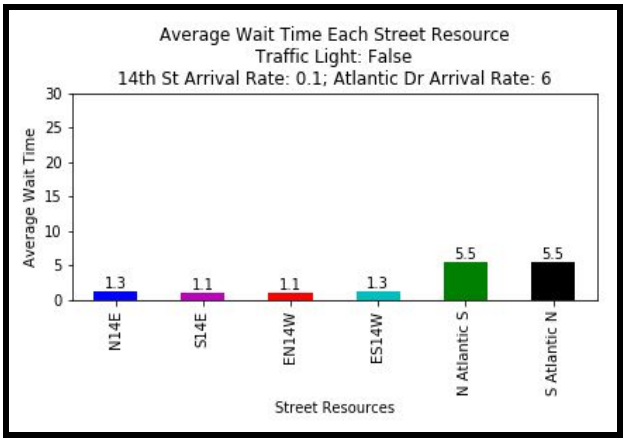
Since I used the exponential random variable to model the arrival rate of cars, I wanted to perform numerous runs for each experiment. As such, I performed 100 iterations for each experiment variant. Ideally, I should have determined the least number of iterations for a given experiment necessary to be significant for this study, but I did not perform that analysis.

As mentioned in the first section of this report, my simulation runs for some configured duration of time. Although it is possible to set whatever simulation duration as a command line argument, I decided to not experiment on this variable and so all experiments run with a time duration of 500.

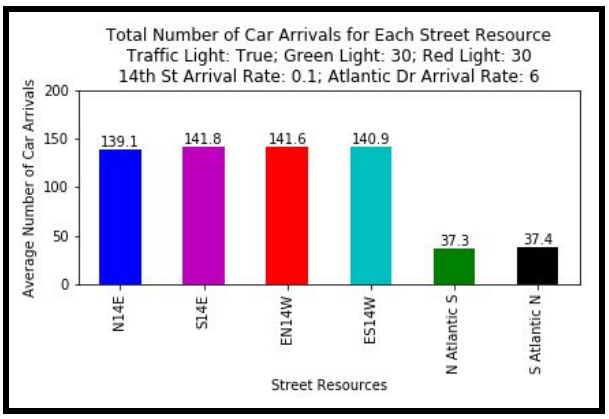
A strong assumption I made about the traffic intersection that I never did test against actual observations was the typical arrival rate for the different road segments during heavy traffic volume. The rate of arrival examined for the 14th Street roads was 0.1 while the rate of arrival for Atlantic Drive was 6. The main traffic volume is across 14th Street based on my daily experiences at the intersection under investigation, so I assumed the proportion of cars on 14th Street compared to Atlantic Drive in my experiments are somewhat accurate.

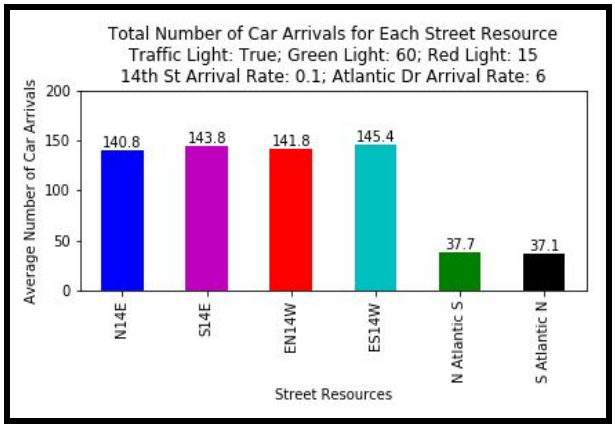
The following figures show the intersection under investigation without a traffic light. Please note that the figure on the right calculates the average wait time by dividing the total wait time for a given segment of road by the number of cars that arrived at and exited the road segment. This calculation is used in all future figures shown for average wait time.



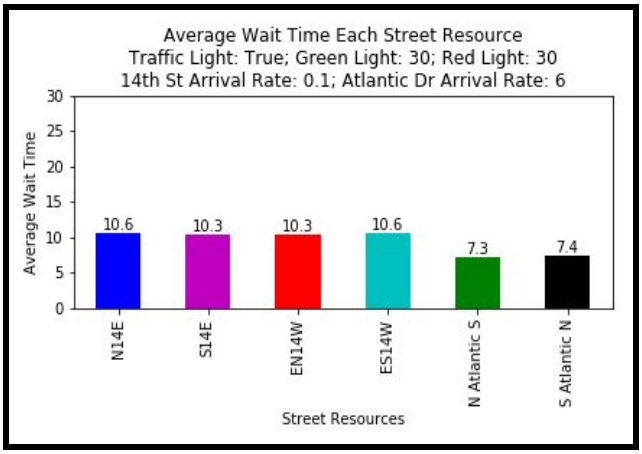


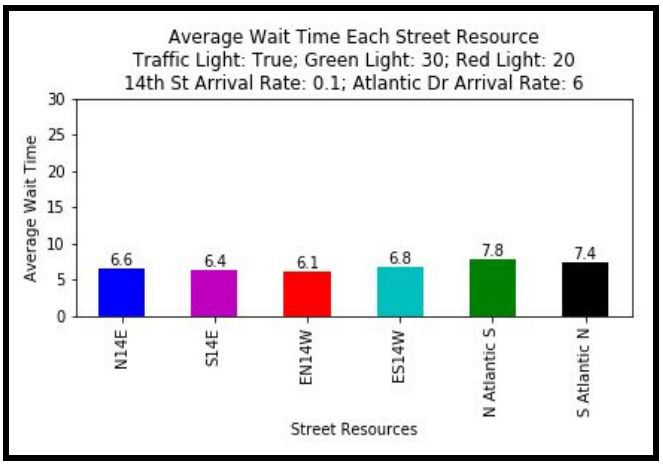
I found that the average number of car arrivals for 100 runs of an experiment hardly varied when the arrival rates for 14th Street and Atlantic Drive were the same as in the figures above. This was true even with the addition of a traffic light and changing the duration of the green or red lights. The figures below show similar average number of car arrivals even with a traffic light present and the green and red lights varying significantly.

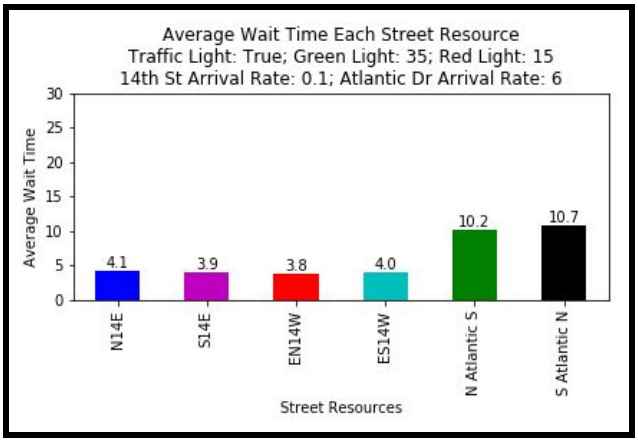


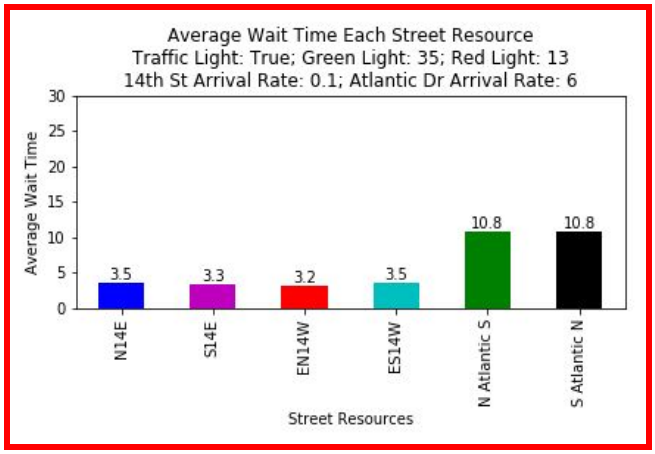


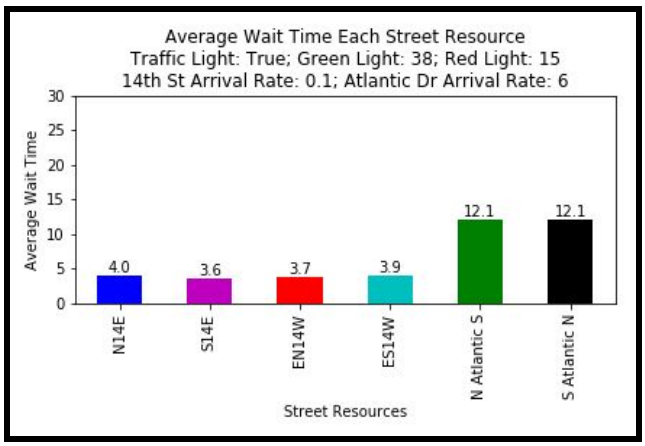
As such, the following figures will only be of the average wait time per car since these statistics did vary. All of the experiment results below include the presence of a traffic light. Conclusions based on the figures are stated below the figures.

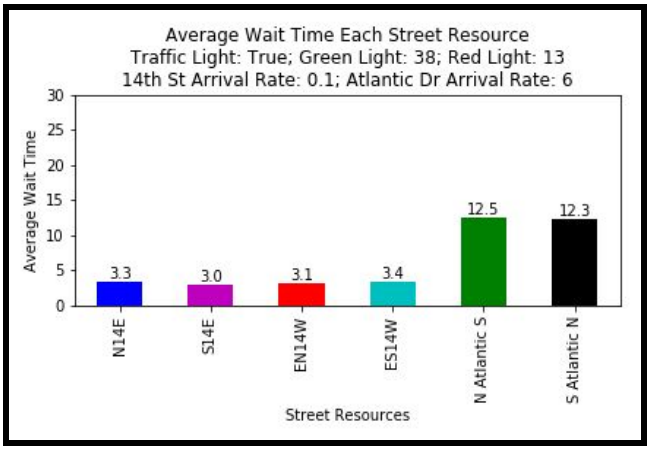


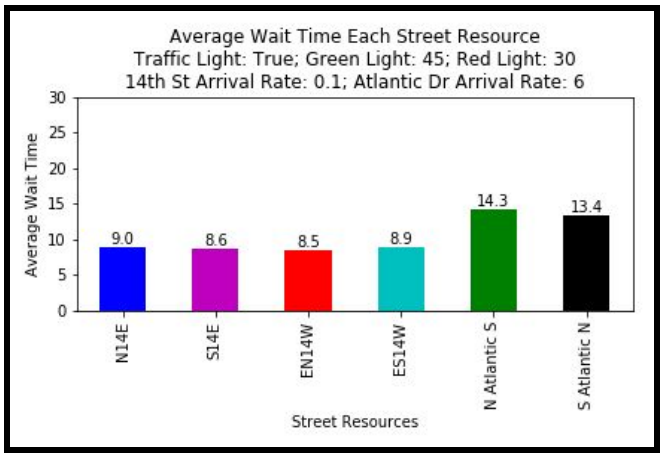


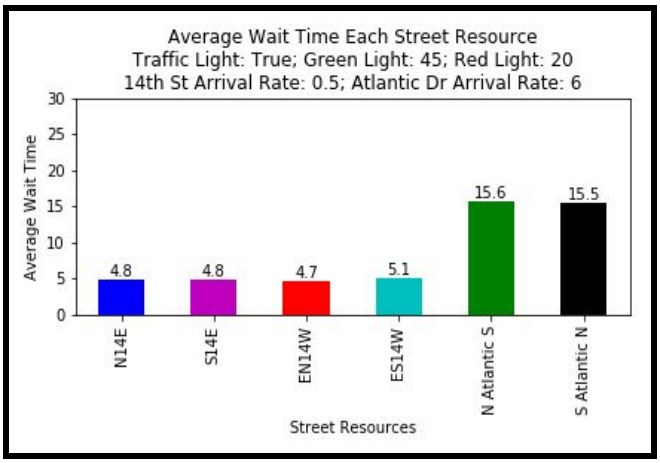


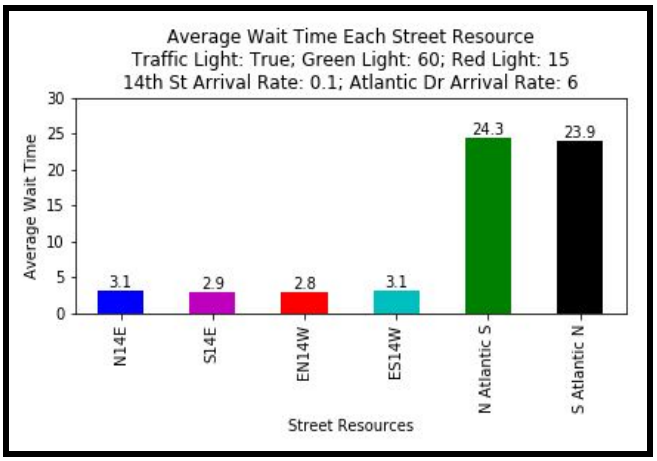


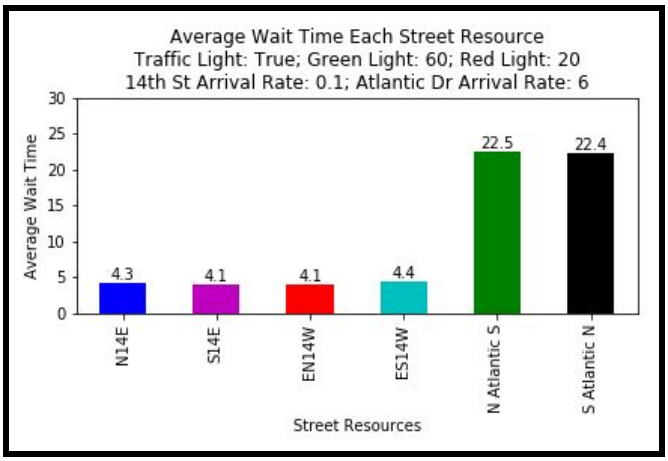




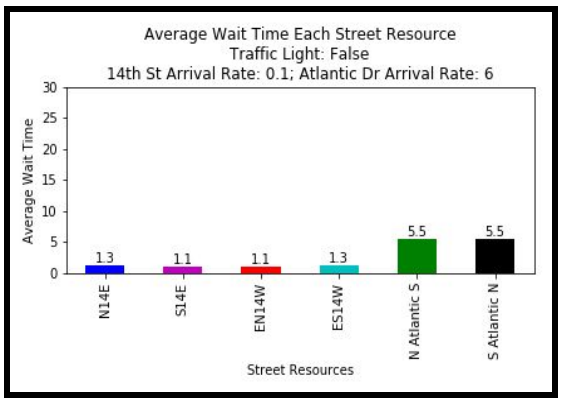








I realize the above figures are a lot to show at once, and ideally, some optimization problem could most likely determine in absolute terms the minimal average wait time for both 14th Street and Atlantic Drive. Nevertheless, the optimal parameters to me appear to be when the green light on 14th Street (and thus the red light on Atlantic Drive), is set to 35 and the red light duration on 14th Street is set to 13 (note this figure has a red border). Part of my decision for that as the optimal setting is a consequence of the significantly higher volume of traffic on 14th Street compared to Atlantic Drive. In general, I claim it would be okay for a few cars to wait compared to making several more cars have to wait a similar amount.

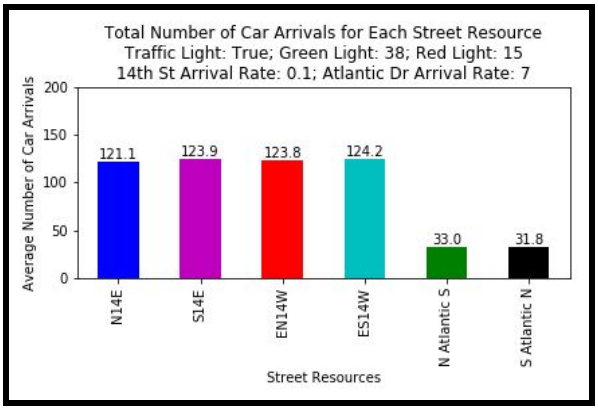


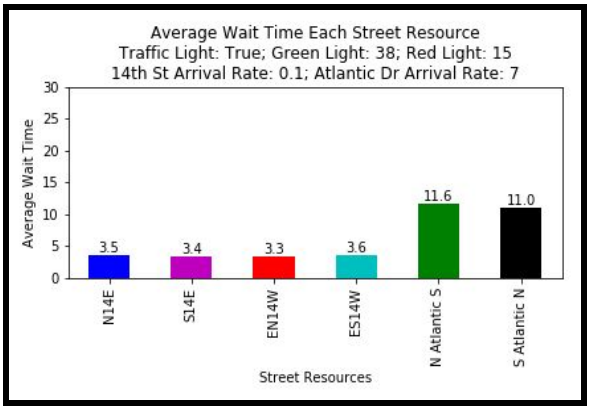
Recall the statistics when no traffic light was present (see figure at right). Although the average wait time is much lower when no traffic light is present, one factor

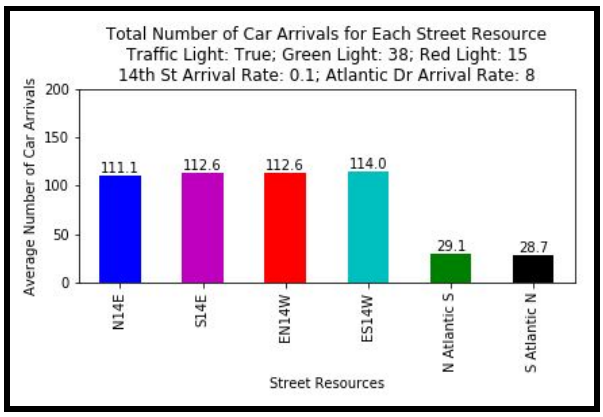
I did not take into account in my model, which I am interested in learning more about, would be some sort of safety index based on the various parameters tested. Specifically, crossing or turning onto 14th Street from Atlantic Drive can be a possibly dangerous experience. Since 14th Street is a four-lane road, there can be cars on this segment of road that have a tendency to accelerate rapidly or be moving at an already high velocity. A traffic light exists fairly close to this intersection of investigation, at 14th Street and State Street, which can cause cars to form a queue. As such, the line-up of cars traveling westbound on 14th Street can make it very difficult for a driver on Atlantic Drive attempting to cross or turn left onto 14th Street from north of the intersection to see if cars are heading eastbound on 14th Street.

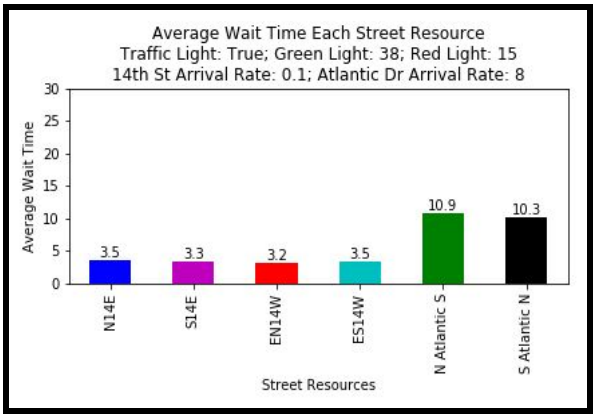
Although the average wait time for the cars would increase for all road segments with the addition of a traffic light at 14th Street and Atlantic Drive, I think forcing cars to slow down or stop at this intersection would make it safer for cars on Atlantic Drive to turn onto 14th Street. Additionally, it would make it much safer for pedestrians to cross 14th Street at Atlantic Drive.

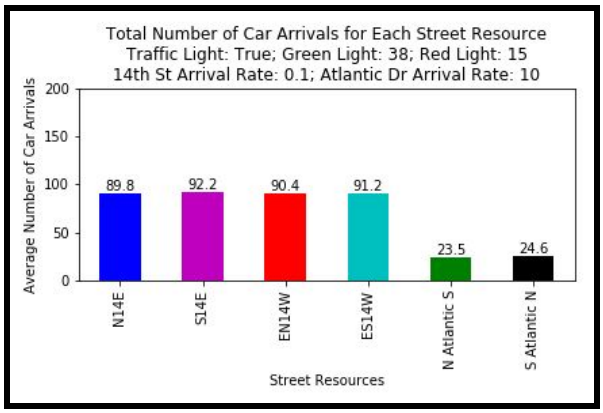
The results shown above do seem somewhat consistent with what I would expect. However, a surprise to me did show-up when I changed the rate of arrival on Atlantic Dr from 6 to a higher value like 7, 8, and 10. I would have thought that the number of cars arriving onto 14th Street would remain the same, but the average number of arrivals over 100 iterations of each experiment showed a decrease in the number of arrivals on 14th Street when the arrival rate on Atlantic Drive increased. I suppose this is a side effect of the Future Event List processing events in sequential order and there being some delaying effect for how long it takes the events associated with Atlantic Drive to be processed compared to events associated with 14th Street. Please see the following figures that show this phenomena.

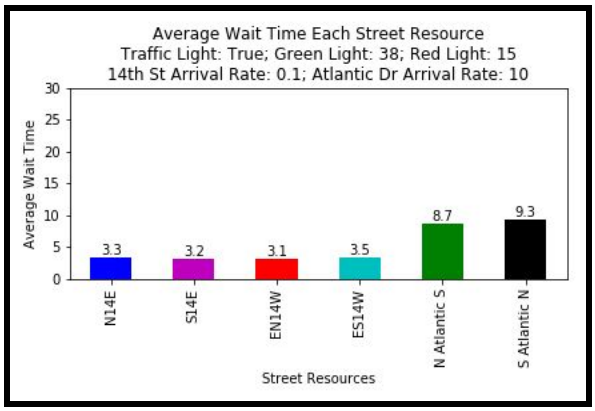












In conclusion, I think developing this simulation has been an interesting experience and demonstrates how much work goes into determining some subset of total behaviors for a given system. I think some odd behavior (like what was just mentioned regarding lower number of car arrivals on 14th Street as the arrival rate on Atlantic Drive increased) could be difficult to debug due to how many activities I developed to do this simulation. If I could determine a way to reduce the number of activities, I would reduce the complexity of the software and more likely be able to more fine-tune the correctness of the simulation regarding model validation.

I did perform more experiments than what have been presented above. For all graphs and experiments, see the *ExperimentResults* and *Graphs* folders in my submission. The bash script to perform the 100 iterations of each experiment is found in *experiments.sh*. The python script to read the simulation data, process the data, and create the figures above is found in *experiment_analysis.py*. Finally, I updated the *intersection_simulation.py* code to write the output of each simulation to a csv file for data processing. All other software and documentation remains the same from my previous submission.

Appendix

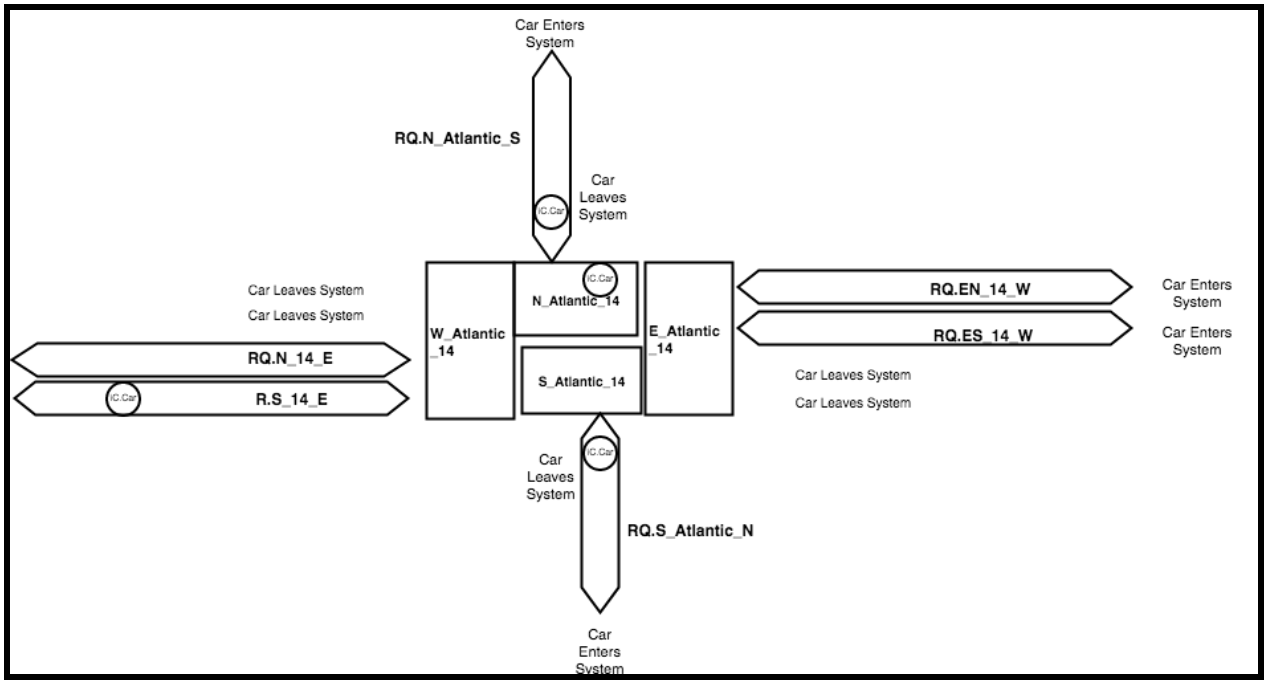


Figure 1: Conceptual Model

Entities

Consumer Class: Car
Represent cars traveling through this system.

Resource Unary: N_Atlantic_14	
Represents space of intersection between Atlantic Dr and 14 Street	
Attributes	**Description**
N_Atlantic_14_Free	Boolean; true if no car on N Atlantic Dr is using intersection making turn

Resource Unary: S_Atlantic_14	
Represents space of intersection between Atlantic Dr and 14 Street	
Attributes	**Description**
S_Atlantic_14_Free	Boolean; true if no car on S Atlantic Dr is using intersection making turn

Resource Unary: W_Atlantic_14	
Represents western part of 14/Atlantic Dr intersection, for Atlantic Dr traffic movement	
Attributes	**Description**
W_Atlantic_14_Free	Boolean; true if no car on Atlantic Dr is using this area making turn

Resource Unary: E_Atlantic_14	
Represents eastern part of 14/Atlantic Dr intersection, for Atlantic Dr traffic movement	
Attributes	**Description**
E_Atlantic_14_Free	Boolean; true if no car on Atlantic Dr is using this area making turn

Resource Queue Unary: N_14_E	
Represents cars traveling east along northern lane of 14 Street between State St and Atlantic Dr	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Resource Queue Unary: S_14_E	
Represents cars traveling east along southern lane of 14 Street between State St and Atlantic Dr	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Resource Queue Unary: N_Atlantic_S	
Represents cars traveling south along Atlantic Dr north of 14th Street	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Resource Queue Unary: S_Atlantic_N	
Represents cars traveling north along Atlantic Dr south of 14th Street	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
size	Number of cars in this segment

Resource Queue Unary: S_14_N	
Represents cars traveling north along Atlantic Dr south of 14th Street	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Resource Queue Unary: EN_14_W	
Represents cars traveling west along northern lane of 14th St east of Atlantic Dr	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Resource Queue Unary: ES_14_W	
Represents cars traveling west along southern lane of 14th St east of Atlantic Dr	
Attributes	**Description**
IsEmpty	Boolean value; false if any cars on this segment
Size	Number of cars in this segment

Activities

Activity:RQ. S_Atlantic_N Turn Left	
Models a car turning left from RQ.S_Atlantic_N onto RQ.S_14_W	
Precondition	(TurnDirection == LEFT) AND (N_Atlantic_14_Free) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.S_Atlantic_N.NumberCars -= 1; RQ.S_14_W.NumberCars += 1; Atlantic_14_Free = TRUE

Activity: RQ.S_Atlantic_N Go Across	
Models a car going north from S_Atlantic_N across 14th St and out of SUI	
Precondition	(TurnDirection == STRAIGHT) AND (N_Atlantic_14_Free) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	(S_Atlantic_14_Free = FALSE) AND (N_Atlantic_14_Free = FALSE)
Duration	GoAcross
Terminating Event	RQ.S_Atlantic_N.NumberCars -= 1; S_Atlantic_14_Free = TRUE; N_Atlantic_14_Free = TRUE

Activity: RQ.S_Atlantic_N Turn Right	
Models a car turning right from RQ.S_Atlantic_N out of SUI	
Precondition	(TurnDirection == RIGHT) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.S_Atlantic_N.NumberCars -= 1; S_Atlantic_14_Free = TRUE

Activity: RQ.N_Atlantic_S Turn Left	
Models a car turning left from RQ.N_Atlantic_S out of SUI	
Precondition	(TurnDirection == LEFT) AND (N_Atlantic_14_Free) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE; S_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; N_Atlantic_14_Free = TRUE; S_Atlantic_14_Free = TRUE

Activity: RQ.N_Atlantic_S Go Across	
Models a car going south on Atlantic Dr across 14th St and out of SUI	
Precondition	(TurnDirection == STRAIGHT) AND (N_Atlantic_14_Free) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE; S_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; N_Atlantic_14_Free = TRUE; S_Atlantic_14_Free = TRUE

Activity: RQ.N_Atlantic_S Turn Right	
Models a car turning right onto 14th St from Atlantic Dr north of intersection	
Precondition	(TurnDirection == RIGHT) AND (N_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; N_Atlantic_14_Free = TRUE

Activity: RQ.ES_14_W Turn Left	
Models a car turning left from 14th St onto Atlantic Dr and out of SUI	
Precondition	(TurnDirection == LEFT) AND (S_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.ES_14_W.NumberCars -= 1; S_Atlantic_14_Free = TRUE

Activity: RQ.ES_14_W Go Across	
Models a car continuing west on 14th St in south lane across and past Atlantic Dr	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirection == RIGHT) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.ES_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE

Activity: RQ.EN_14_W Turn Right	
Models a car heading west on 14th St in north lane turning right onto Atlantic Dr	
Precondition	(TurnDirection == RIGHT) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.EN_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE

Activity: RQ.EN_14_W Go Across	
Models a car continuing west on 14th St in north lane across and past Atlantic Dr	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirction == LEFT) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.EN_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE

Activity: RQ.N_14_E Turn Left	
Models a car heading east on 14 St in northern lane taking left onto Atlantic Dr	
Precondition	(TurnDirection = LEFT) AND (N_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.N_14_E.NumberCars -= 1; N_Atlantic_14_Free = TRUE

Activity: RQ.N_14_E Go Across	
Models a car continuing east on 14 St in northern lane through Atlantic Dr and 14th Street intersection	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirection == RIGHT) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.N_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE

Activity: RQ.S_14_E Go Across	
Models a car continuing east on 14 St in southern lane through Atlantic Dr and 14th Street intersection	
Precondition	(TurnDirection = STRAIGHT) OR (TurnDirection = LEFT) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	R.S_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE

Activity: RQ.S_14_E Turn Right	
Models a car heading east on 14 St in southern lane, turning right onto Atlantic Dr	
Precondition	(TurnDirection = RIGHT)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	R.S_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE

Activity:_14_light_turns_green	
Models traffic light turning red (Traffic_Light_Green becomes false)	
Causal	Immediately scheduled with _14_light_turns_red
Initiating Event	
Duration	GreenLightDuration
Terminating Event	_14LightGreen = TRUE and _AtlanticLightGreen = FALSE and check for cars in queue on 14 st and schedules turn events for waiting cars

Activity: _14_light_turns_red	
Models traffic light turning green (Traffic_Light_Green becomes true)	
Causal	Immediately scheduled with _14_light_turns_green
Initiating Event	
Duration	RedLightDuration
Terminating Event	_14LightGreen = FALSE and _AtlanticLightGreen = TRUE and check for cars in queue on Atlantic Dr and schedules turn events for waiting cars

Activity: RQ.N_14_E_Turn_Left Traffic Light	
Models a car heading east on 14 St in northern lane taking left onto Atlantic Dr through traffic light	
Precondition	(TurnDirection = LEFT) AND (N_Atlantic_14_Free) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.N_14_E.NumberCars -= 1; N_Atlantic_14_Free = TRUE; If !(RQ.N_14_E.isEmpty): schedule another turn event for this lane.

Activity: RQ.N_14_E Go Across Traffic Light	
Models a car continuing east on 14 St in northern lane through Atlantic Dr and 14th Street intersection	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirection == RIGHT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.N_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE; If !(RQ.N_14_E.isEmpty): schedule another turn event for this lane.

Activity: RQ.S_14_E Go Across Traffic Light	
Models a car continuing east on 14 St in southern lane through Atlantic Dr and 14th Street intersection	
Precondition	(TurnDirection = STRAIGHT) OR (TurnDirection = LEFT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	R.S_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE; If !(RQ.S_14_E.isEmpty): schedule another turn event for this lane.

Activity: RQ.S_14_E Turn Right Traffic Light	
Models a car heading east on 14 St in southern lane, turning right onto Atlantic Dr	
Precondition	(TurnDirection = RIGHT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	R.S_14_E.NumberCars -= 1; S_Atlantic_14_Free = TRUE; If !(RQ.S_14_E.isEmpty): schedule another turn event for this lane.

Activity: RQ.EN_14_W Turn Right Traffic Light	
Models a car heading west on 14th St in north lane turning right onto Atlantic Dr	
Precondition	(TurnDirection == RIGHT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.EN_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE; If !(RQ.EN_14_W.isEmpty): schedule another turn event for this lane.

Activity: RQ.EN_14_W Go Across Traffic Light	
Models a car continuing west on 14th St in north lane across and past Atlantic Dr	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirection == LEFT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.EN_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE; If !(RQ.EN_14_W.isEmpty): schedule another turn event for this lane.

Activity: RQ.ES_14_W Turn Left Traffic Light	
Models a car turning left from 14th St onto Atlantic Dr and out of SUI	
Precondition	(TurnDirection == LEFT) AND (S_Atlantic_14_Free) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	S_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.ES_14_W.NumberCars -= 1; S_Atlantic_14_Free = TRUE; If !(RQ.ES_14_W.isEmpty): schedule another turn event for this lane.

Activity: RQ.ES_14_W Go Across Traffic Light	
Models a car continuing west on 14th St in south lane across and past Atlantic Dr	
Precondition	(TurnDirection == STRAIGHT) OR (TurnDirection == RIGHT) AND (_14LightGreen) AND (Car at front of queue)
Initiating Event	N_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.ES_14_W.NumberCars -= 1; N_Atlantic_14_Free = TRUE; If !(RQ.ES_14_W.isEmpty): schedule another turn event for this lane.

Activity: RQ.N_Atlantic_S Go Across Traffic Light	
Models a car going south on Atlantic Dr across 14th St and out of SUI	
Precondition	(TurnDirection == STRAIGHT) AND (_AtlanticLightGreen) AND (W_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	W_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; W_Atlantic_14_Free = TRUE; If !(RQ.N_Atlantic_S.isEmpty): schedule another turn event for this lane.

Activity: RQ.N_Atlantic_S Turn Left Traffic Light	
Models a car turning left onto 14th St from Atlantic Dr north of intersection	
Precondition	(TurnDirection == LEFT) AND (_AtlanticLightGreen) AND (E_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	E_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; E_Atlantic_14_Free = TRUE; If !(RQ.N_Atlantic_S.isEmpty): schedule another turn event for this lane.

Activity: RQ.N_Atlantic_S Turn Right Traffic Light	
Models a car turning right onto 14th St from Atlantic Dr north of intersection	
Precondition	(TurnDirection == RIGHT) AND (_AtlanticLightGreen) AND (Car at front of queue)
Initiating Event	W_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; W_Atlantic_14_Free = TRUE; If !(RQ.N_Atlantic_S.isEmpty): schedule another turn event for this lane.

Activity: RQ.S_Atlantic_N Go Across Traffic Light	
Models a car going north on Atlantic Dr across 14th St and out of SUI	
Precondition	(TurnDirection == STRAIGHT) AND (_AtlanticLightGreen) AND (E_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	E_Atlantic_14_Free = FALSE
Duration	GoAcross
Terminating Event	RQ.S_Atlantic_N.NumberCars -= 1; E_Atlantic_14_Free = TRUE; If !(RQ.S_Atlantic_N.isEmpty): schedule another turn event for this lane.

Activity: RQ.S_Atlantic_N Turn Left Traffic Light	
Models a car turning left onto 14th St from Atlantic Dr south of intersection	
Precondition	(TurnDirection == LEFT) AND (_AtlanticLightGreen) AND (W_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	W_Atlantic_14_Free = FALSE
Duration	TurnLeft
Terminating Event	RQ.S_Atlantic_N.NumberCars -= 1; W_Atlantic_14_Free = TRUE; If !(RQ.S_Atlantic_N.isEmpty): schedule another turn event for this lane.

Activity: RQ.S_Atlantic_N Turn Right Traffic Light	
Models a car turning right onto 14th St from Atlantic Dr south of intersection	
Precondition	(TurnDirection == RIGHT) AND (_AtlanticLightGreen) AND (E_Atlantic_14_Free) AND (Car at front of queue)
Initiating Event	E_Atlantic_14_Free = FALSE
Duration	TurnRight
Terminating Event	RQ.N_Atlantic_S.NumberCars -= 1; E_Atlantic_14_Free = TRUE; If !(RQ.S_Atlantic_N.isEmpty): schedule another turn event for this lane.

Actions

Action: RQ.N_14_E Arrival	
Input stream of arriving cars on RQ.N_14_E	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.33 cars a unit
Event	RQ.N_14_E.Size += 1

Action: R.S_14_E Arrival	
Input stream of arriving cars on R.S_14_E	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.33 cars a unit
Event	R.S_14_E.Size += 1

Action: S_Atlantic_N Arrival	
Input stream of arriving cars on RQ.S_Atlantic_N	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.083 cars a unit
Event	RQ.S_Atlantic_N.Size += 1

Action: N_Atlantic_S Arrival	
Input stream of arriving cars on RQ.N_Atlantic_S	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.083 cars a unit
Event	RQ.N_Atlantic_S.Size += 1

Action: EN_14_W Arrival	
Input stream of arriving cars on RQ.EN_14_W	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.4167 cars a unit
Event	RQ.EN_14_W.Size += 1

Action: ES_14_W Arrival	
Input stream of arriving cars on RQ.ES_14_W	
TimeSequence	Exponential random variable on Poisson process with arrival rate of 0.4167 cars a unit
Event	RQ.ES_14_W.Size += 1

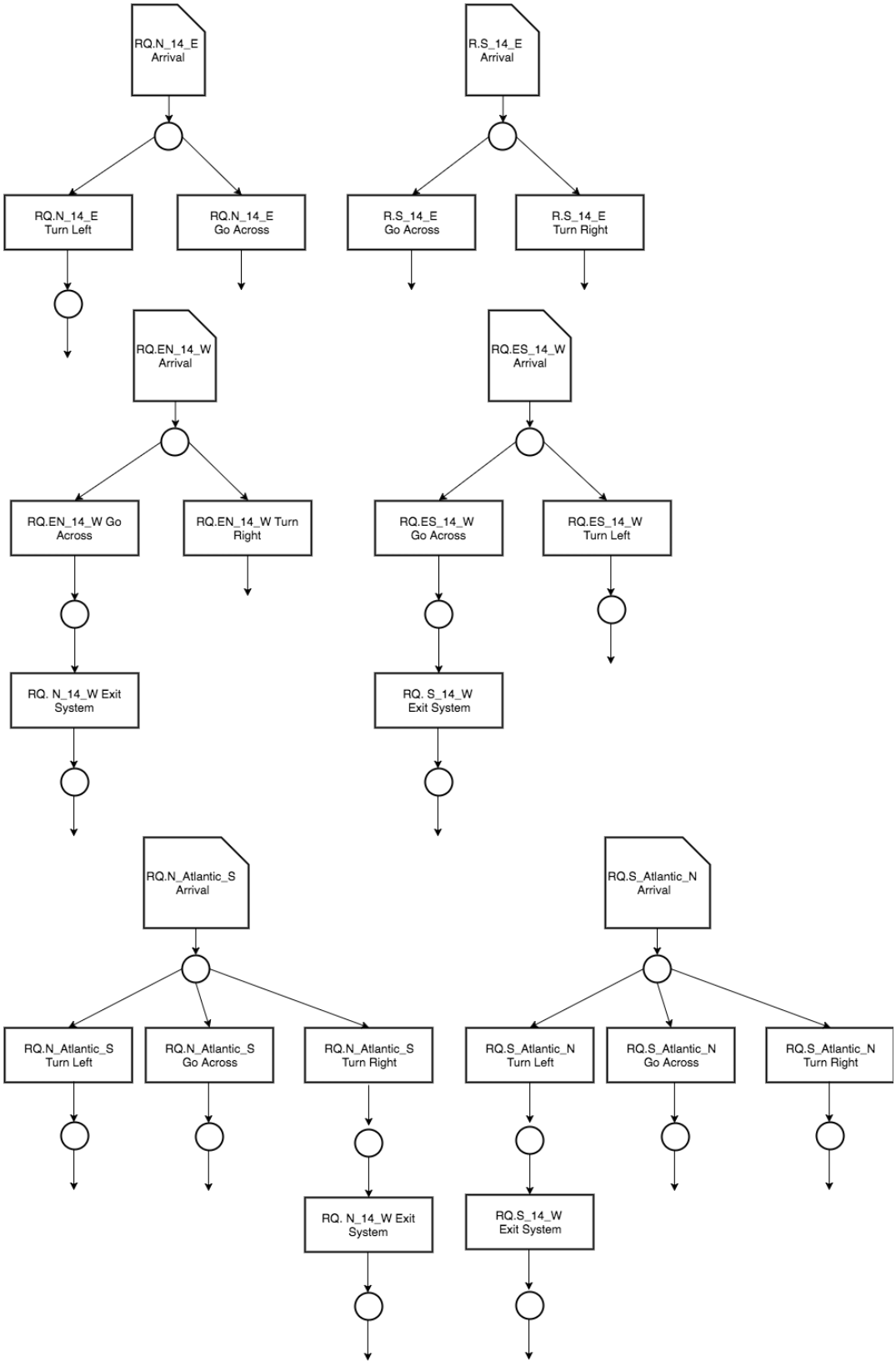
Stochastic Values

Name	**Description**
TurnDirection	Uniformly random distribution over three discrete values, LEFT, RIGHT, STRAIGHT

Constants

Name	**Description**	**Value**
GoAcross	Time for car to turn left or straight across any intersection	2 units
TurnRight	Time for car to turn right at any intersection	3 units
TurnLeft	Time for car to turn left at any intersection	4 units
GreenLightDuration	Time traffic light stays green for 14 st cars traveling west.	45 units
RedLightDuration	Time traffic light stays red for 14 St cars traveling west (shorter since 14 St has a higher traffic volume than State St)	15 units

Car Life Cycles -Dependent on point of entry into SUI, arrow to nothing indicates exit from SUI



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