Logistics Laboratory, POSTECH

SITE Manual

Smart Intersection for Traffic Efficiency User Guideline

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0. Introduction

Traffic signal control is one of the most significant challenges in alleviating traffic congestion in urban areas. One commonly used strategy for traffic signal control is fixed-time traffic signals, which are preferred because they only require historical data within predefined intervals. Enhancing traffic flow at a single intersection through fixed-time traffic signals requires identifying a suitable phase sequence and optimizing corresponding phase durations for the intersection.

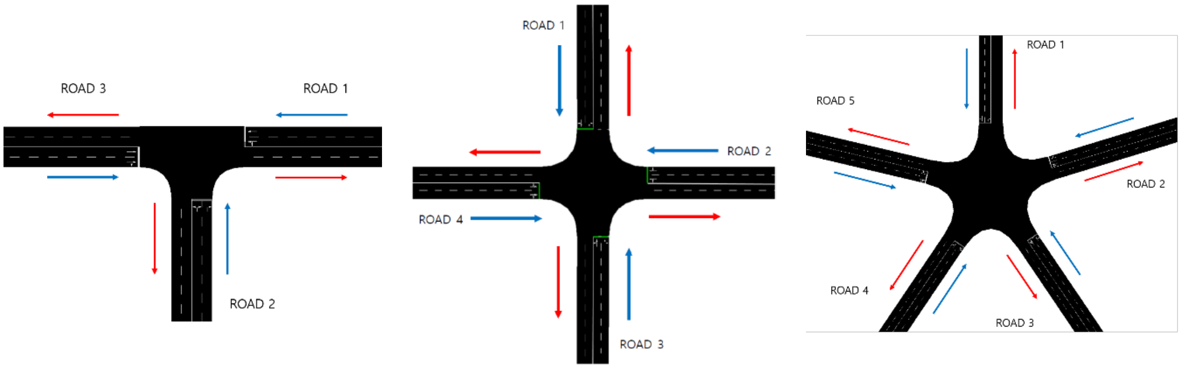
Many studies have employed microscopic simulators to optimize fixed-time traffic signals, considering diverse road users and assessing the viability of various signal configurations. However, optimizing traffic signals presents challenges for institutions responsible for traffic signal management, such as police agencies, due to their limited expertise in simulation tools, coding skills, and optimization methodologies required for deploying advanced signal control systems. Recognizing this gap, we developed **SITE** (**S**mart **I**ntersection for **T**raffic **E**fficiency) to provide a solution.

SITE (http://logistics.postech.ac.kr/site) is designed to offer a web-based, user-friendly interface that allows decision-makers, even without prior installation, knowledge of simulation, or programming, to generate an optimized fixed-time traffic signal at a single intersection. The system provides the best phase sequence and durations for user-defined arbitrary intersections and traffic demand, along with a detailed explanation of the network building, demand modeling, and simulation configuration processes in the following sections. By leveraging the power of SITE, traffic signal control becomes more accessible to institutions and individuals lacking the technical expertise required for complex simulation tools. This innovative approach aims to bridge the gap between advanced traffic signal optimization research and practical implementation in real-world traffic management.

1. Network Modeling

1.1. Road number

SITE can manage three, four, and five-legged intersections with predefined shapes, as illustrated in Figure 1(a) T shape, (b) cross shape, and (c) star shape. While the user can configure the number of roads and lanes, the angle between the adjacent roads remains fixed for each configuration. The user can select one of them by selecting a radio button in Figure 2.



(a) Three-legged (b) Four-legged (c) Five-legged

Figure 1. Types of intersections available in SITE

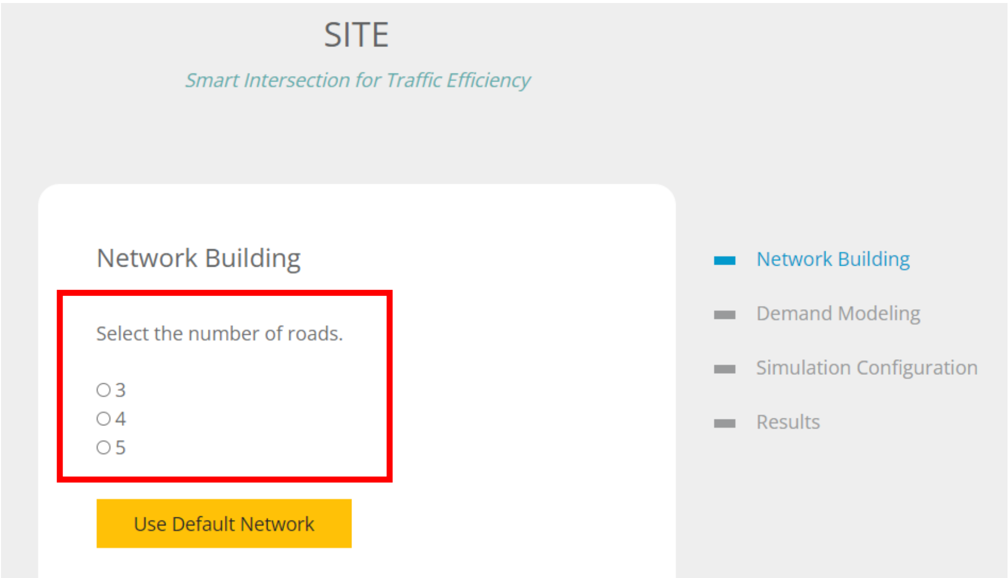
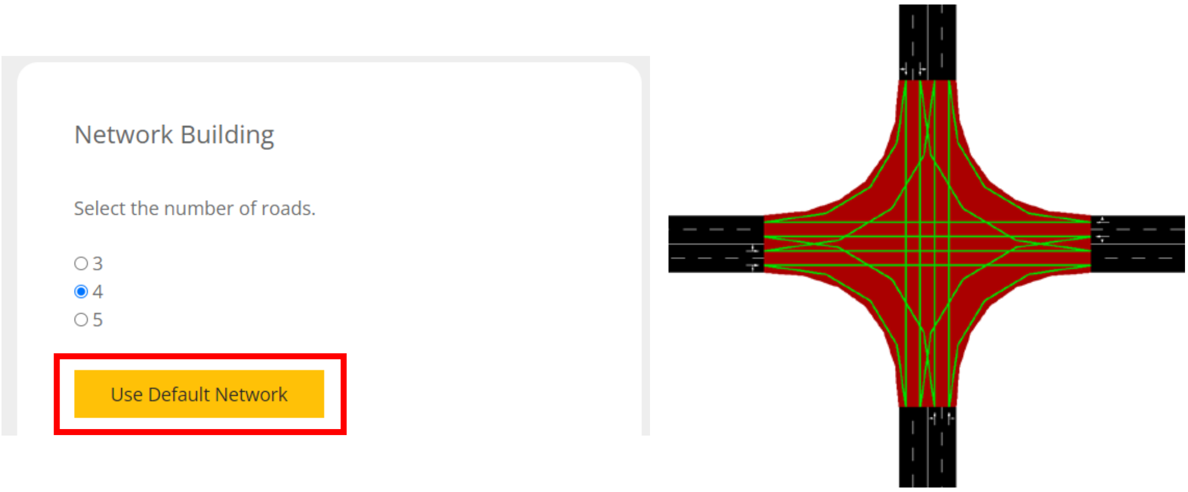


Figure 2. Selection of number of roads

1.1.1. Default settings

If necessary, the user has the option to choose the default settings as described in Figure 3(a). The default network is configured as a 4-legged intersection with 2 forward lanes and 2 backward lanes for each road as described in Figure 3(b). The leftmost lane allows for going straight and turning left, while the rightmost lane allows for going straight and turning right. By selecting 'Use Default Network,' all network settings—such as the number of roads, the number of lanes, and the connections—are automatically configured. This default configuration serves as an example for users, demonstrating how to set the number of roads, lanes, and lane-to-lane connections.



(a) Click default network (b) Illustration of default network

Figure 3. Setting default road network

1.2. Lane number

If the user prefers not to use the default setting or wishes to make modifications, the user can input the desired number of lanes in the tables provided in Figure 4. The term 'IN' refers to the number of lanes entering the intersection for each road, while 'OUT' represents the number of lanes exiting the intersection. In the figure below, the 'IN' direction is marked in blue, and the 'OUT' direction is highlighted in red. The user can choose any number of lanes from 1 to 7. Once the values are entered, the user can proceed to the next step by clicking the 'NEXT' button.

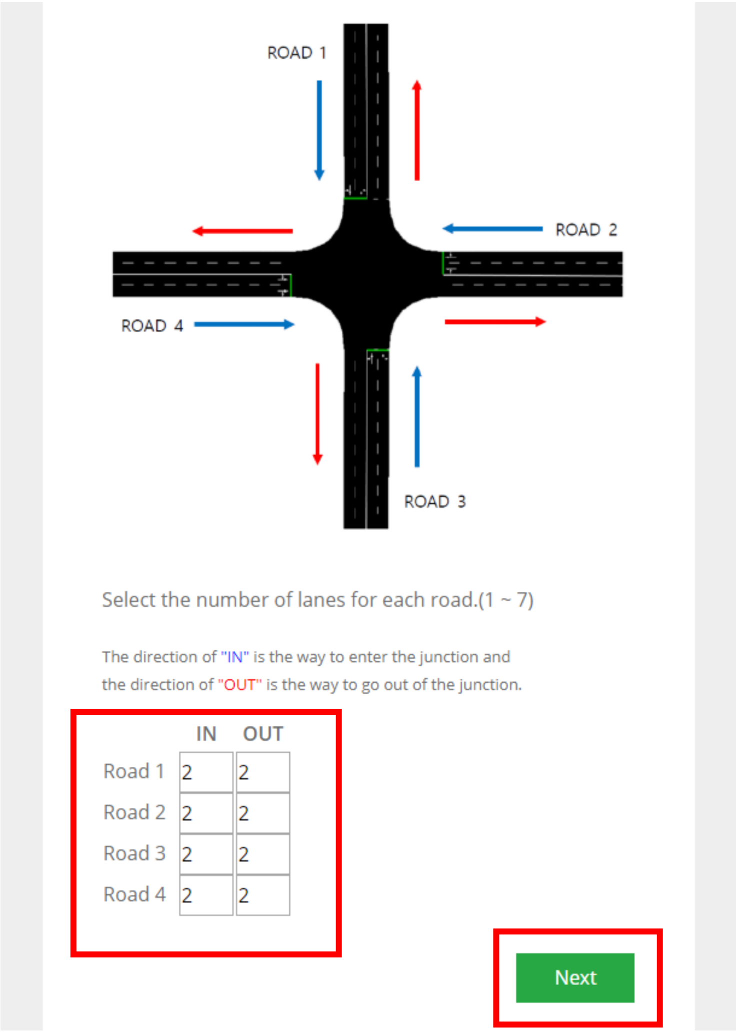


Figure 4. Configuration of number of lanes

1.3. Connections

The user can now configure connections between lanes. For each lane, the user can determine which lane in the other roads can be connected. The road indexing at 12 o'clock is number 1, followed by 2, 3, 4, and 5 in clockwise order as described in Figure 4. Lane indexing is determined starting from number 1 in the order closest to the center line, as shown in the Figure 5. In this order, the rightmost lane has the largest index, and the leftmost lane has the smallest index. Lane indices are divided into two groups: forward lanes and backward lanes. In the Figure 5, indices of forward lanes are colored blue, while indices of backward lanes are colored red. Vehicles can follow the described connection from the starting lane of the starting road to the ending lane of the ending road. If a connection is not defined, vehicles cannot travel the road network as desired. The SITE assumes that input data are valid.

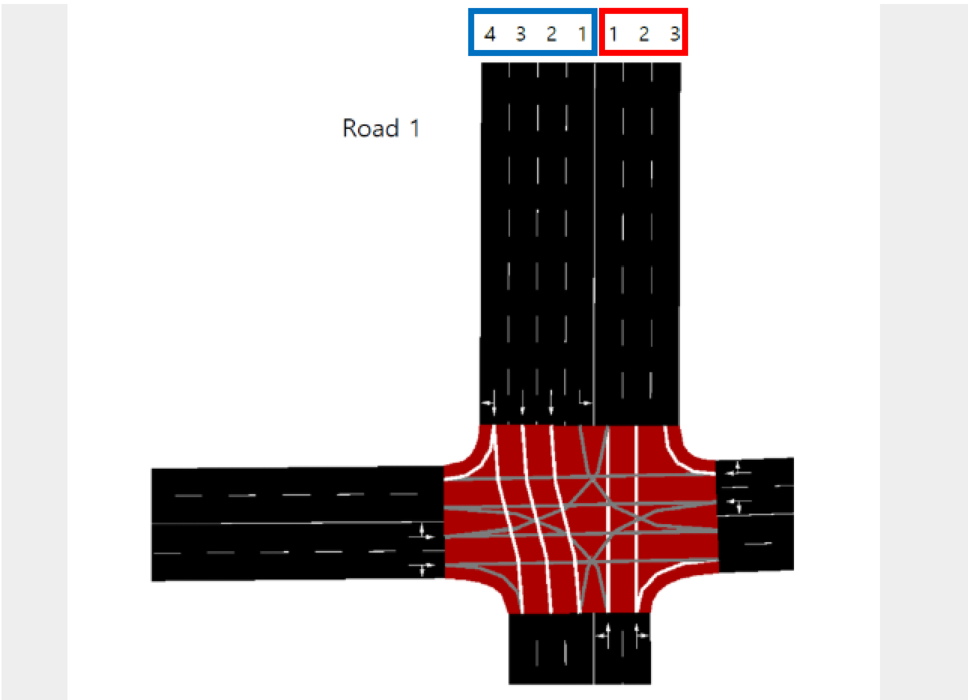
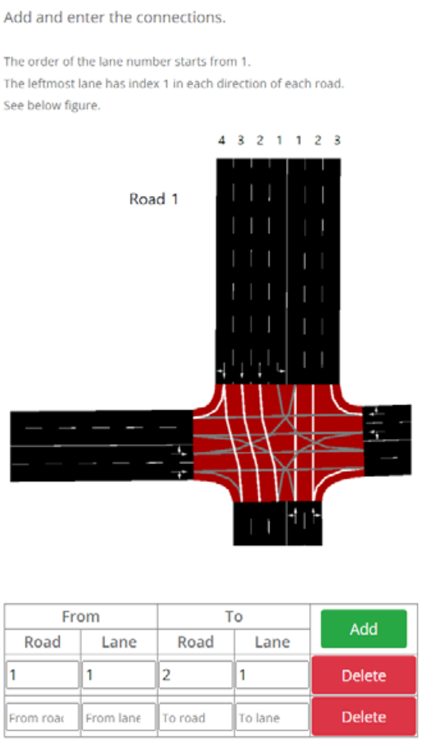


Figure 5. Lane indices of sample intersection

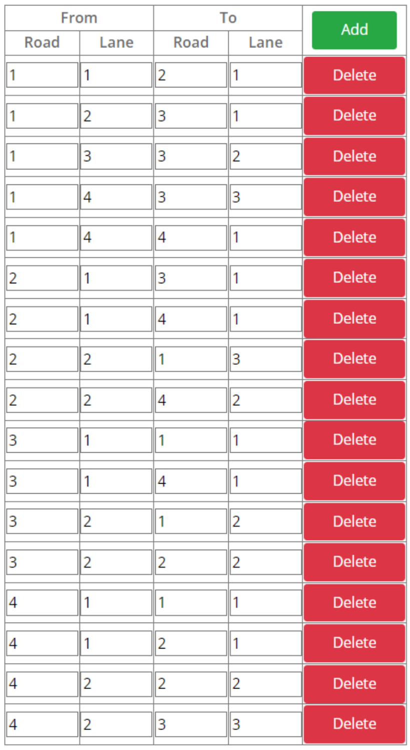
By clicking the 'Add' button in Figure 6, the user can add an additional connection. Input the index of the starting road in the 'Road' field and the index of the starting lane in the 'Lane' field under the 'From' category. Similarly, fill in the index of the ending road in the 'Road' field and the index of the ending lane in the 'Lane' field under the 'To' category. Figure 6(b) specifies connections corresponding to those described in the sample intersection in Figure 6(a).

The user has the option to specify a U-turn where the starting road and the ending road are the same. For example, a connection can be defined from lane 1 (forward direction) of road 1 to lane 1 (backward direction) of the same road. Due to the technical issues with the simulator SUMO running on the backend, lane 1 of the “To Road” must be specified if the user wants to add a U-turn. Therefore, for example, if (From Road, From Lane, To Road, To Lane) represents the connection, then typing only (2, 1, 2, 2) is invalid, while typing both (2, 1, 2, 1) and (2, 1, 2, 2) is valid.

By clicking the 'Delete' button, the user can remove the defined connection. After entering all connections, please double-check to ensure that all desired connections have been accurately input. All inputs must be filled and must be positive integer. The roads and lanes should be within the range specified in sections 1.1 and 1.2. Users can validate their inputs by clicking “Validate Connections” in Figure 7. If the input is invalid, SITE will provide a warning message as described in Figure 7(a). If the input is valid, the “Complete Network” button, depicted in Figure 7(b), will appear. If everything is correct, proceed to complete the network building by clicking the 'Complete Network' button and advance to the next page. Please note that it may take some time to build the network.



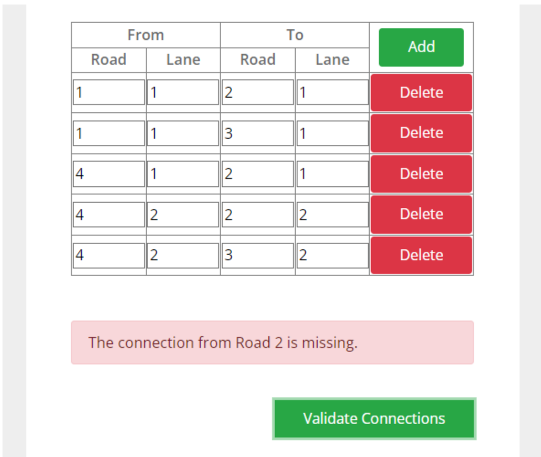
From		To		Add
Road	Lane	Road	Lane	
1	1	2	1	Delete
From road	From lane	To road	To lane	Delete



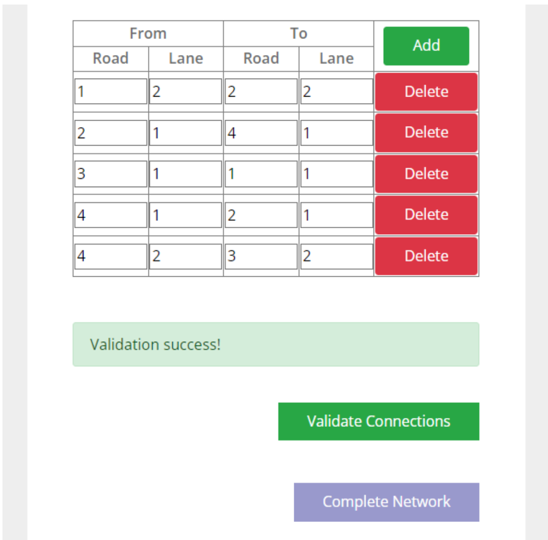
From		To		Add
Road	Lane	Road	Lane	
1	1	2	1	Delete
1	2	3	1	Delete
1	3	3	2	Delete
1	4	3	3	Delete
1	4	4	1	Delete
2	1	3	1	Delete
2	1	4	1	Delete
2	2	1	3	Delete
2	2	4	2	Delete
3	1	1	1	Delete
3	1	4	1	Delete
3	2	1	2	Delete
3	2	2	2	Delete
4	1	1	1	Delete
4	1	2	1	Delete
4	2	2	2	Delete
4	2	3	3	Delete

(a) Illustration of connections (b) Connections of intersection in (a)

Figure 6. Lane-to-lane connection configuration



From		To		Add
Road	Lane	Road	Lane	
1	1	2	1	Delete
1	1	3	1	Delete
4	1	2	1	Delete
4	2	2	2	Delete
4	2	3	2	Delete



From		To		Add
Road	Lane	Road	Lane	
1	2	2	2	Delete
2	1	4	1	Delete
3	1	1	1	Delete
4	1	2	1	Delete
4	2	3	2	Delete

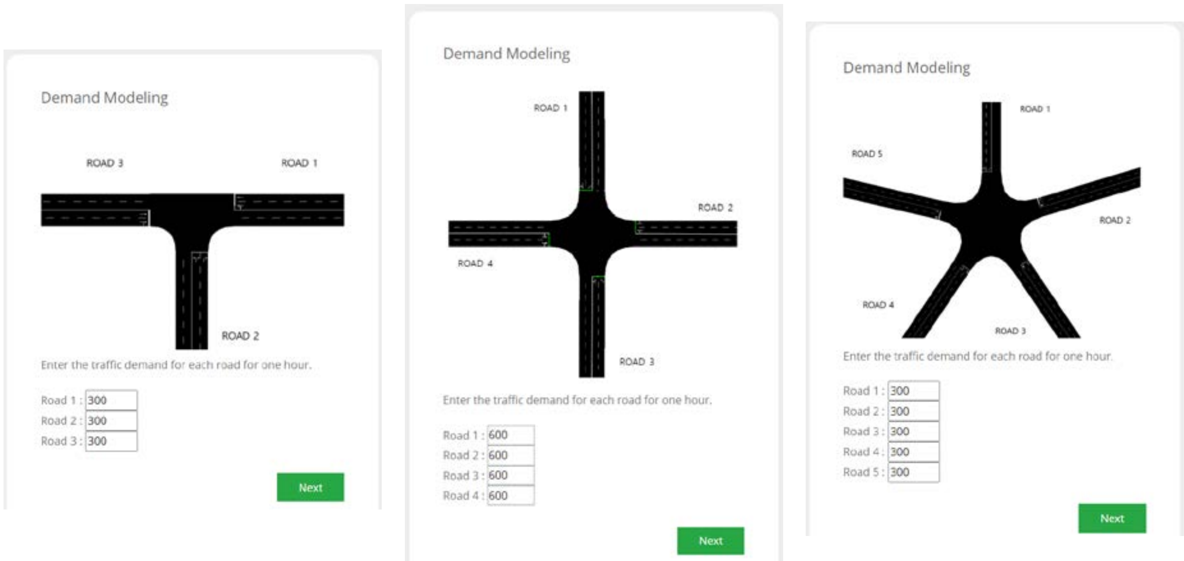
(a) Invalid input (b) Valid input

Figure 7. Connection validation

2. Demand modeling

2.1. Arrival rate

Enter the desired number of vehicles to generate per hour for each road in Figure 8, representing the arrival rate of the Poisson process. For each simulation step (1 second), a vehicle is generated with a probability equal to (the entered number of vehicles) / 3600. For instance, if the user inputs 600 in the field, an average of 600 vehicles will be generated per hour, resulting in a probability of 0.167 per second. Click the 'Next' button to proceed to the next step.



(a) Three-legged (b) Four-legged (c) Five-legged

Figure 8. Setting number of vehicles

2.2. Turning ratio

Specify the percentage of 'To' road destinations for vehicles originating from each 'From' road in Figure 9. In a four-way intersection, this can include options like going straight, turning left, turning right, and making a U-turn. For example, entering '33' in the field under 'From 2' and 'To 3' means that 33% of the vehicles generated on Road 2 will proceed to Road 3. Adjust these percentages to ensure that the sum of probabilities for each row is 100%. Refer to the Figure 9 for guidance. Click the 'Next' button to proceed to the next step.

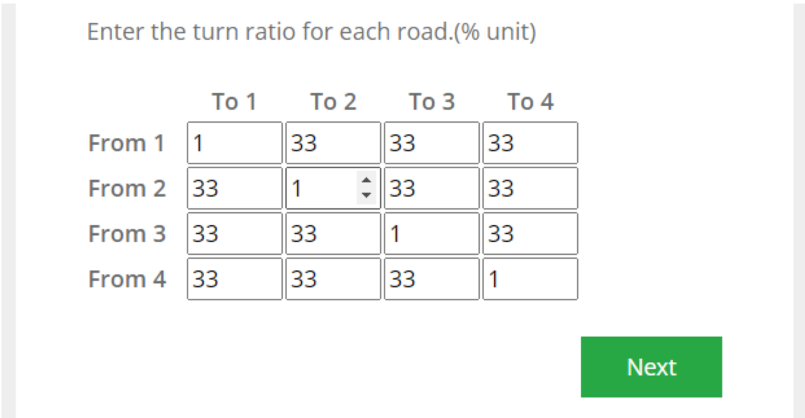


Figure 9. Setting turning ratio

2.3. Vehicle types

The user must define at least one vehicle type in Figure 10. For each vehicle type, 'id', 'vClass', and 'probability' are required fields. By specifying the attributes of the vehicle type, the user can test customized vehicles freely. Clicking the 'Add' button in each table adds the attributes of the vehicle type. Clicking the 'Delete' button in each row removes the corresponding attribute. Clicking 'Add new vehicle type' generates a new table addressing a new vehicle type. Click 'Complete Demand' to finish modeling demand and proceed to the next page. Here are some details regarding the attributes:

- 'id' can be any name chosen by the user but must be unique.
- 'vClass' is referenced from this link and should be chosen from the options listed here.
- The sum of 'probability' for all vehicles must be 1.
- Additional attributes are referenced here.
- If additional attributes are not defined, the default value of 'vClass' is applied.

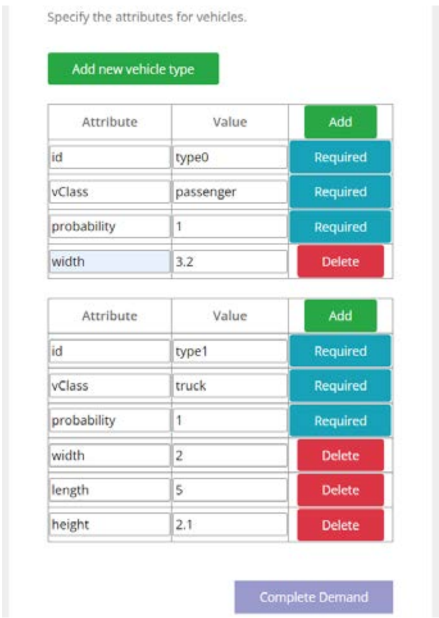


Figure 10. Vehicle type configuration

3. Simulation configuration

3.1. Phase sequences

Now, the user can view the available phase sequences as guidelines for the intersection. For three-legged and five-legged intersections, typically only one phase sequence is available due to pedestrian considerations. In these cases, the user must choose the phase sequence. In contrast, for a four-legged intersection, the Korean National Police Agency suggests 9 phase sequences, as described in Figure 11. In this case, the user can select at least one phase sequence to test.

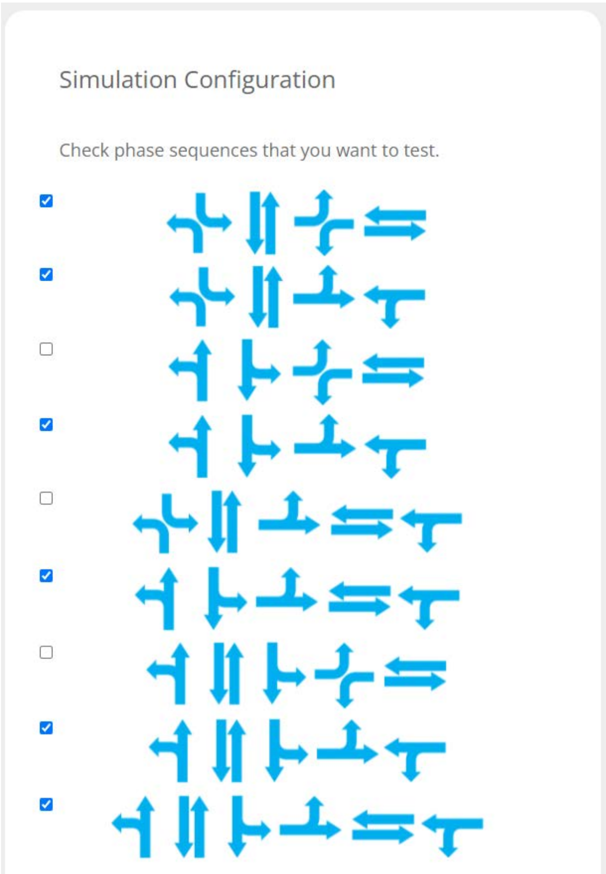


Figure 11. Phase sequences for four-legged intersections

3.2. Method

There are two methodologies to determine phase duration: Guideline and SITE Optimizer. When using the Guideline method, constraints such as minimum and maximum phase duration, pedestrian considerations, and maximum cycle length are not taken into account. However, SITE Optimizer allows for the consideration of these constraints; please refer to sections 3.2.1 and 3.2.2 for details.

3.2.1. Guideline

If the user prefers to use Guideline phase durations suggested by the Korean National Policy Agency, choose 'Guideline' in Figure 12. The phase durations are based on Webster's method. By selecting 'Guideline,' the user can configure warm-up time, running time, and replication of the simulation. Warm-up time refers to the time during which data is not considered while running the simulation. Running time signifies the duration until the simulation finishes. Replication indicates how many times the stochastic simulation is repeated for the same setting with different seeds. Default settings are already configured; modify them if necessary. Additionally, there is another setting for the duration of the yellow phase. SITE provides a fixed and equal duration for all yellow phases.

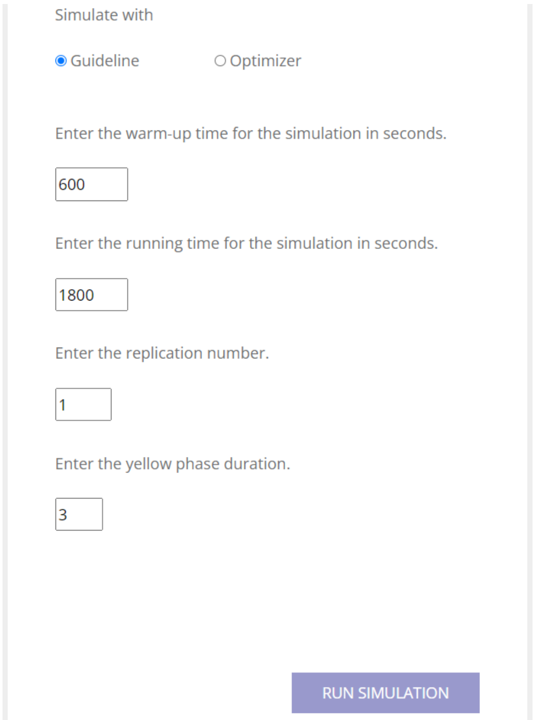


Figure 12. Configuration of Guideline option

3.2.2. Optimizer

If the user wants to use Optimizer phase durations proposed by SITE, choose an 'Optimizer' box. In contrast to the Guideline method, constraints—such as minimum phase duration, maximum cycle length, and minimum length of each pedestrian signal—should be specified for Optimizer, as shown in Figure 13. While the minimum phase duration and maximum cycle length are straightforward, the last constraint is somewhat complicated. For instance, in Figure 13, if the minimum length of the pedestrian signal is set to 15 for the five-legged intersection, the phases affected by the pedestrian signal (in this case, only the second phase) should have a duration greater than or equal to 15 seconds.

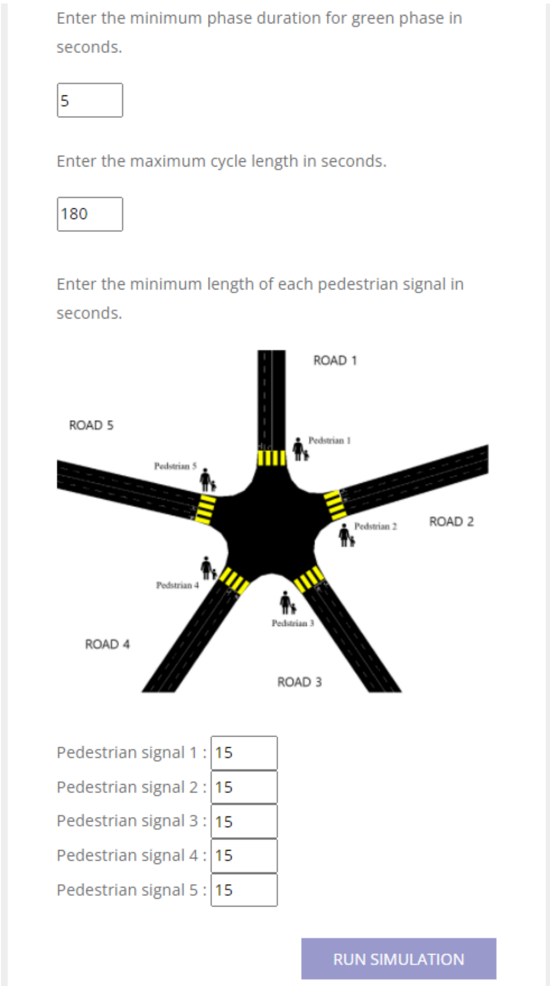


Figure 13. Configuration of Optimizer option

By clicking 'RUN SIMULATION', the user can obtain results. The time taken to receive results depends on the replication and the number of phase sequences selected. Using Optimizer, in particular, may take tens of minutes. The user can monitor the progress of the simulation in the browser window, as illustrated in Figure 14.

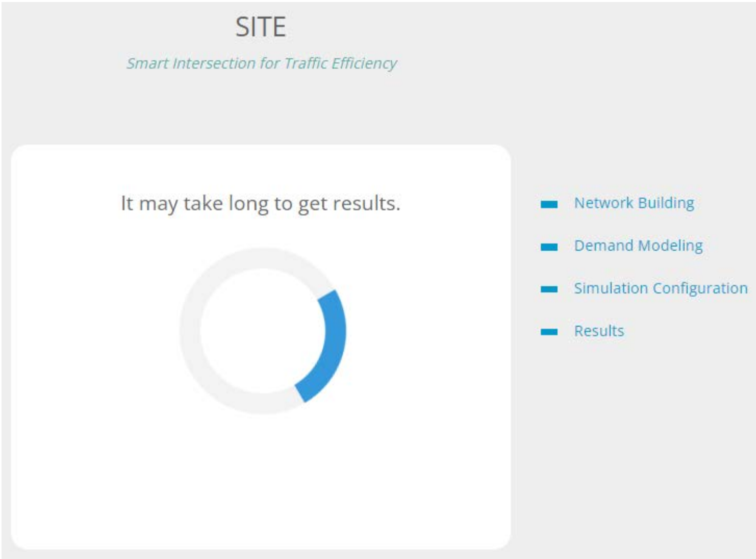
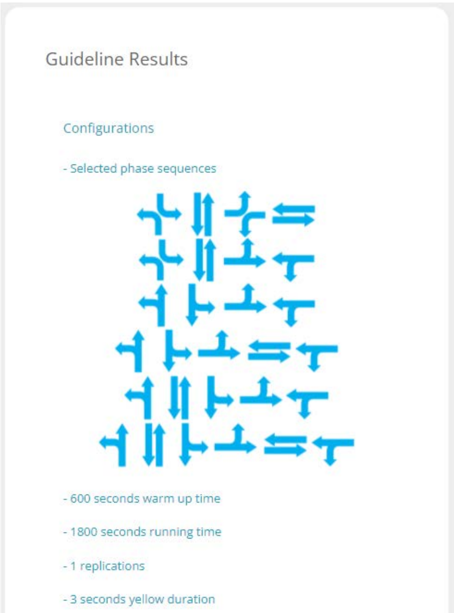


Figure 14. Progress page to get results

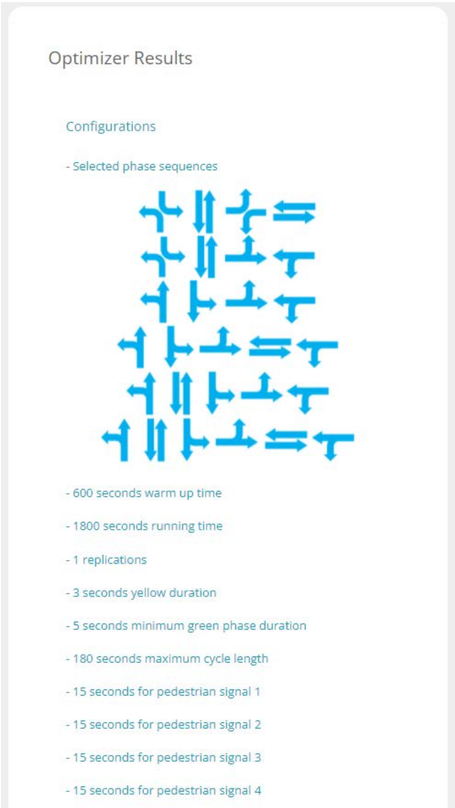
4. Results

4.1. Configurations

The settings specified in the previous simulation configuration page are described in Figure 15. For example, in Figure 15(a), the user chooses Optimizer, selects six phase sequences, 600 warm-up time, 1800 running time, 1 replication, and 3-second yellow duration. In Figure 15(b), the user selects Optimizer, six phase sequences, 600 warm-up time, 1800 running time, 1 replication, 3-second yellow duration, 5 seconds minimum green phase duration, 180 seconds maximum cycle length, and 15 seconds minimum length for every pedestrian signal.



(a) Guideline

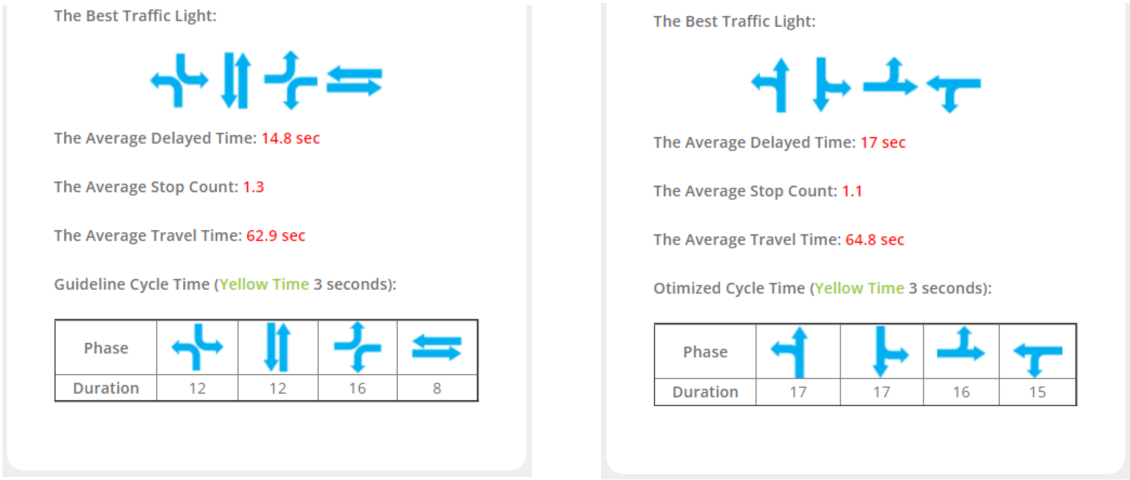


(b) SITE Optimizer

Figure 15. Configuration settings in the result pages

4.2. Best traffic signal

Among the selected phase sequences, two methods output the phase sequence with the least average travel time as the Best Traffic Light in Figure 16. This includes average travel time, average delayed time, and average stop count. The resulting phase durations is reported with predefined yellow duration between two consecutive phases. In Figure 16, the result of Optimizer is worse than Guideline because Guideline does not consider any constraints.



(a) Guideline (b) SITE Optimizer

Figure 16. Results of the best traffic signal