JOINT TRANSPORTATION RESEARCH PROGRAM
INDIANA DEPARTMENT OF TRANSPORTATION
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Performance of Alternative Diamond Interchange Forms

Volume 2
Guidelines for Selecting Alternative Diamond Interchanges

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16. Abstract

Service interchanges connect freeways to arterial roads and are the backbone of the U.S. road network. Improving the operations of service interchanges is possible by applying one of several new solutions: diverging diamond, single point interchanges, and double or single roundabout diamonds.

VISSIM was used to perform 13,500 experiments to simulate the traffic performance of the studied alternative interchanges during a typical day for a wide range of geometry and traffic scenarios. Five performance measures were investigated: daily-average delay, level of service of critical movement, daily-average number of stops, longest off-ramp queue, and longest crossing road queue. The obtained daily-average delays at the alternative interchanges were consistent with expectations. Roundabouts had the highest average delay while single-point interchanges had the lowest average delays. Roundabouts exhibited the lowest numbers of stops among all the alternatives in the low traffic range up to non-freeway 30,000 veh/day. Diverging diamonds tended to have the shortest and roundabouts tended to have the longest queues on their off-ramps. Overall, single-point interchanges had the shortest queues among all the alternatives.

The study developed guidelines for early stage screening of alternative diamond. The guidelines exhibit performance measures for 25 traffic and geometric scenarios and a wide range of traffic volumes. The guidelines provide a fair comparison procedure for alternative diamond interchanges in the preliminary planning and conceptual design stages.

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EXECUTIVE SUMMARY

PERFORMANCE OF ALTERNATIVE DIAMOND INTERCHANGE FORMS: VOLUME 2—GUIDELINES FOR SELECTING ALTERNATIVE DIAMOND INTERCHANGES

Introduction

Service interchanges connect freeways to arterial roads and are the backbone of the U.S. road network. Improving the operations of service interchanges is possible by increasing the capacity of the off-ramp intersections with a crossing road and eliminating or reducing the traffic interference between these two closely spaced intersections. Recently proposed solutions use three different methods: (1) eliminating the interference by merging the two intersections into a single one (single-point interchange), (2) adding roundabouts to eliminate traffic signals (single- or dual-roundabout diamond), or (3) improving the traffic flow by swapping the directions of traffic within the interchange area and redesigning traffic signals (diverging diamond). In addition, tight diamonds are proposed where space restrictions in the developed areas force planners and designers to reduce the interchange footprint. Together with a traditional diamond interchange, decision makers have available several forms of service interchanges.

These alternatives may perform quite differently depending on traffic and local conditions. The existing research for selecting alternative diamond interchange forms is incomplete for site-specific conditions. This study investigated the operational performance of six alternative diamond interchange forms: conventional diamond (DI), tight diamond (TDI), diverging diamond (DDI), single point (SPI), and double and single roundabout (RA). Performance comparison has been used for developing guidelines (Volume 2 of this report) for early stage screening of diamond forms. The guidelines will help identify the traffic and/or geometric conditions that support the use of one type of interchange over another, focusing on the traffic performance.

Findings

VISSIM has been used to perform 13,500 experiments to simulate the traffic performance of the studied alternative interchanges during a typical day for 25 geometry and traffic scenarios. Five measures of effectiveness (MOEs) were chosen for the alternative interchange performance comparison of the alternative diamond interchanges. These MOEs can effectively demonstrate the actual time lost at signalized and unsignalized interchange intersections and the queue spillback onto the freeway and adjacent surface intersections, as well as the perception of the traffic conditions by drivers. Five performance measures were investigated in this research: daily-average delay, level of service (LOS) of critical movement, daily-average number of stops, longest off-ramp queue, and longest crossing road queue.

Daily-Average Delay

- The obtained daily-average delays at the alternative interchanges were consistent with expectations.
- Roundabouts had the highest average delay across all off-ramp and crossing road traffic shares; TDI had the second highest average delay; and with an increase in the off-ramp volume share, DDI exhibited a lower average delay.
- Overall, SPI had the lowest average delay among all the alternatives.

Level of Service (LOS) of Critical Movement

- Roundabouts outperformed DI and TDI in terms of critical movement delay for 20 and 30 percent off-ramp volumes in the lower range of non-freeway flow rates.
- With the increased share of off-ramp traffic, DDI exhibited lower critical movement delays.
- With 50 percent and 60 percent off-ramp shares, DDI exhibited critical movement delays similar to SPI's.

Daily-Average Number of Stops

- Roundabouts had the lowest number of average stops among all the alternatives up to 30,000 non-freeway AADT across all off-ramp and crossing road traffic shares.
- DI, TDI, and roundabouts had almost double the number of stops of DDI and SPI.
- With an increase in the off-ramp traffic share, DDI exhibited a smaller number of stops.
- Overall, SPI had the lowest number of average stops among all the alternatives.

Longest Off-Ramp Queue

- DDI had the shortest and roundabouts had the longest queues on the off-ramp among all the alternatives across all off-ramp and crossing road traffic shares.
- With an increased share of off-ramp traffic, SPI exhibited queues on off-ramps shorter than DI and TDI.

Longest Crossing Road Queue

- TDI had shorter queues on the crossing road DDI, DI, and roundabouts up to 3,500 veh/hr across all off-ramp and crossing road traffic shares.
- With the increased share of off-ramp traffic, DDI exhibited shorter queues on the crossing road.
- Overall, SPI had the shortest queues among all the alternatives.

Implementation

The results of this study were used to develop guidelines (Volume 2 of this report) that exhibit operational performance of six alternative diamond interchanges for 25 traffic and geometric scenarios and a wide range of traffic volumes. Each of these scenarios involve five performance measures (average delay, critical movement delay, average stops, longest queue on the off-ramp, and longest queue on the crossing road) to compare the alternative interchanges against each other. The guidelines provide a fair comparison procedure for alternative diamond interchanges in the preliminary planning and conceptual design stages.

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PURPOSE AND SCOPE

The purpose of these Guidelines is to help Indiana road designers and planners identify service interchange design alternatives that meet the traffic performance requirements for known traffic demands and space restrictions. The Guidelines provide a set of exhibits that serve as a quick and convenient tool for predicting user delay, level of service (LOS), and queue ranges in the user-selected design hour (or corresponding peak hour) of the analysis year. These tools cover a wide range of traffic and geometric conditions likely in Indiana. The alternative diamond interchanges included in the Guidelines are (Figure 1):

- Conventional Diamond Interchange (DI)
- Tight Diamond Interchange (TDI)
- Single Point Interchange (SPI)
- Diverging Diamond Interchange (DDI)
- Roundabout Diamond Interchange—Single or Double (RI)

Double and Single RI may be considered as a single group because the difference in their performance is negligible. The schematics of the six design alternatives are presented in Figure 1. The non-freeway traffic on DI, TDI, SPI, and DDI is controlled by traffic signals while a RI is unsignalized.

The Guidelines are developed for early stage analysis and screening of alternatives to facilitate efficient identification of reasonable/feasible diamond interchange form(s) prior to investing effort in downstream detailed analysis of traffic operational performance and cost. The Guidelines for evaluating alternative interchanges are based on the results of extensive simulation experiments with VISSIM calibrated to Indiana conditions. The details of the study (Project No. SPR-3866) can be found in the companion Volume 1, Research Report. The Guidelines address specific traffic and space conditions that may favor some alternative interchanges over others and therefore are meant to support the planning and design efforts by reducing the number of alternatives considered in the remaining phases. Although selection of interchange type may be streamlined and supported by these Guidelines, this selection should be confirmed through more specific analysis of operational performance and cost.

The following part explains the method and other details needed to use the material properly. Figure 1 shows the schematic diagram of the study interchanges.

MEASURES OF PERFORMANCE

Freeway traffic passing through the interchange area in the freeway mainline lanes is not affected by the interchange design if the non-freeway part of the interchange operates without queue spillback onto the freeway. For this reason, the operational performance of the evaluated interchanges focuses on the ten traffic movements on the non-freeway portion that includes the non-freeway crossroad and off-ramps where traffic interruptions are expected (Figure 2). Five measures are used to evaluate the performance of the interrupted non-freeway traffic on the five types of service interchanges briefly presented below.

Daily-Average Delay

Average delay is one of the components of operational costs. The delay experienced by a vehicle inside the interchange area is measured as the difference between the actual travel time and the minimum travel time. The actual travel time is affected by the traffic, controls, and geometry along the actual path inside the interchange area. The minimum travel time is calculated along the shortest path that passes through the center of the interchange area when there are neither other vehicles nor traffic controls. In such conditions, drivers can move at their desired speeds. Vehicle delays are measured for each non-freeway movement between the vehicle's entry and exit points and along its path. The results are averaged across all the vehicles and non-freeway movements on an average day of the analysis year.

Daily-Average Number of Stops

Stops are also a component of operational costs. A vehicle is considered stopped if its speed is less than five miles per hour, which typically indicates the impact of traffic controls or the presence of traffic queues. Vehicles' stops are counted for each non-freeway movement between its entry and exit points and along its path. The results are averaged across all the vehicles and non-freeway movements on an average day of the analysis year.

Level of Service (LOS) of Critical Movement

LOS reflects an interchange's performance as perceived by motorists. According to the *Highway Capacity Manual* (Transportation Research Board, 2010), LOS is determined based on the average delay during the peak 15 minutes of the design hour in the analysis year. LOS reflects the performance of an interchange's weakest element—the critical movement with the highest delay; and LOS F indicates an interchange's capacity failure.

Longest Off-Ramp Queue

The longest off-ramp queue length is used to detect the potential safety problem caused by a queue that reaches the freeway mainline lane. The Guidelines provide the longest queue expected during the busiest 15 minutes of the design hour in the analysis year The Guidelines user is expected to compare the longest off-ramp queue length obtained with the critical distance from the off-ramp stop line to the point beyond which the impact of the queue is present. There are two possible solutions if the problem is detected: (1) extend the length of the ramp and (2) use a service interchange with shorter off-ramp queues.

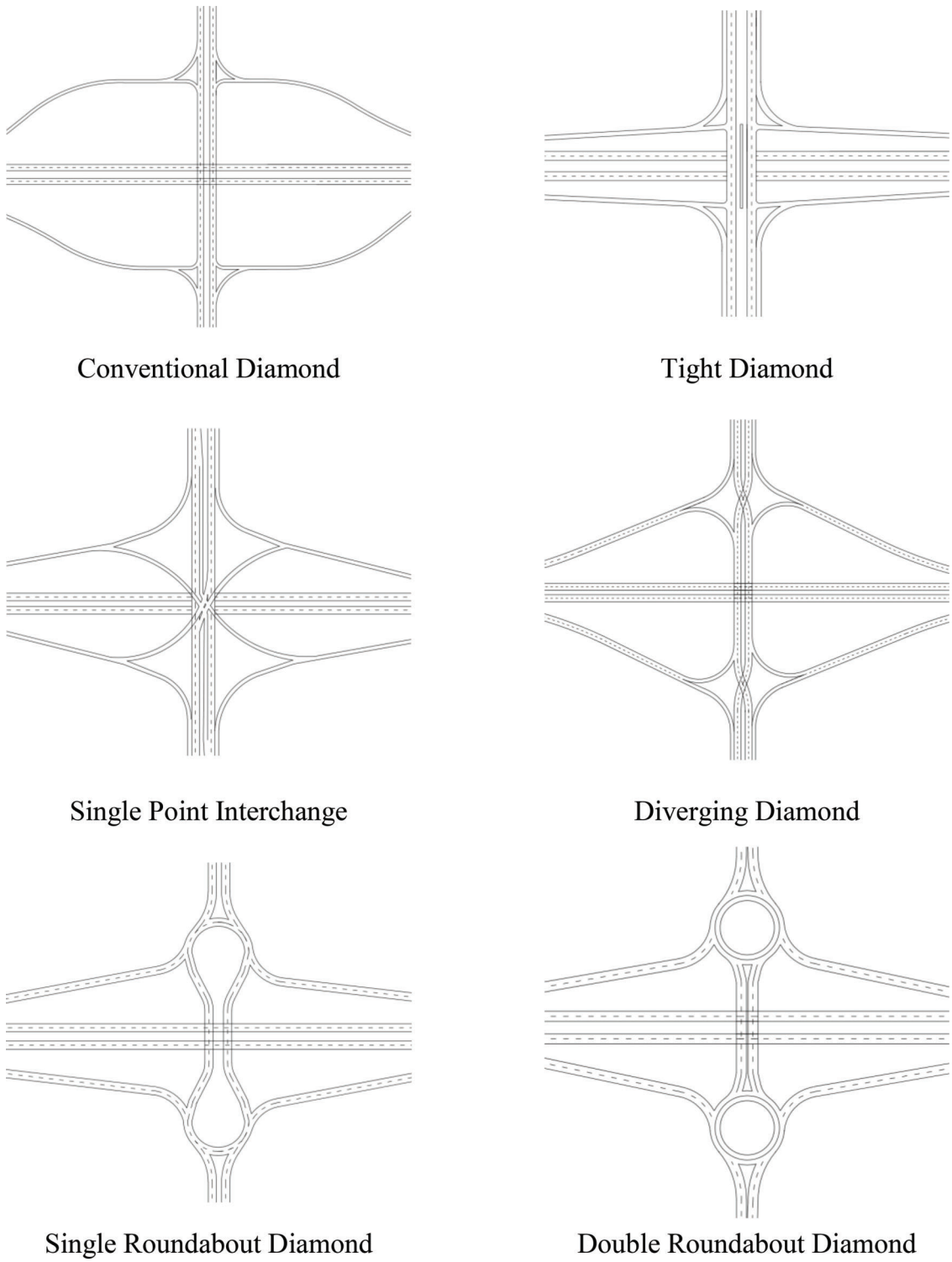


Figure 1 Design forms of diamond interchanges.

Longest Crossing Road Queue

The longest queue length along the crossing road is helpful in detecting a potential operational problem caused by a queue that reaches the adjacent intersection. The Guidelines therefore provide in each direction the longest queue length expected during the busiest 15-minute period of the design hour in the analysis year. This length then must be compared to the distance between the center of the interchange and the adjacent upstream major intersection.

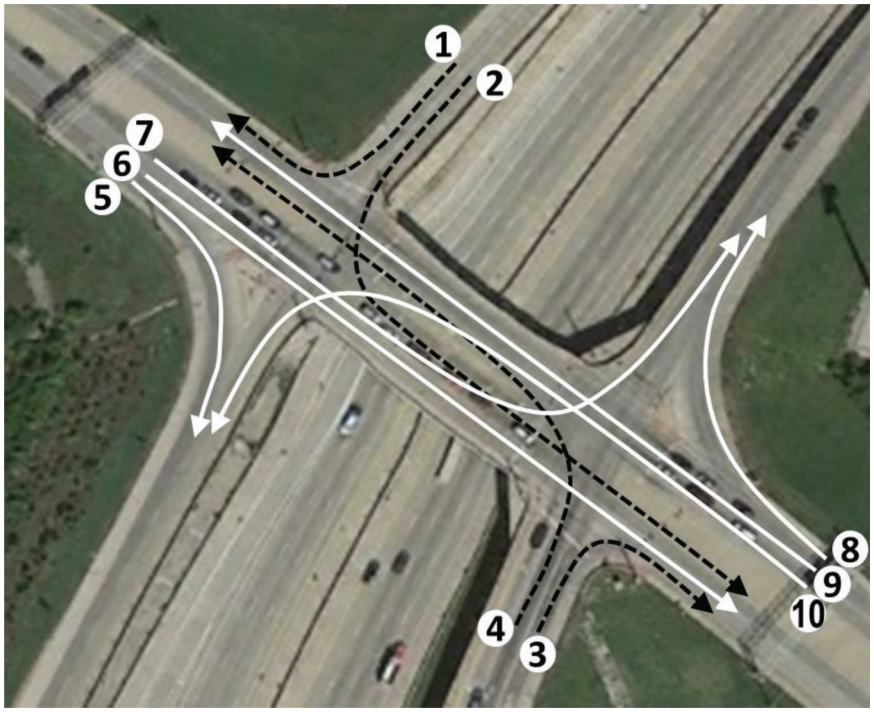


Figure 2 Non-freeway traffic movements. (Off-ramp traffic movements are represented by black dashed lines, crossroad traffic movements are represented by white solid lines.)

GEOMETRIC AND TRAFFIC CONDITIONS

The performance of interchanges is affected by geometric design and traffic volumes. Design hour can be the hour with the 30 highest hourly volume (30 HV) during the analysis or a selected rush hour that represents the design hour. Although typically the 30th highest hourly volume is assumed, other ranks are also used. The design flow rate represents the peak 15-minute traffic during the design hour.

Based on the Indiana service interchange traffic pattern, it has been assumed that one approach (ramp or crossing road approach) may carry up to 60% of the total non-freeway flow. The roundabout diamond alternative is not expected on six-lane roads; thus, this alternative is not included.

INTERCHANGE PERFORMANCE EXHIBITS

The remainder of these guidelines provides graphs that compare the traffic performance and the operational footprint of the alternative interchanges for the scenarios listed in Table 1 and Table 2 in the Exhibits.

Table 1 lists twenty-five scenarios (T1–T25) for which the three performance measures: daily-average delay, critical movement delay and daily-average stops are provided on the corresponding graphs. The user should select in Table 1 a scenario that best represents the design conditions:

- number of continuous lanes on crossing road: two, four, or six
- number of continuous lanes on the off-ramps: one or two
- number of lanes on the off-ramp approach to the terminal intersection
- percent of the non-freeway traffic on the off-ramps: 20, 30, 40, 50, or 60%
- percent of the non-freeway traffic on the crossroad: 80, 70, 60, 50, or 40%

Once the geometric configuration and traffic scenario is selected, the corresponding exhibits are entered either with the **non-freeway AADT** during the analysis year or the **non-freeway design flow rate** for the design hour to compare the traffic performance measures: daily-average delay, critical movement delay and daily-average stops.

The operational footprint of an interchange during the design hour is defined with the longest queue lengths on off-ramps and on the crossing road. Table 2 provides thirty-five scenarios (F1–F35) for which the longest queue lengths can be estimated on each off-ramp and in each direction on the crossing road. The user should first select a scenario that best represents the design conditions (Table 2):

- number of continuous lanes on crossing road: two, four, or six
- number of continuous lanes on the off-ramps: one or two
- number of lanes on the off-ramp approach to the terminal intersection
- non-freeway design hour flow rate: 2,000 veh/hr -12,000 veh/hr

To determine the longest queues on off-ramps and on the crossing road, user enters the corresponding exhibits with the **off-ramp design flow rates** and the **crossing road directional design flow rates**.

REFERENCE

Transportation Research Board. (2010). *Highway capacity manual*. Washington, DC: Transportation Research Board.

INTERCHANGE PERFORMANCE EXHIBITS

In each scenario:

1. The number of auxiliary left-turn lanes on the crossing road matches the number of lanes on the ramp which receives the left-turn traffic.
2. A single auxiliary lane serves right-turn traffic from the crossing road.
3. The number of left-turn lanes is equal to the number of right-turn lanes on each ramp approach.

TABLE 1
Traffic Performance

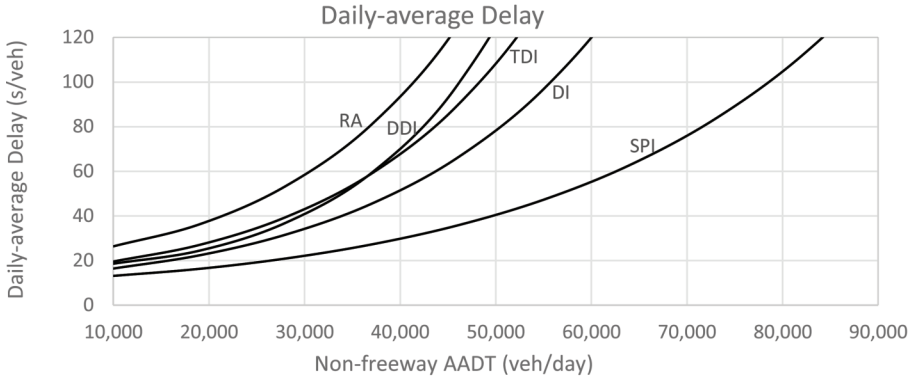
Scenario	Number of Continuous Lanes on Crossroad	Number of Continuous Lanes on Off-ramp	Number of Lanes on Off-ramp Approach	Percent of Non-freeway Traffic on Crossroad	Percent of Non-freeway Traffic on Off-ramp	Page
T 1	2	1	2	80	20	11
T 2	2	1	2	70	30	12
T 3	2	1	2	60	40	13
T 4	2	1	2	50	50	14
T 5	2	1	2	40	60	15
T 6	4	1	4	80	20	16
T 7	4	1	4	70	30	17
T 8	4	1	4	60	40	18
T 9	4	1	4	50	50	19
T 10	4	1	4	40	60	20
T 11	4	2	2	80	20	21
T 12	4	2	2	70	30	22
T 13	4	2	2	60	40	23
T 14	4	2	2	50	50	24
T 15	4	2	2	40	60	25
T 16	4	2	4	80	20	26
T 17	4	2	4	70	30	27
T 18	4	2	4	60	40	28
T 19	4	2	4	50	50	29
T 20	4	2	4	40	60	30
T 21	6	2	4	80	20	31
T 22	6	2	4	70	30	32
T 23	6	2	4	60	40	33
T 24	6	2	4	50	50	34
T 25	6	2	4	40	60	35

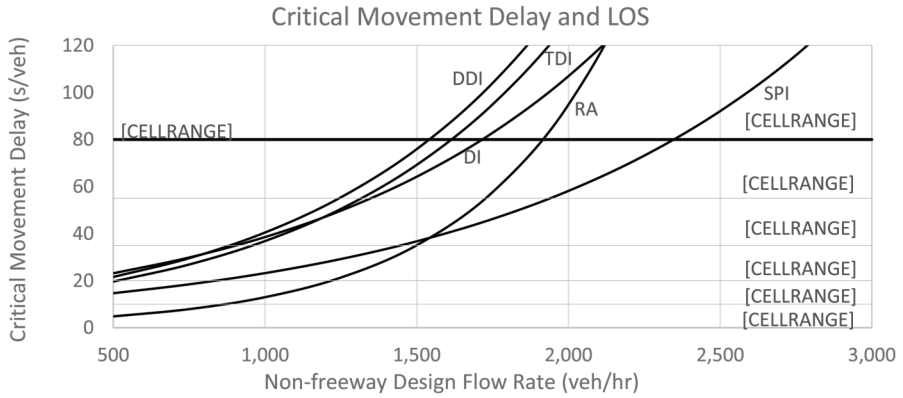
TABLE 2
Operational Footprint

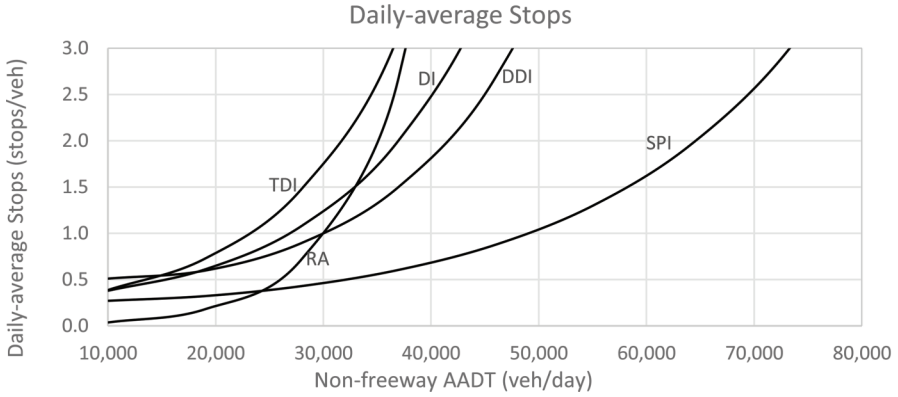
Scenario	Number of Continuous Lanes on Crossroad	Number of Continuous Lanes on Off-ramp	Number of Lanes on Off-ramp Approach	Non-freeway Design Flow Rate	Page
F 1	2	1	2	2,000	36
F 2	2	1	2	3,000	37
F 3	2	1	2	4,000	38
F 4	2	1	2	5,000	39
F 5	4	1	4	3,000	40
F 6	4	1	4	4,000	41
F 7	4	1	4	5,000	42
F 8	4	1	4	6,000	43
F 9	4	1	4	7,000	44
F 10	4	1	4	8,000	45
F 11	4	2	2	3,000	46
F 12	4	2	2	4,000	47
F 13	4	2	2	5,000	48
F 14	4	2	2	6,000	49
F 15	4	2	2	7,000	50
F 16	4	2	2	8,000	51
F 17	4	2	2	9,000	52
F 18	4	2	2	10,000	53
F 19	4	2	4	3,000	54
F 20	4	2	4	4,000	55
F 21	4	2	4	5,000	56
F 22	4	2	4	6,000	57
F 23	4	2	4	7,000	58
F 24	4	2	4	8,000	59
F 25	4	2	4	9,000	60
F 26	4	2	4	10,000	61
F 27	6	2	4	4,000	62
F 28	6	2	4	5,000	63
F 29	6	2	4	6,000	64
F30	6	2	4	7,000	65
F 31	6	2	4	8,000	66
F 32	6	2	4	9,000	67
F 33	6	2	4	10,000	68
F 34	6	2	4	11,000	69
F 35	6	2	4	12,000	70

T 1 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	20
Percentage of crossing-road volume	80

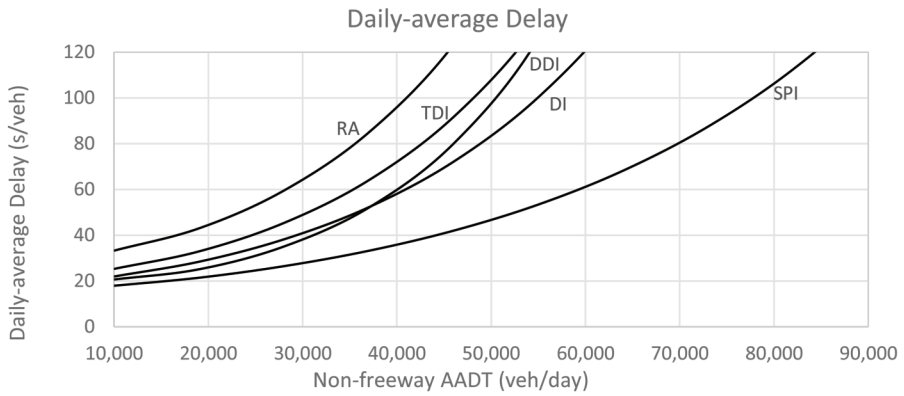


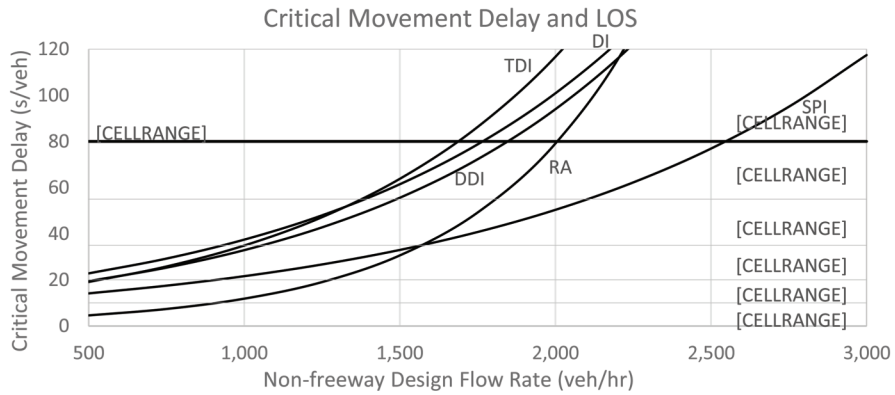


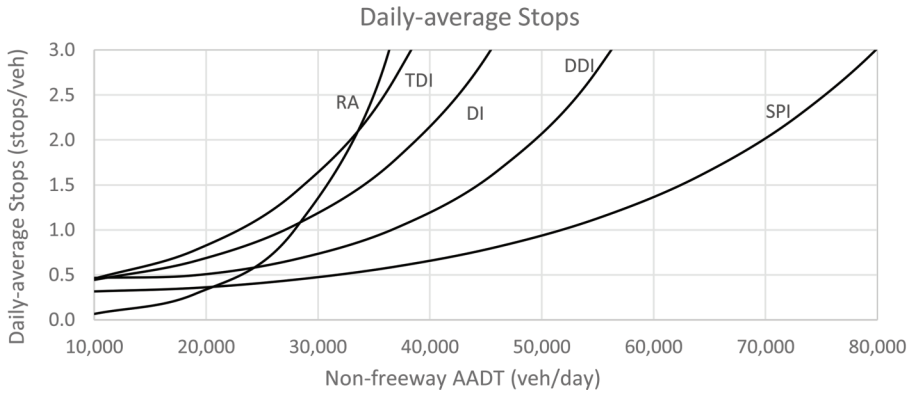


T 2 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	30
Percentage of crossing-road volume	70

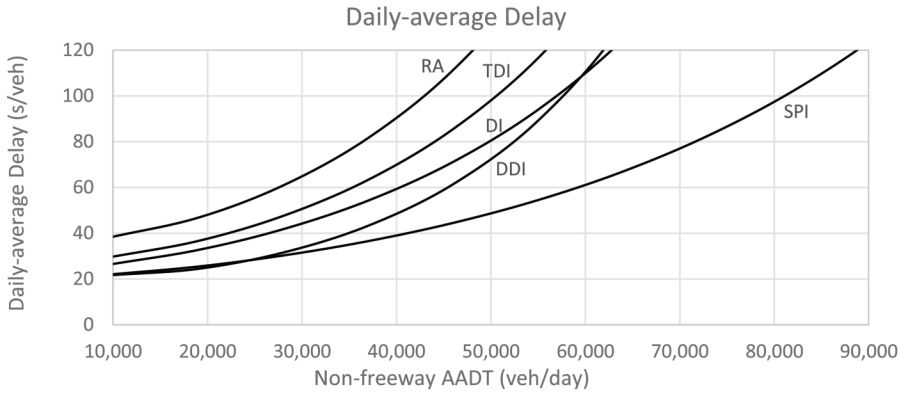


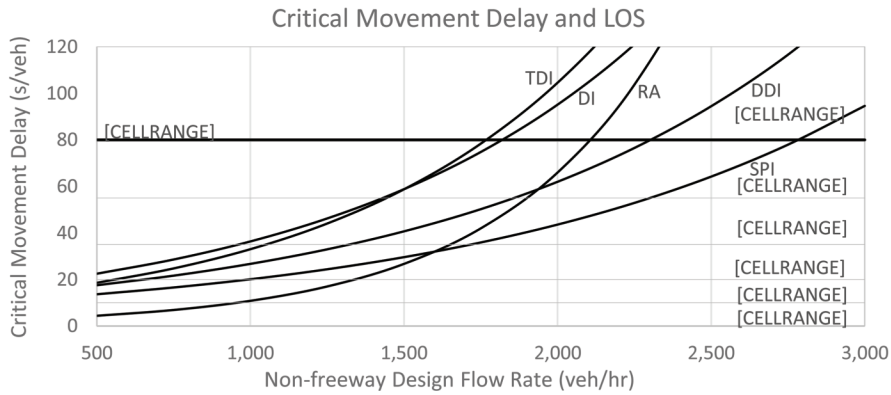


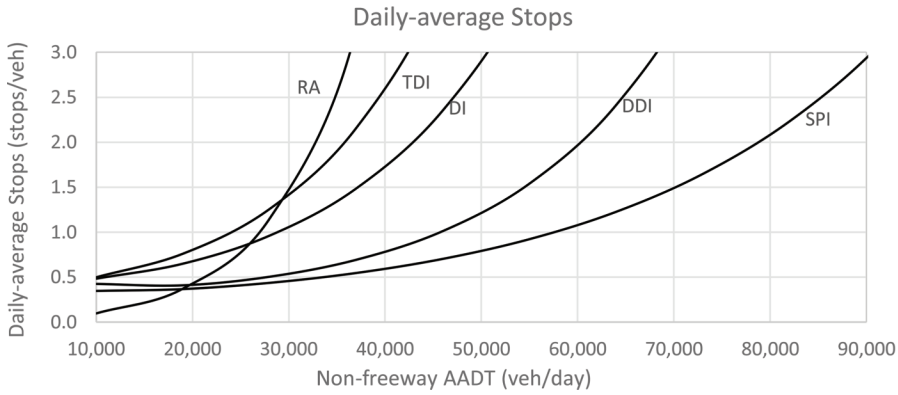


T 3 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	40
Percentage of crossing-road volume	60

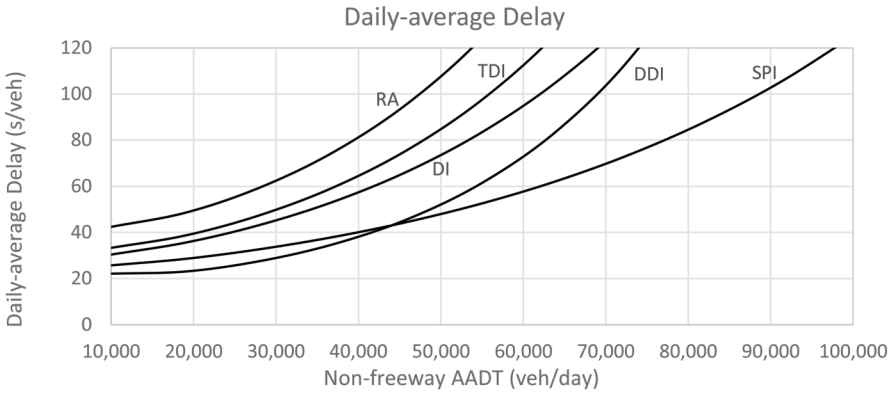


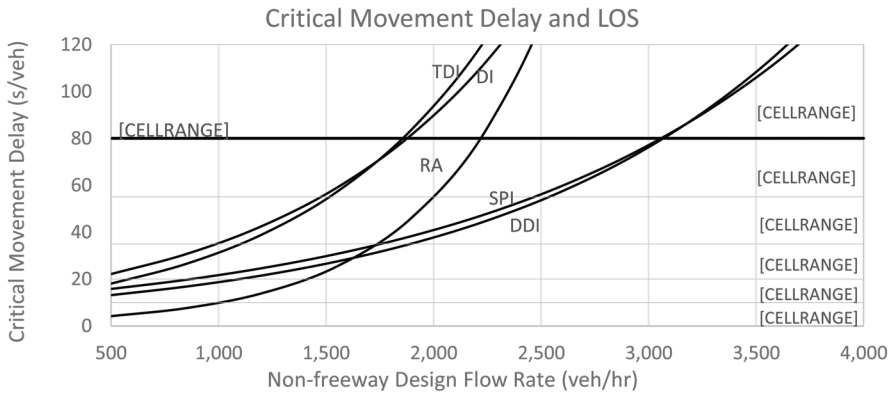


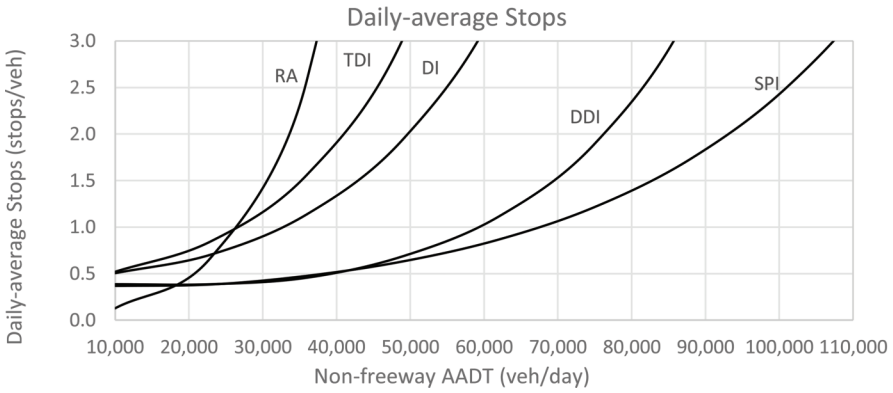


T 4 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	50
Percentage of crossing-road volume	50

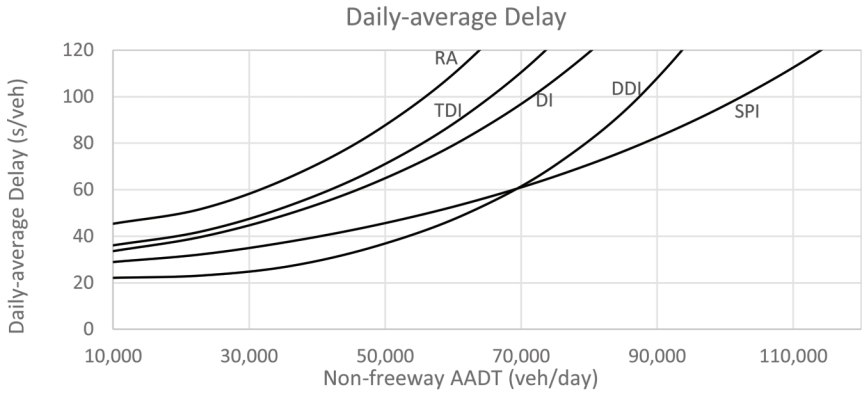


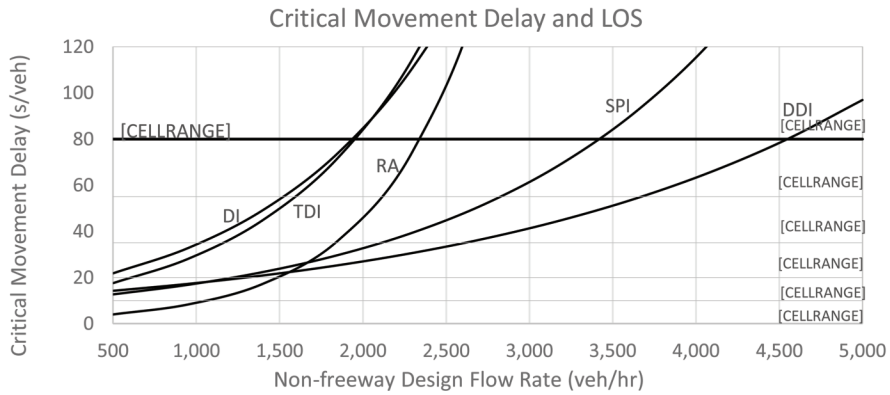


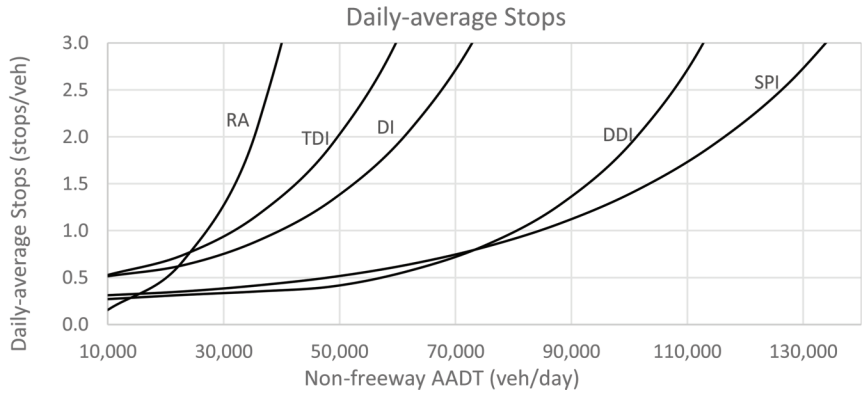


T 5 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	60
Percentage of crossing-road volume	40

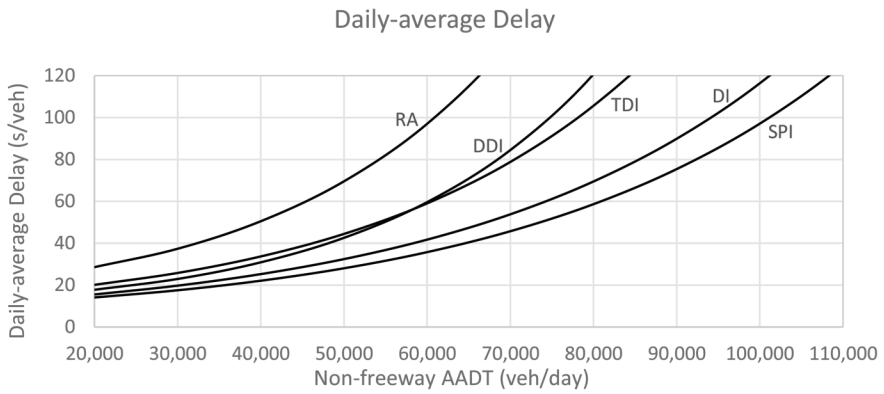


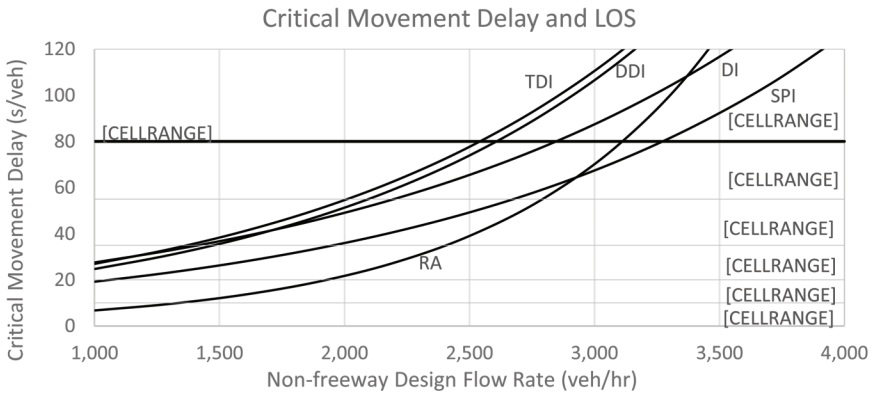


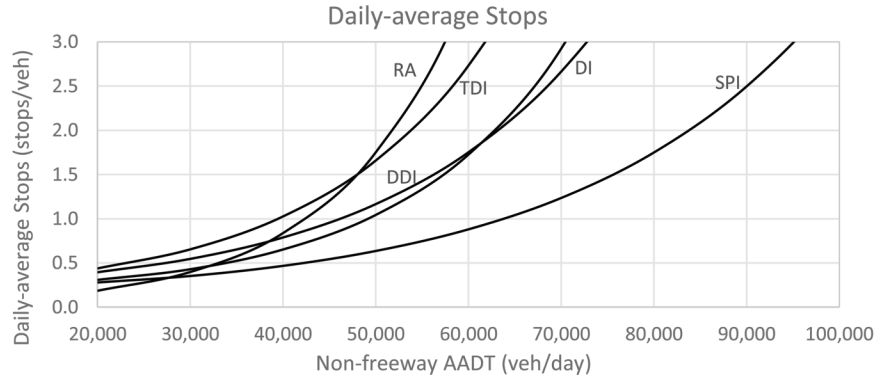


T 6 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	20
Percentage of crossing-road volume	80

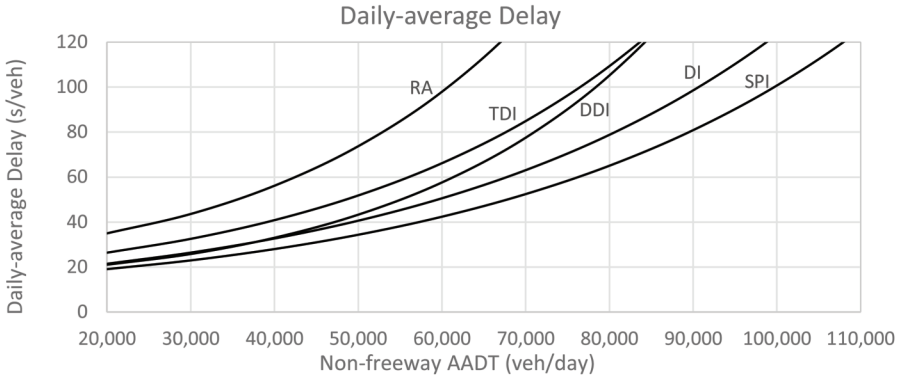


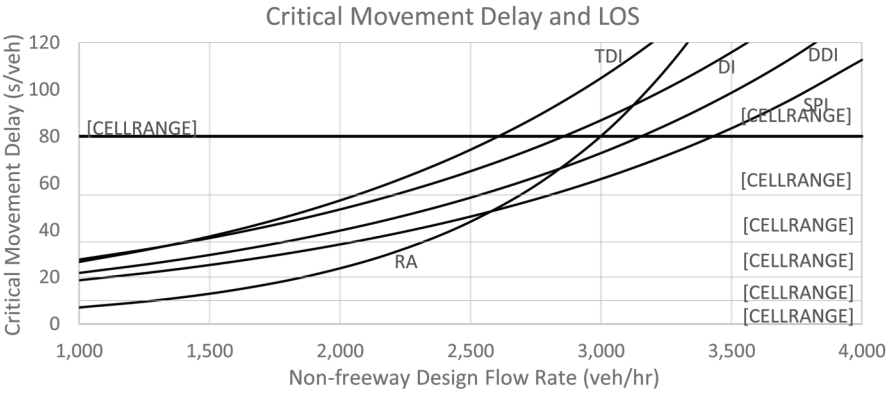


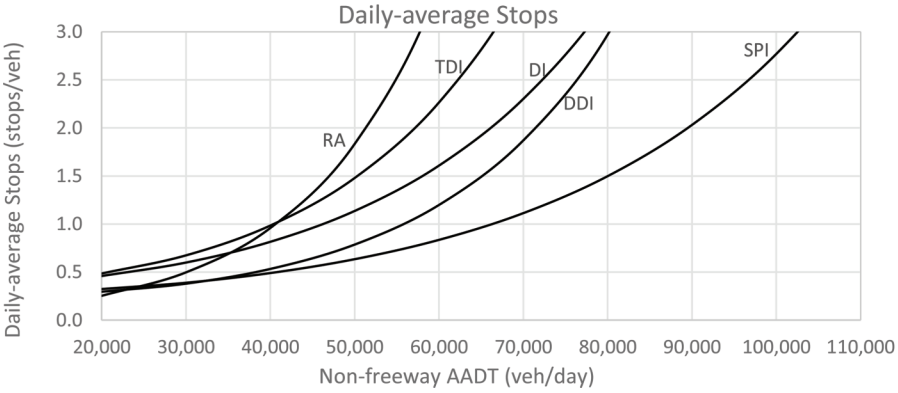


T 7 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	30
Percentage of crossing-road volume	70

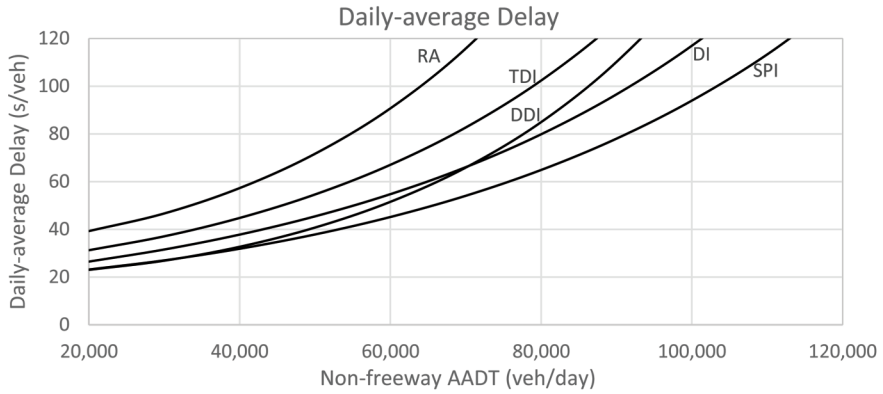


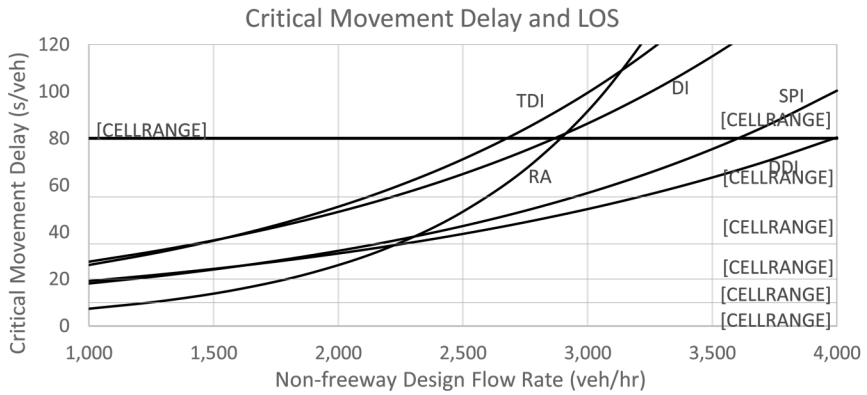


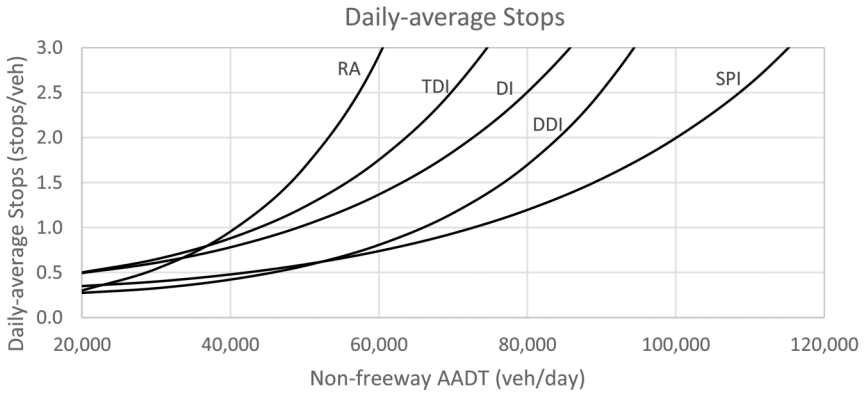


T 8 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	40
Percentage of crossing-road volume	60

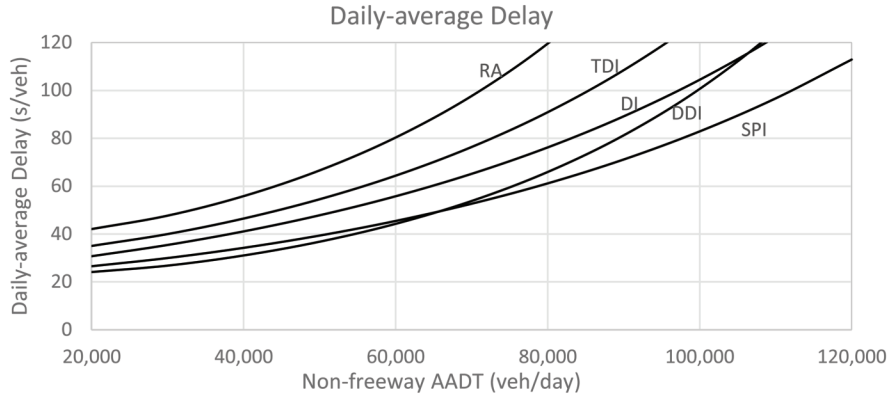


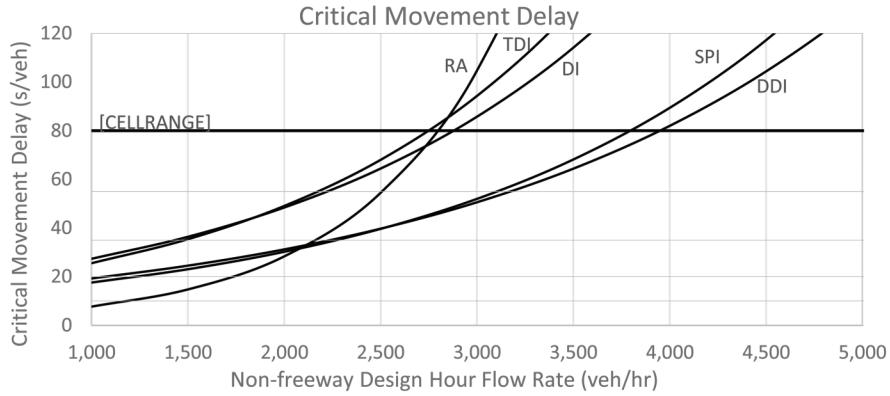


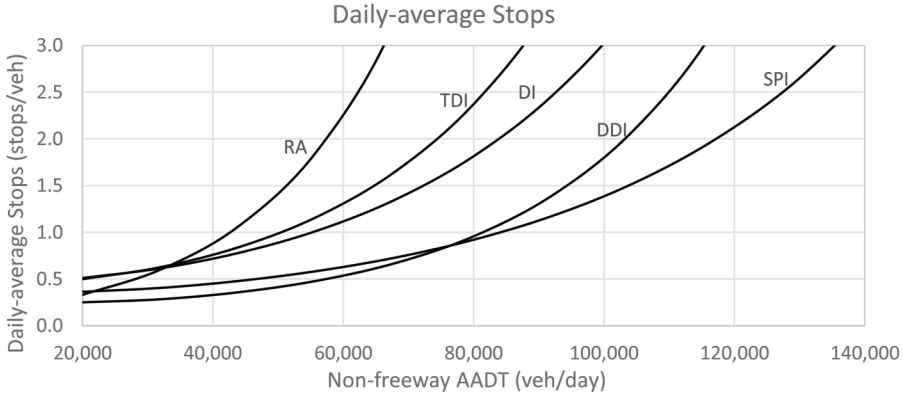


T 9 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	50
Percentage of crossing-road volume	50

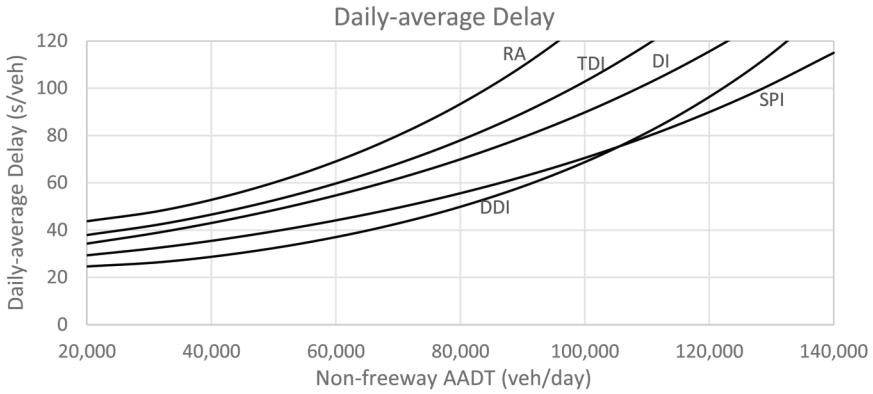


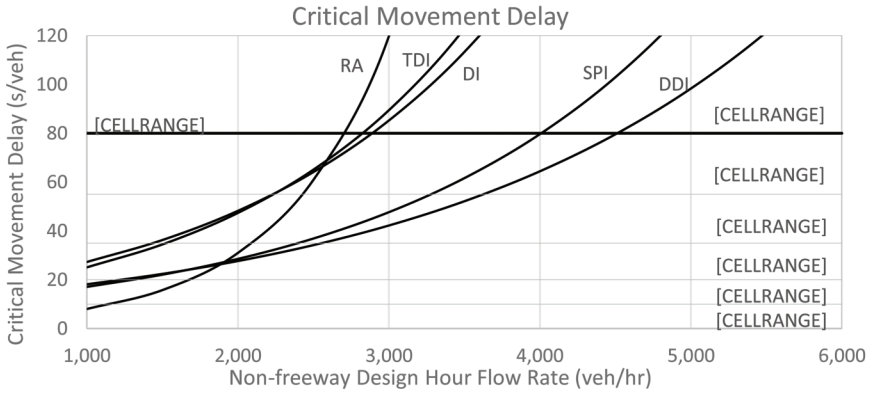


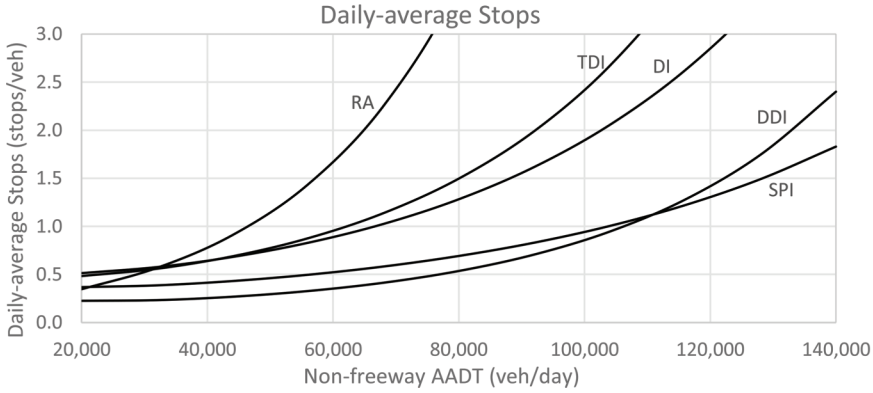


T 10 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	60
Percentage of crossing-road volume	40

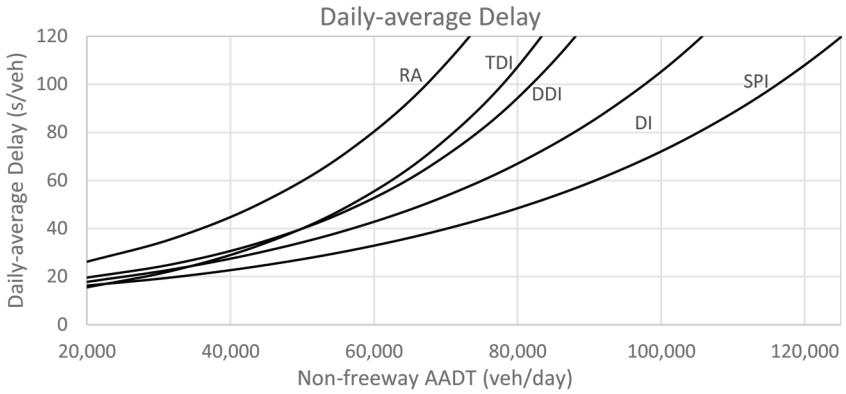


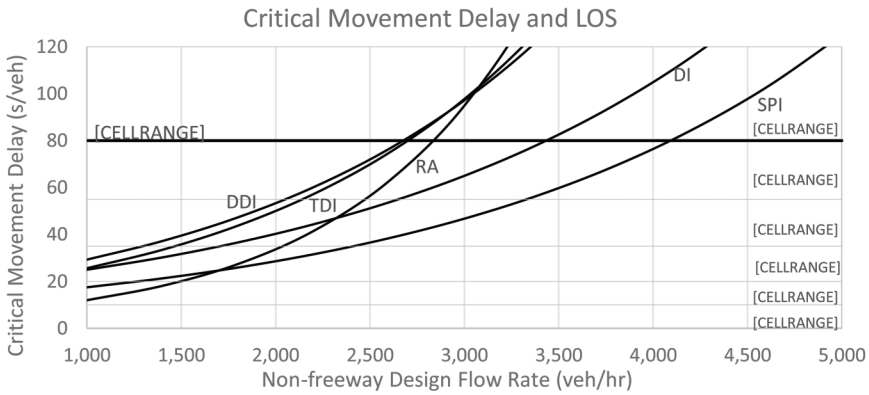


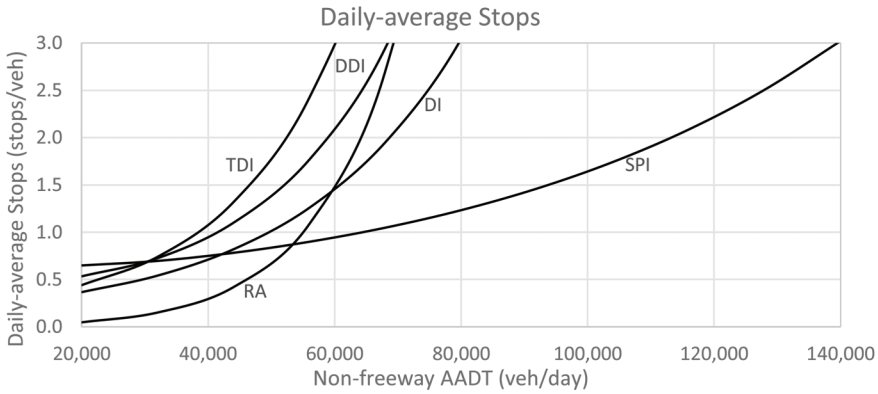


T 11 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	20
Percentage of crossing-road volume	80

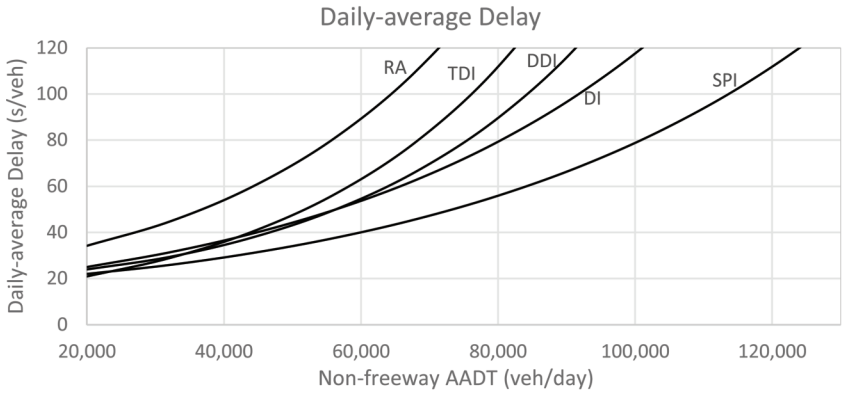


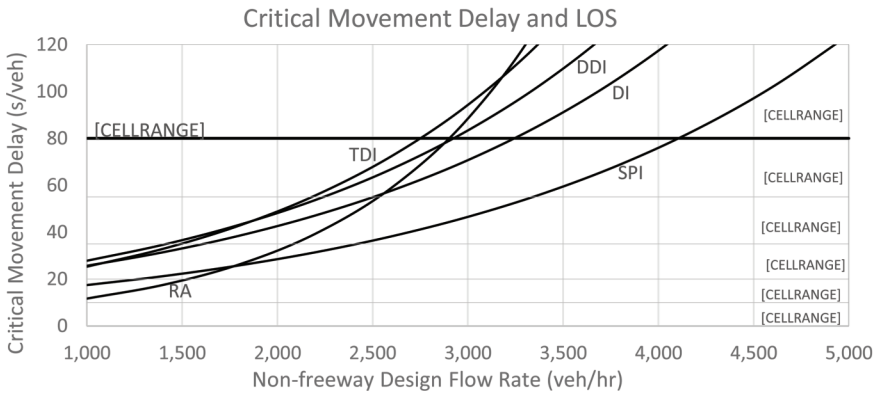


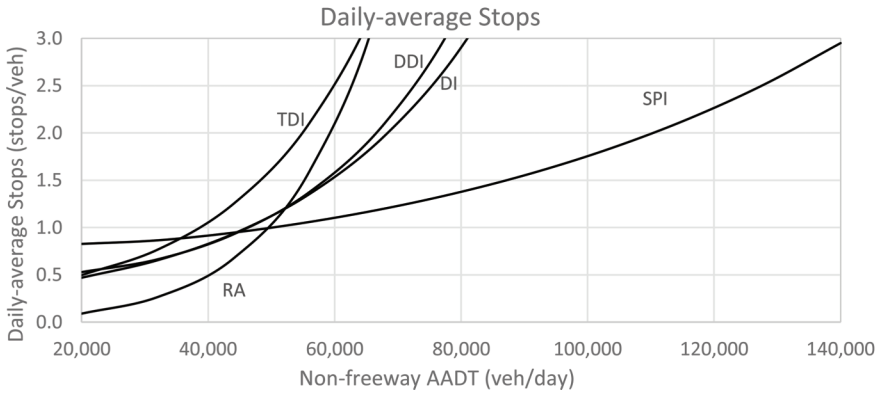


T 12 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	30
Percentage of crossing-road volume	70

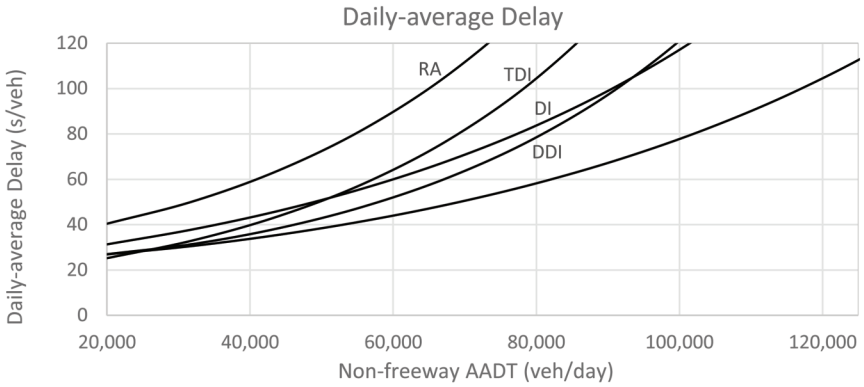


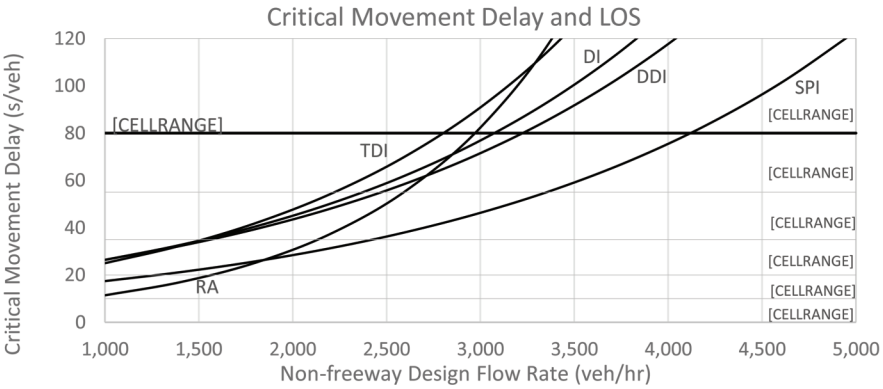


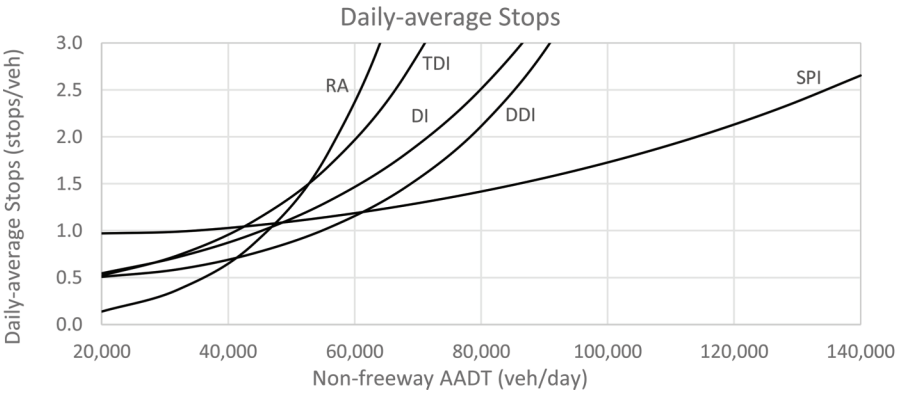


T 13 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	40
Percentage of crossing-road volume	60

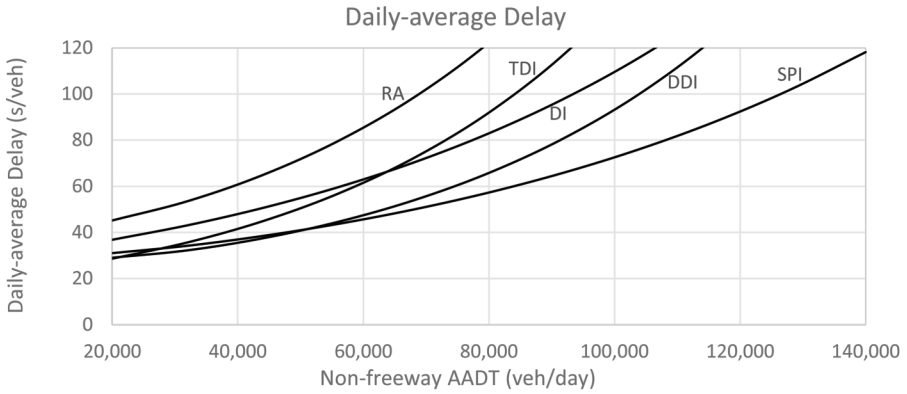


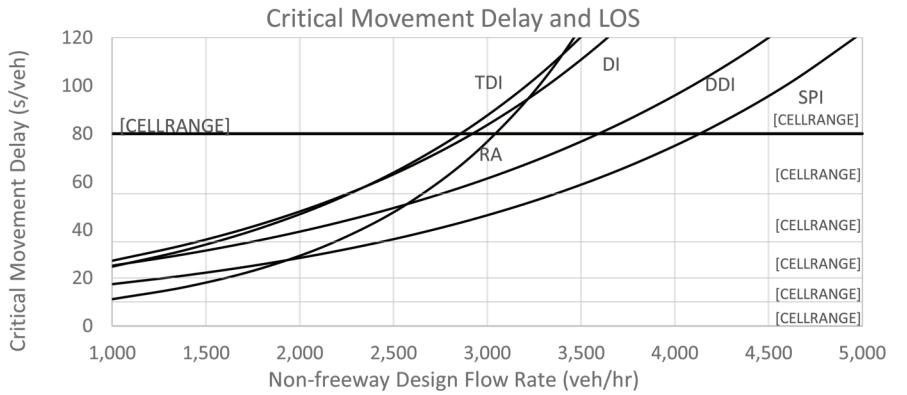


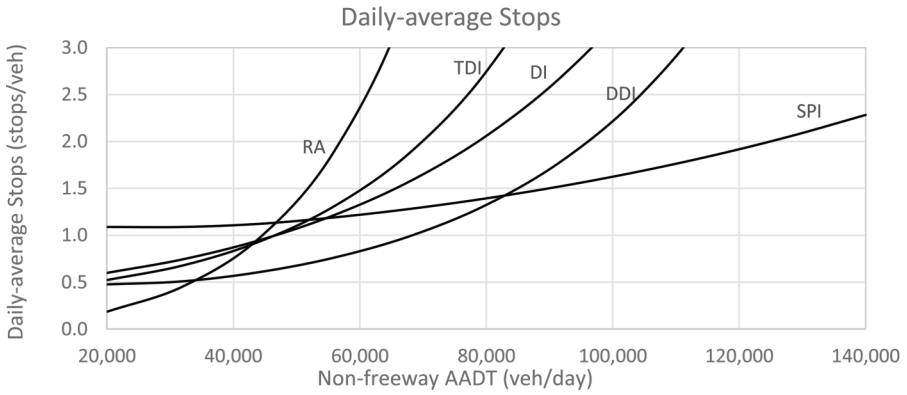


T 14 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	50
Percentage of crossing-road volume	50

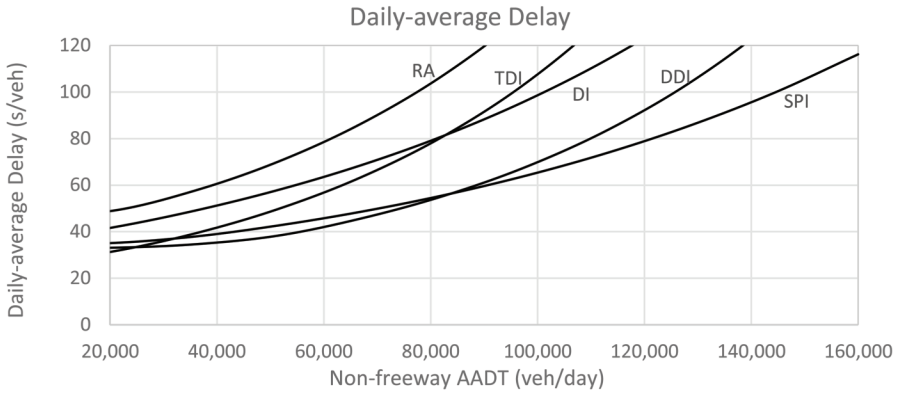


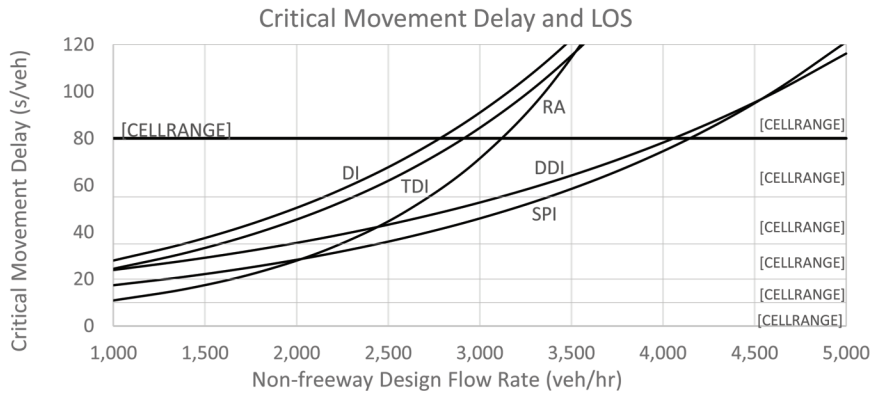


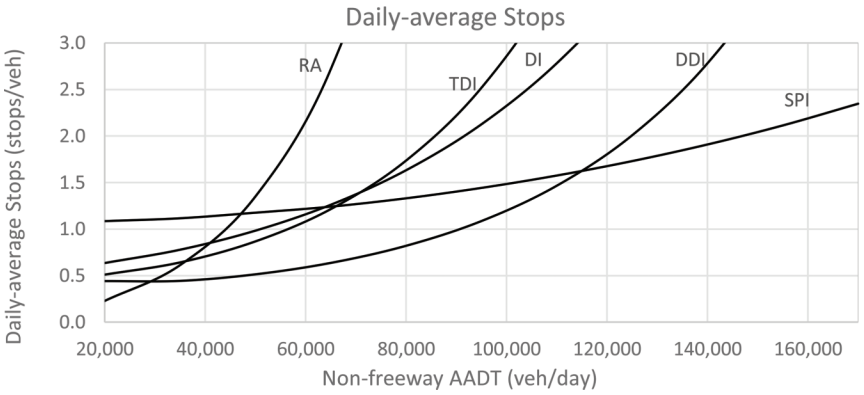


T 15 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Percentage of off-ramp volume	60
Percentage of crossing-road volume	40

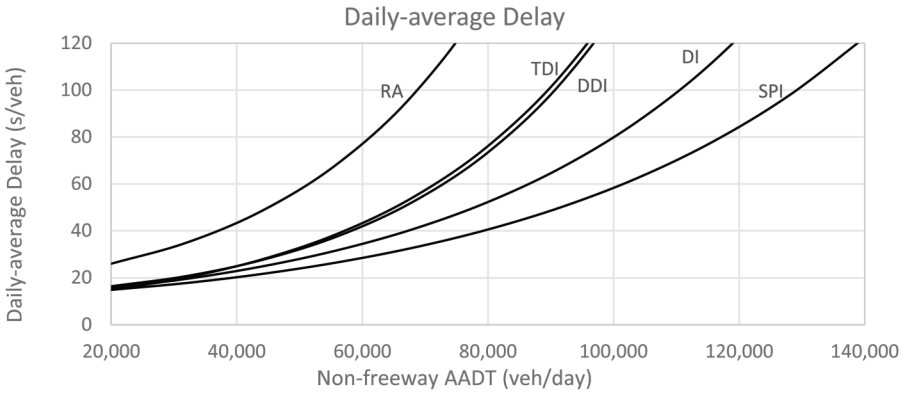


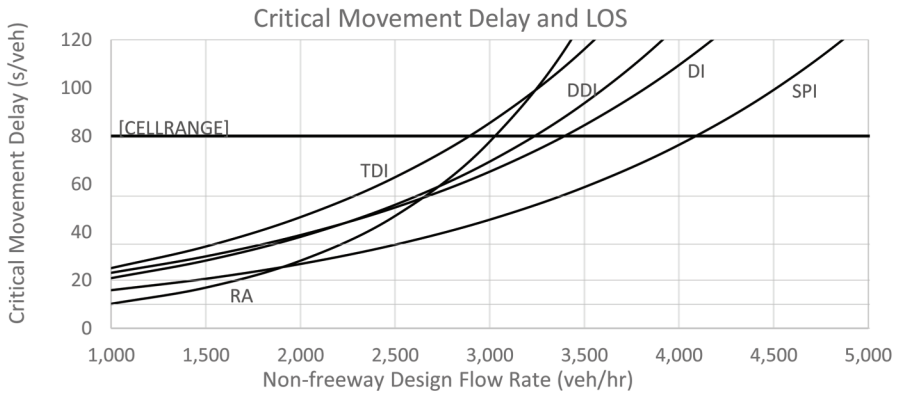


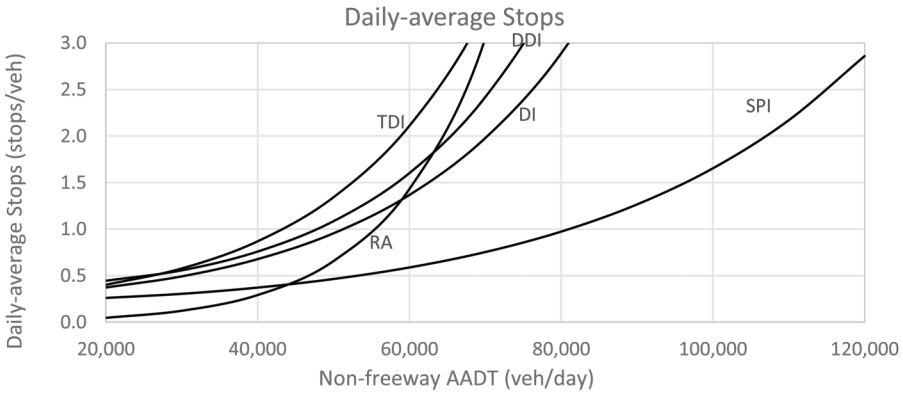


T 16 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	20
Percentage of crossing-road volume	80

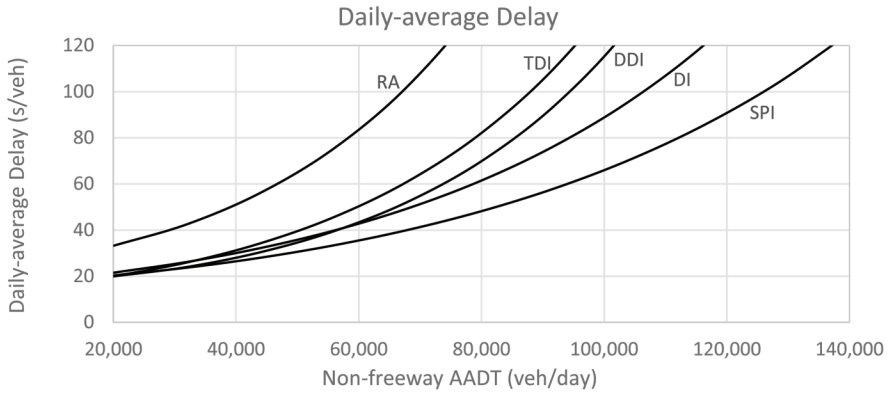


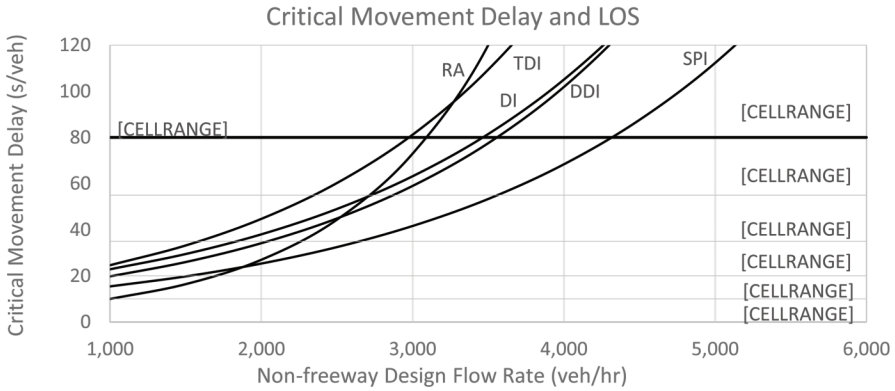


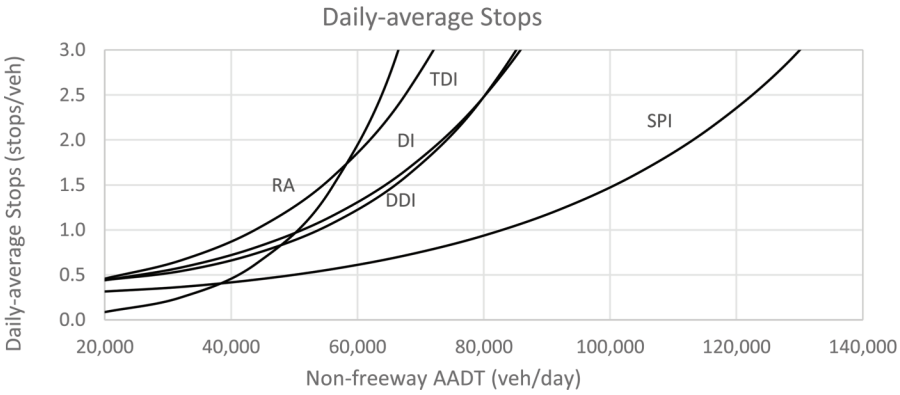


T 17 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	30
Percentage of crossing-road volume	70

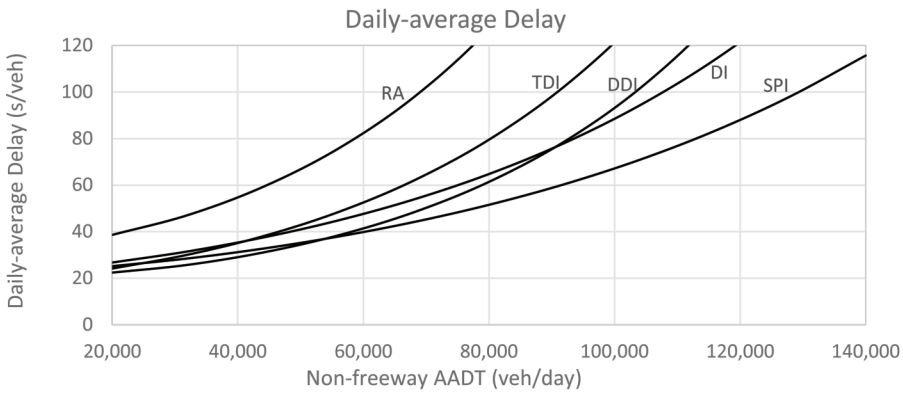


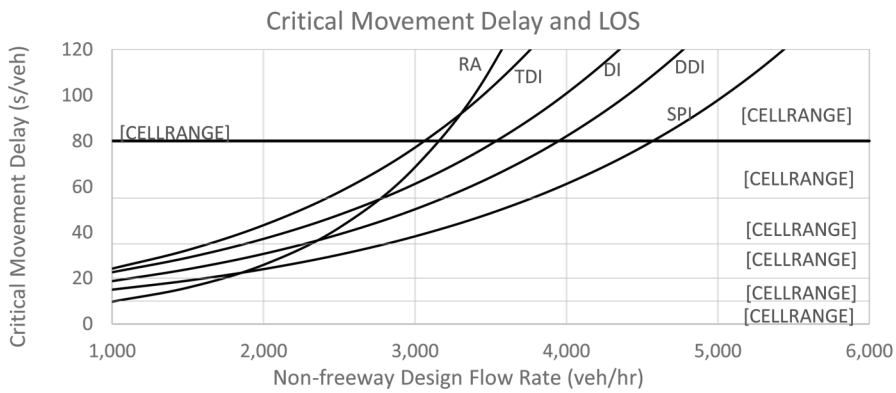


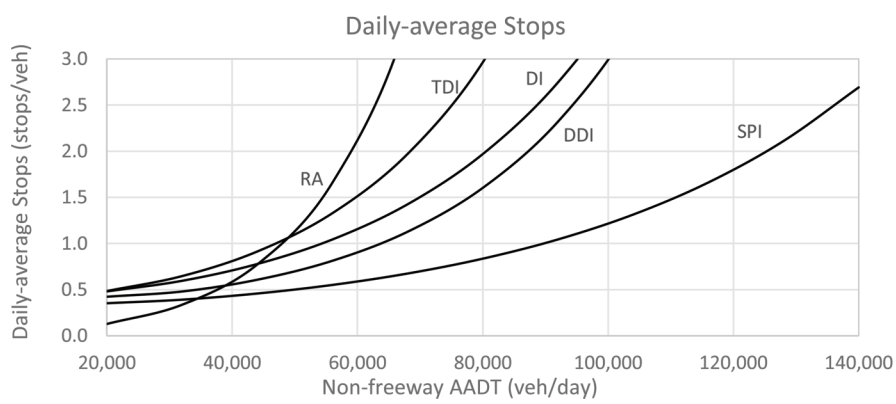


T 18 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	40
Percentage of crossing-road volume	60

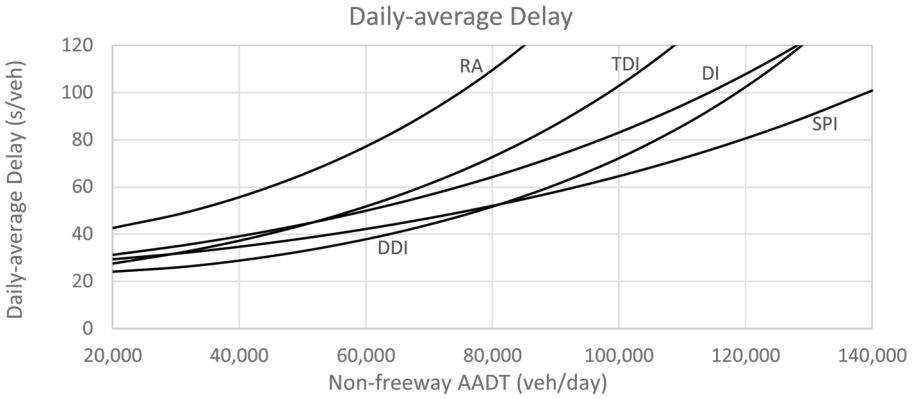


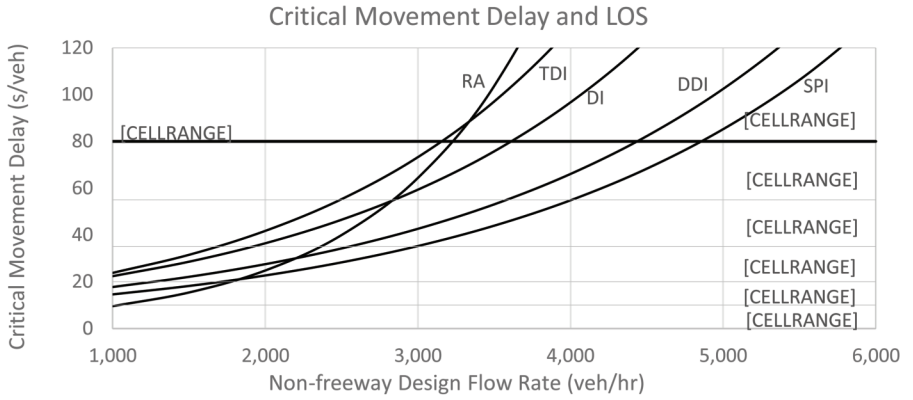


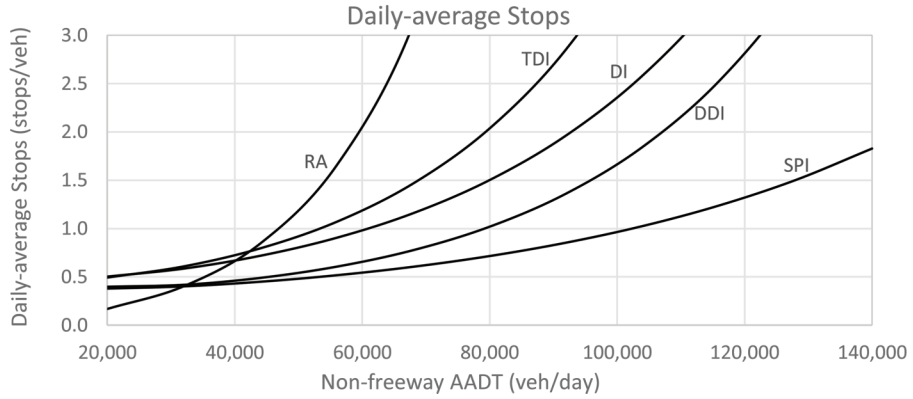


T 19 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	50
Percentage of crossing-road volume	50

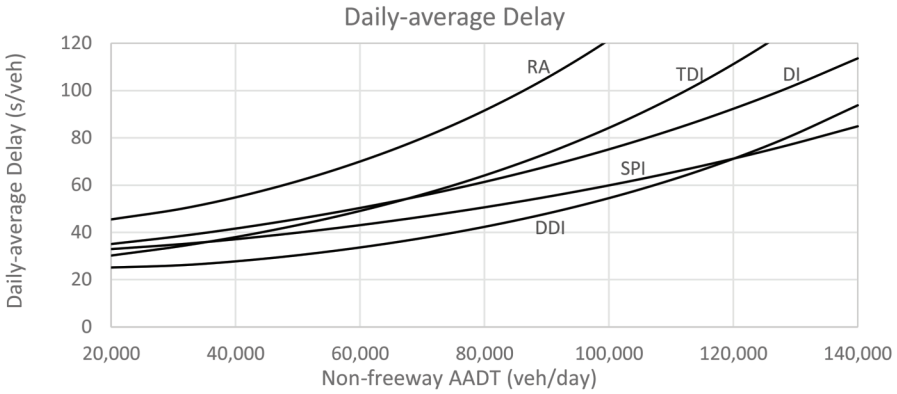


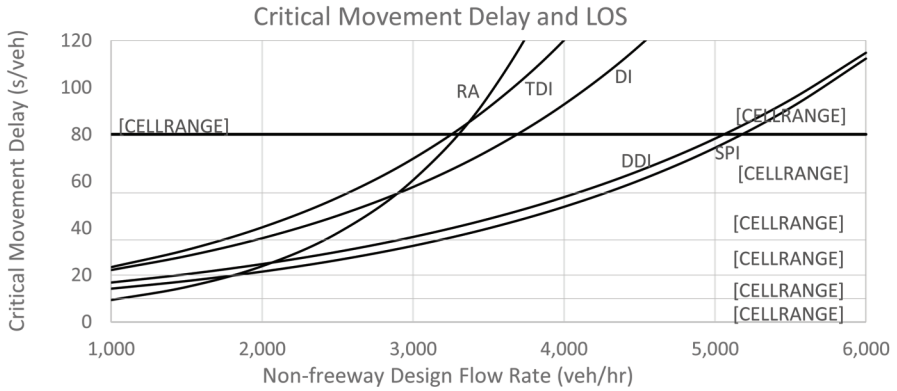


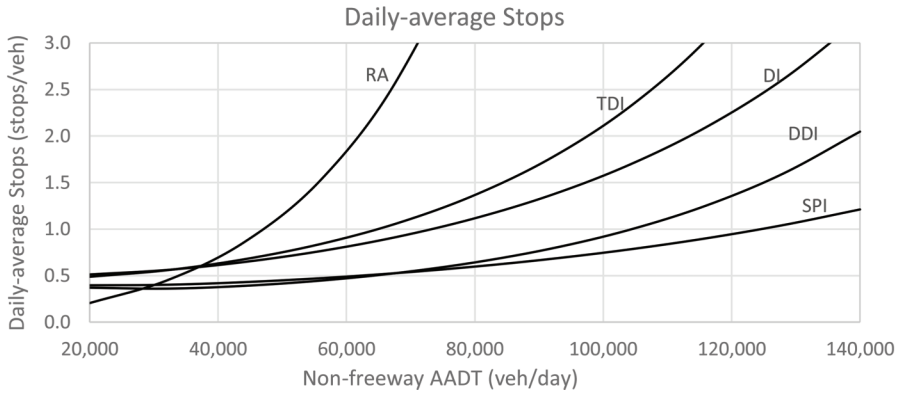


T 20 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	60
Percentage of crossing-road volume	40

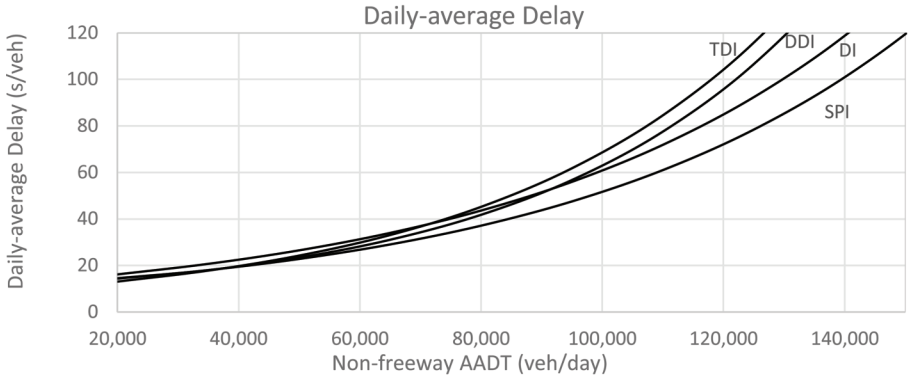


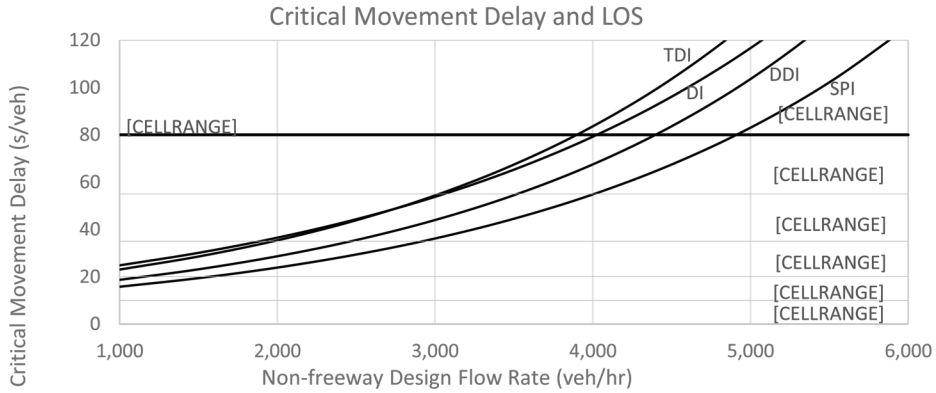


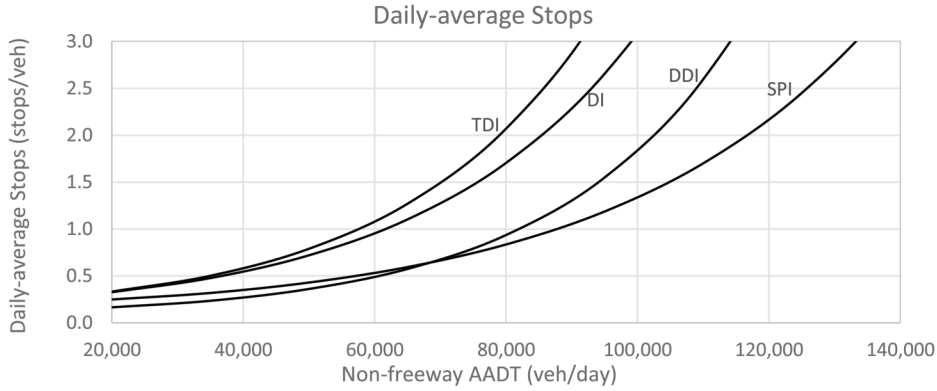


T 21 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	20
Percentage of crossing-road volume	80

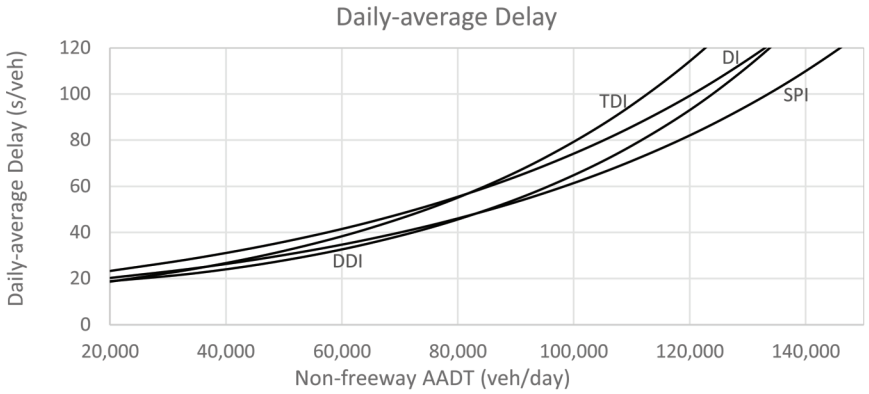


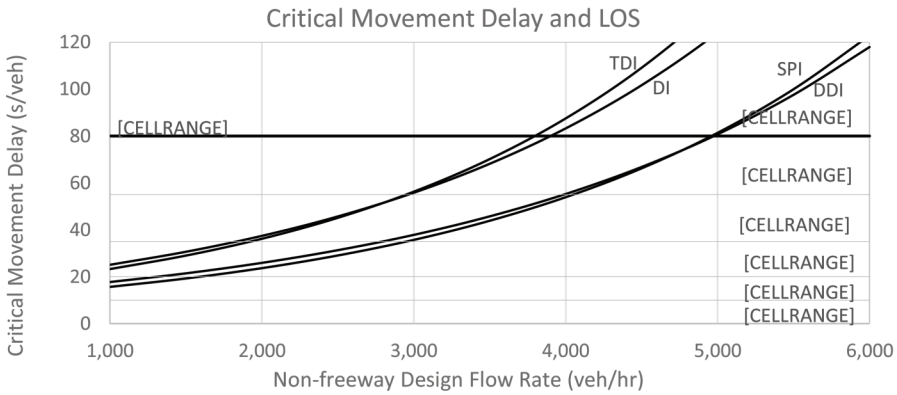


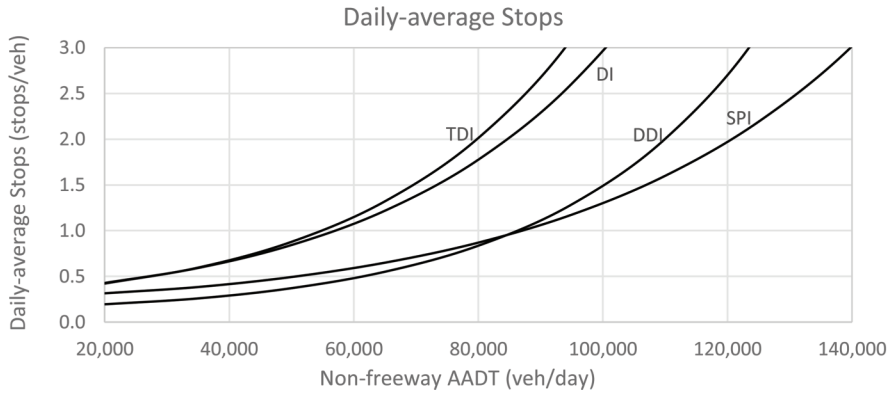


T 22 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	30
Percentage of crossing-road volume	70

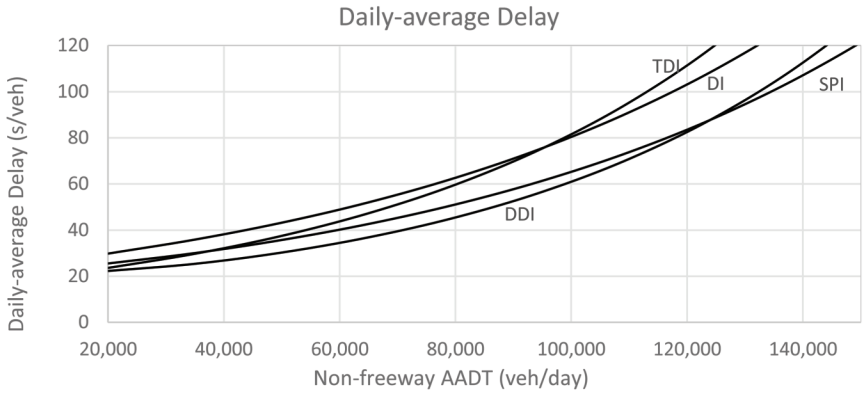


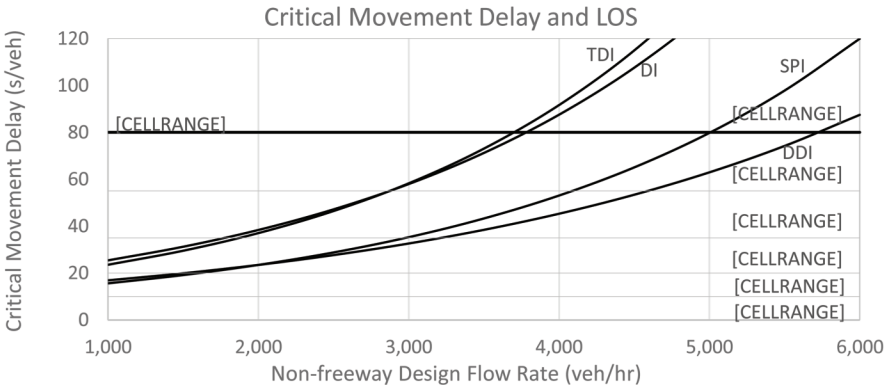


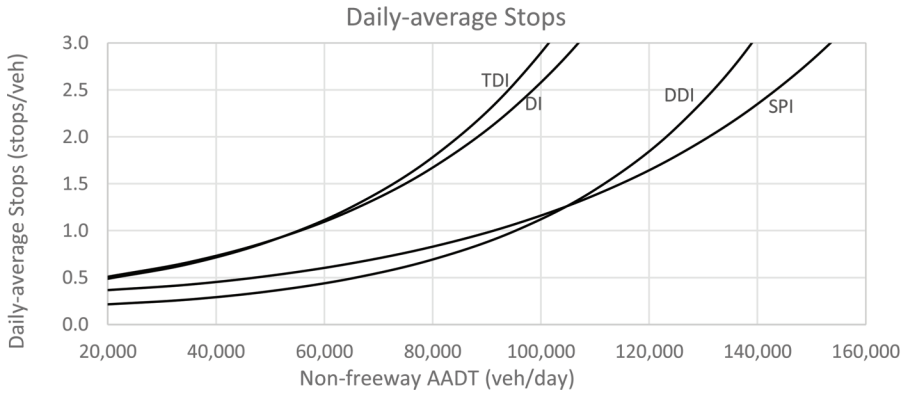


T 23 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	40
Percentage of crossing-road volume	60

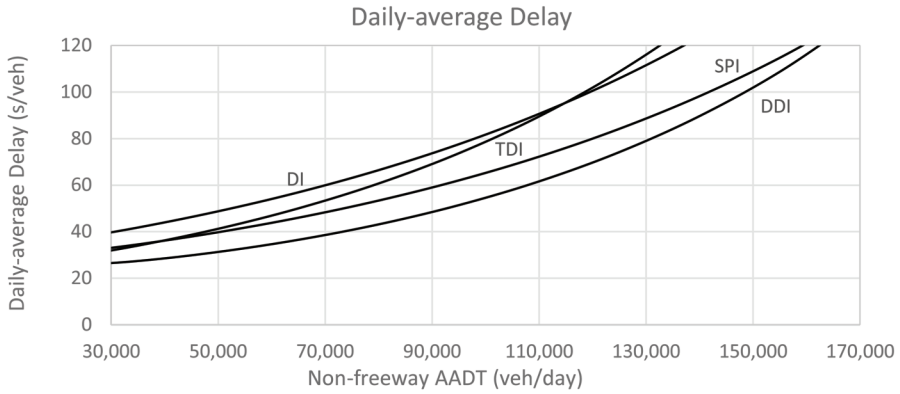


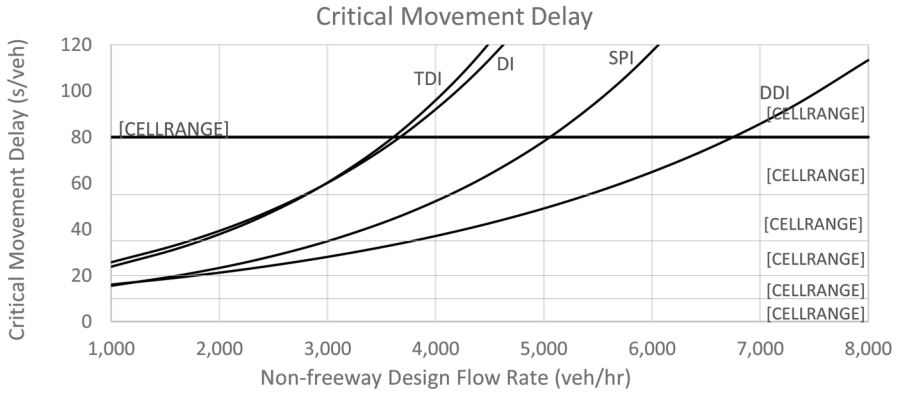


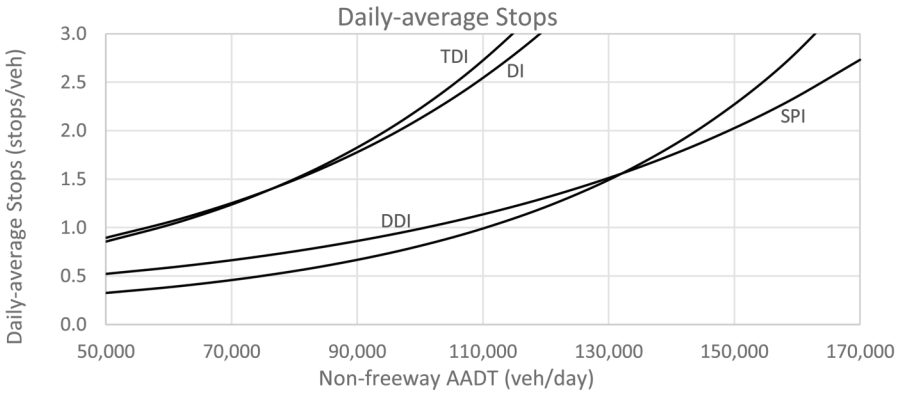


T 24 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	50
Percentage of crossing-road volume	50

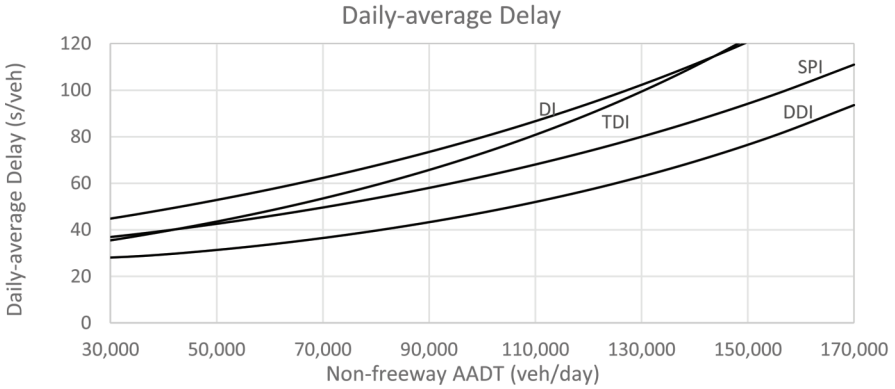


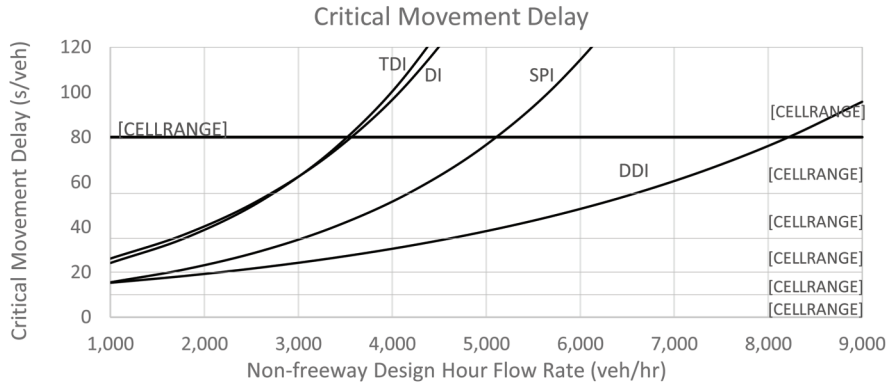


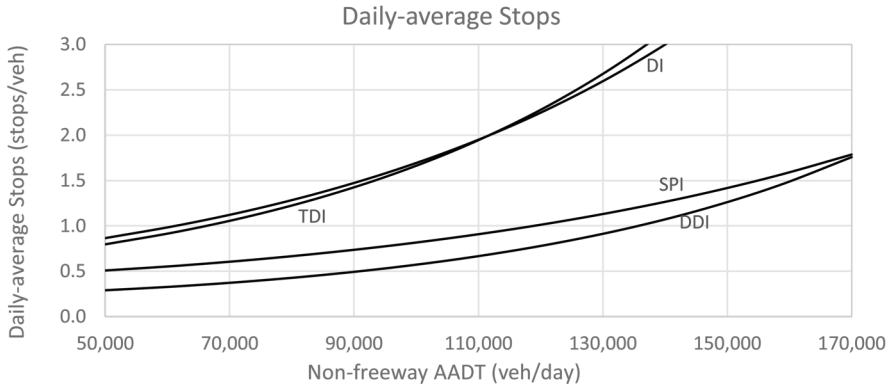


25 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Percentage of off-ramp volume	60
Percentage of crossing-road volume	40

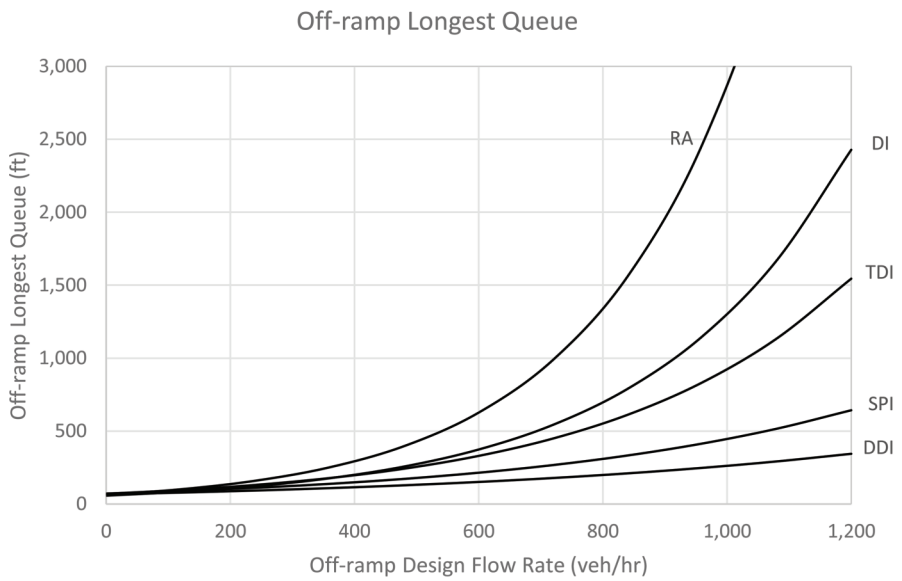


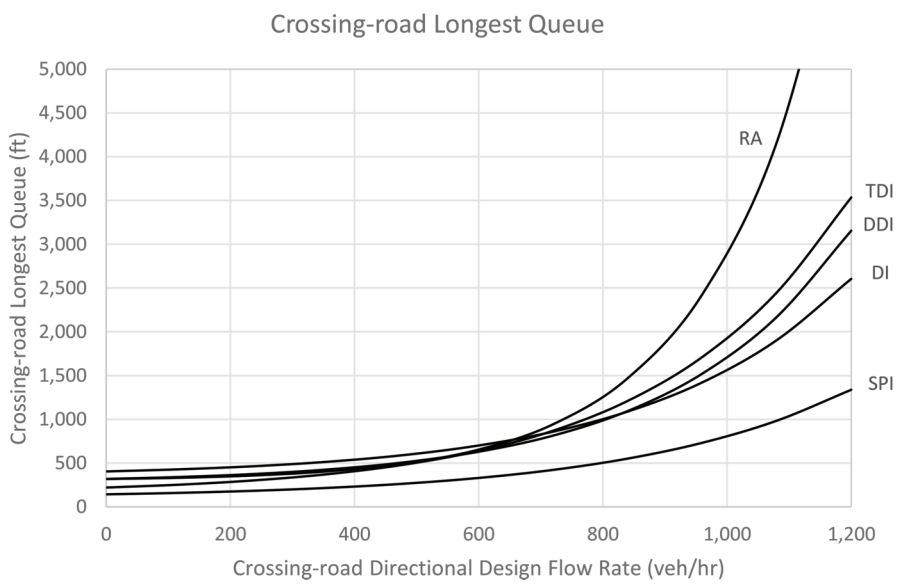




F 1 Geometric and Traffic Conditions

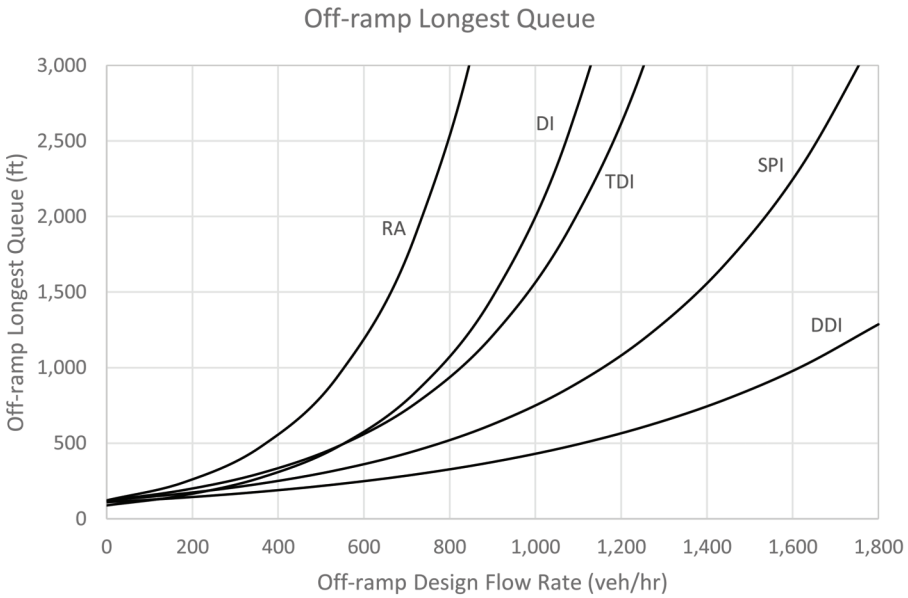
Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	2,000

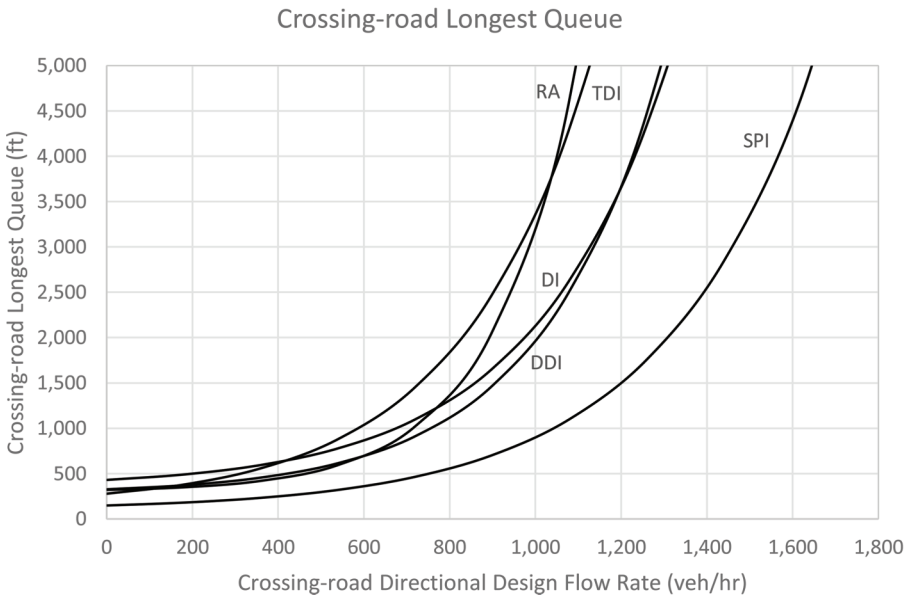




F 2 Geometric and Traffic Conditions

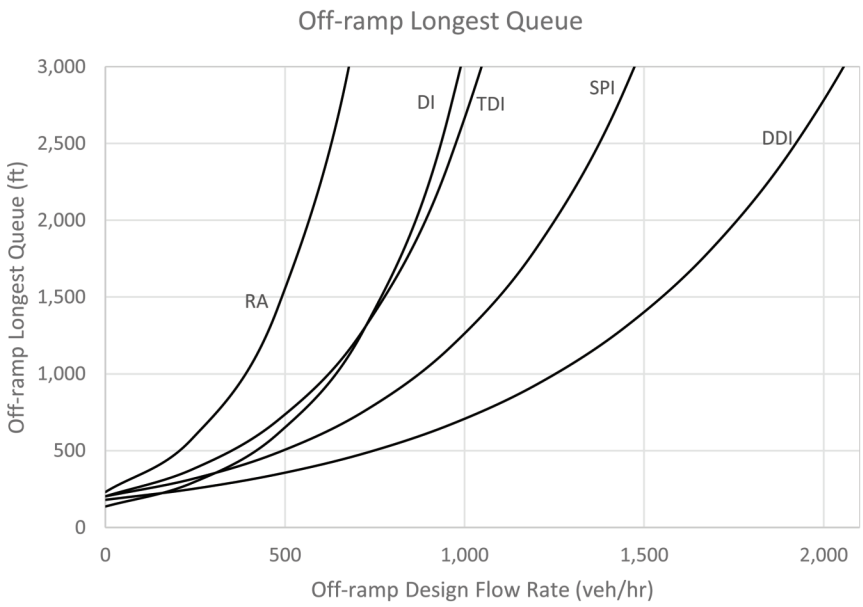
Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	3,000

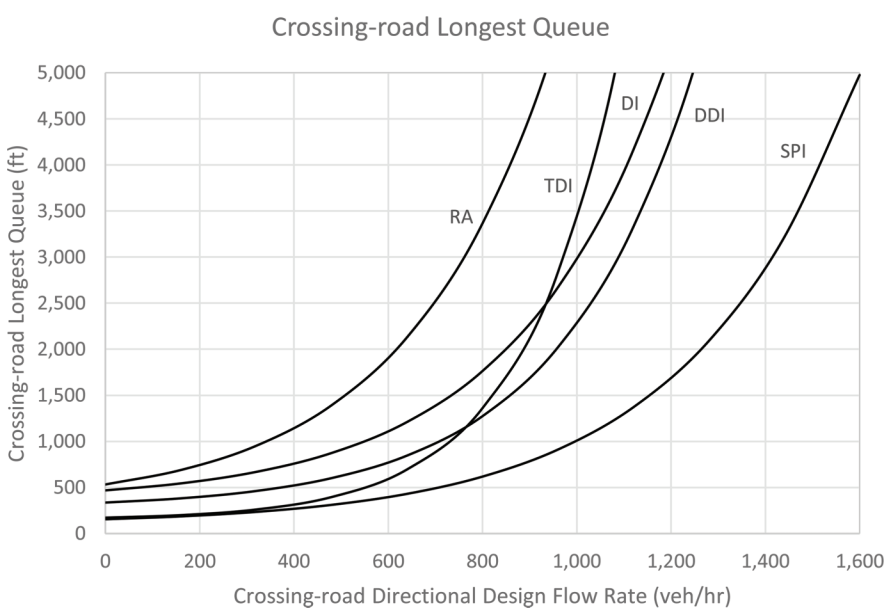




F 3 Geometric and Traffic Conditions

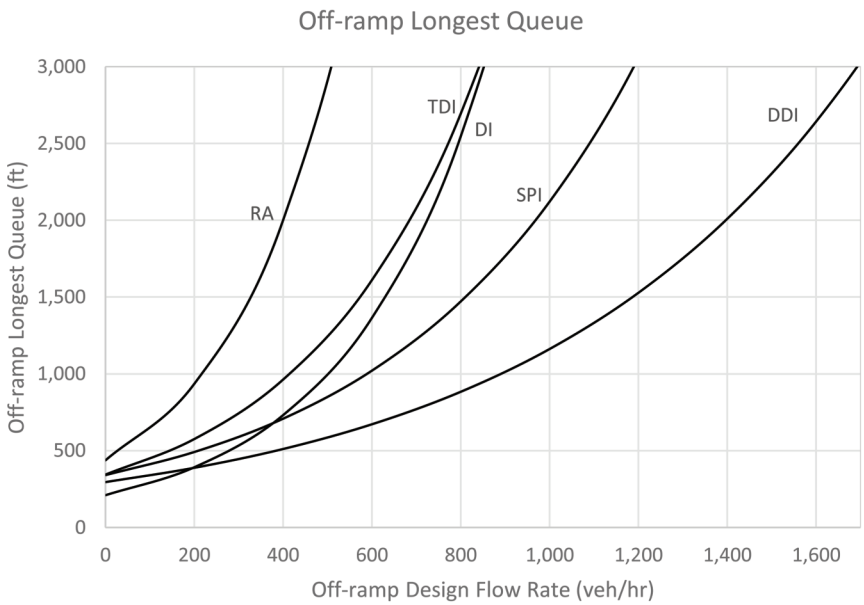
Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	4,000

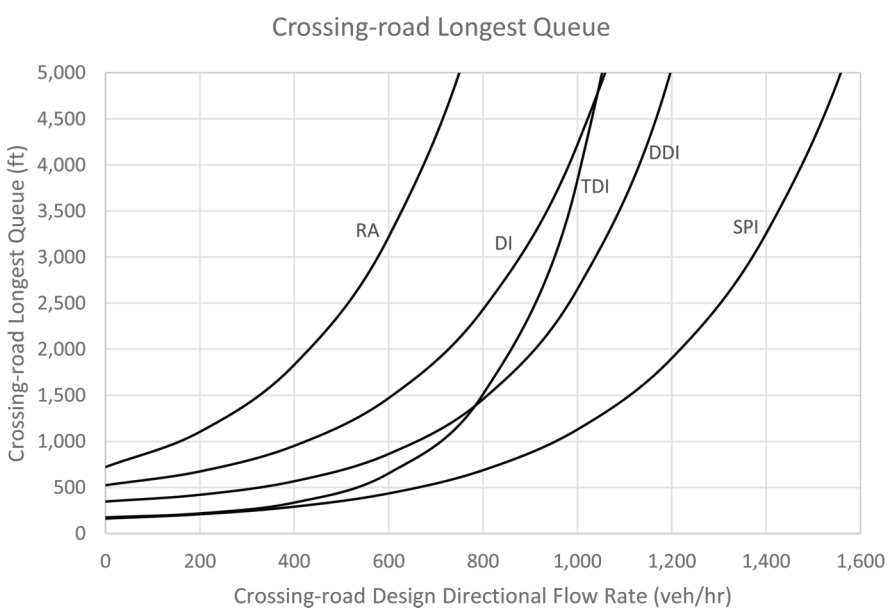




F 4 Geometric and Traffic Conditions

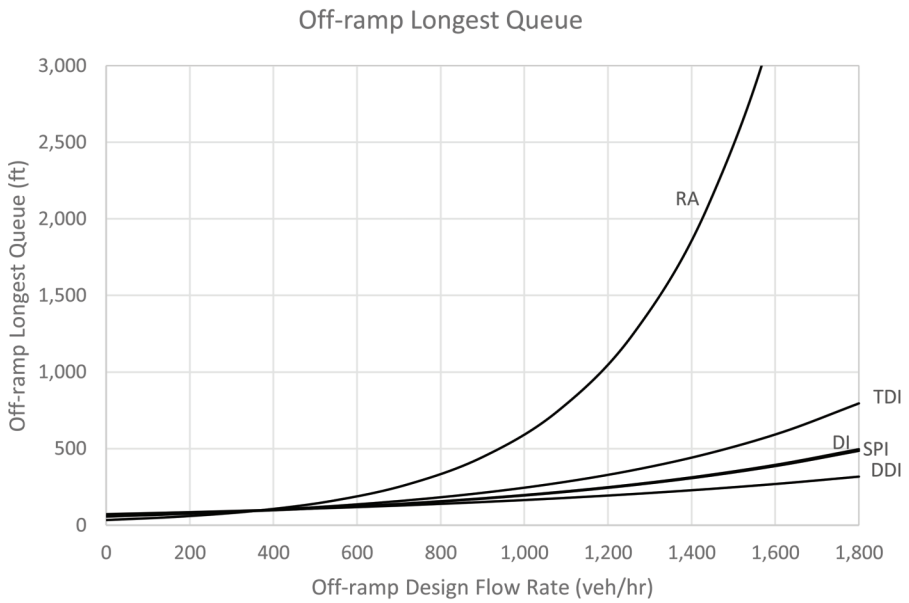
Number of continuous lanes on crossing-road	2
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	5,000

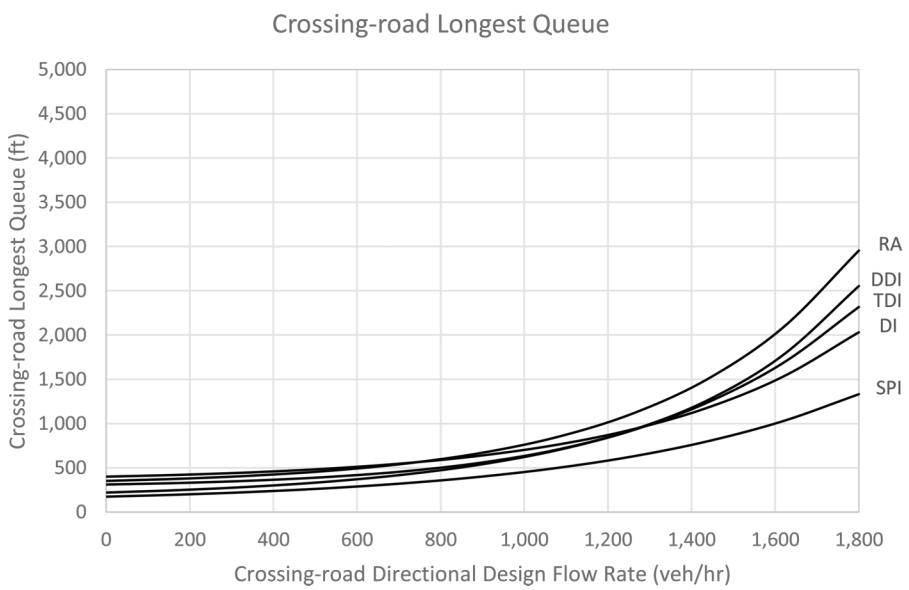




F 5 Geometric and Traffic Conditions

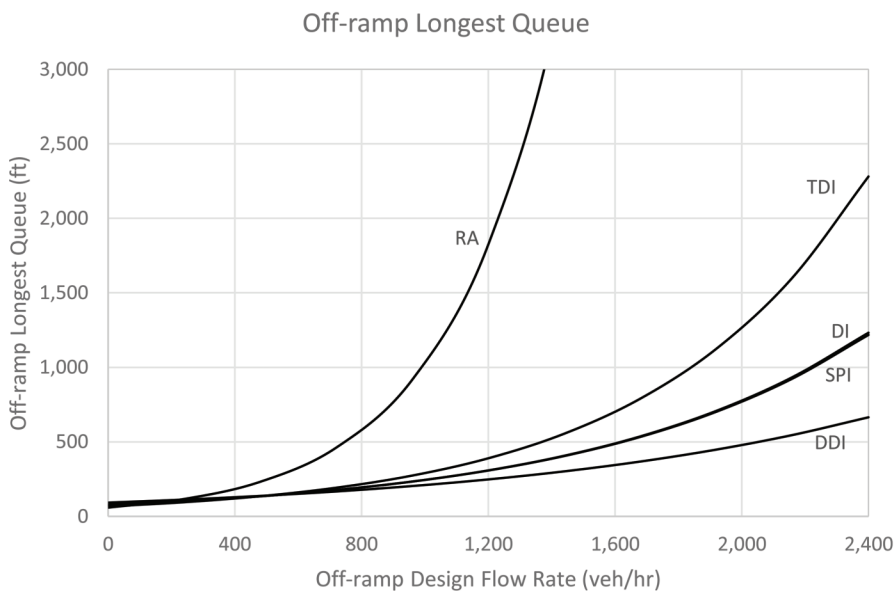
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	3,000

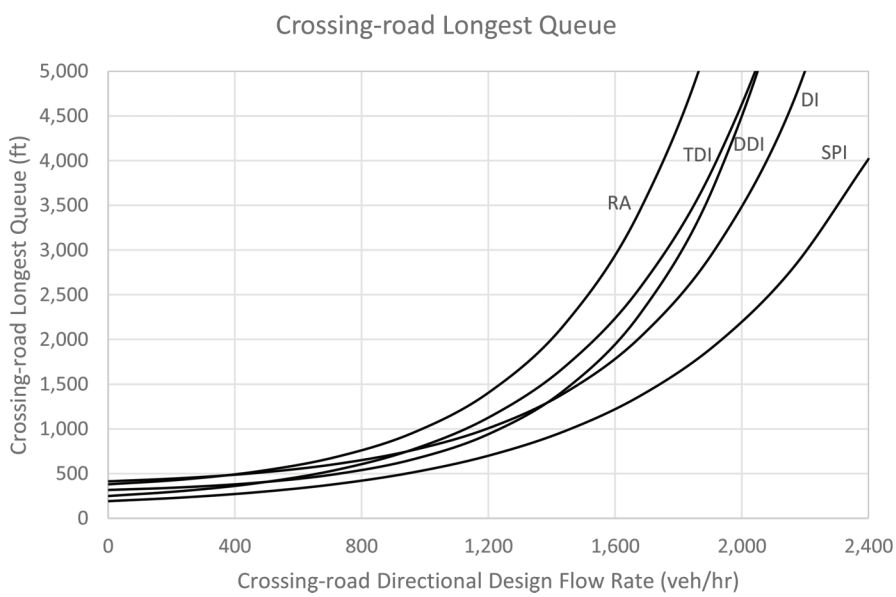




F 6 Geometric and Traffic Conditions

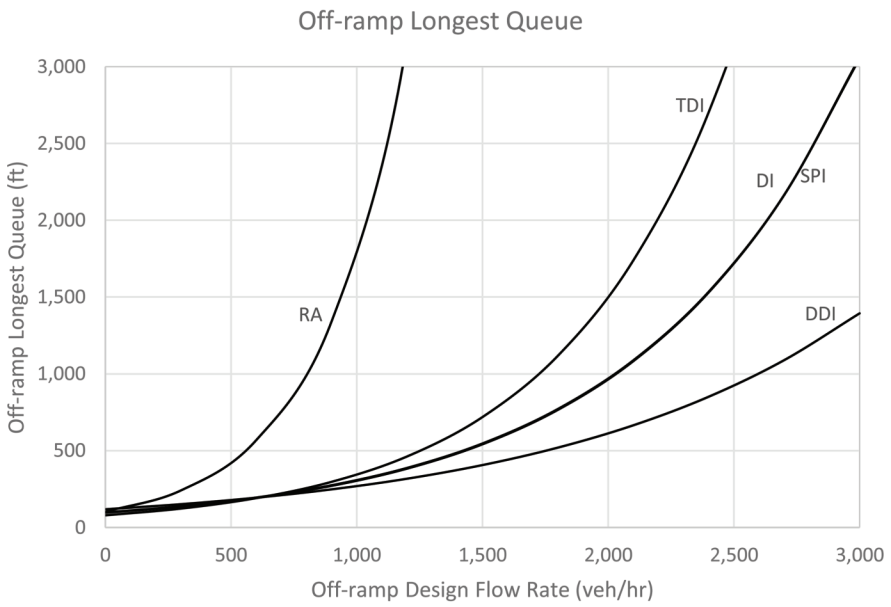
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	4,000

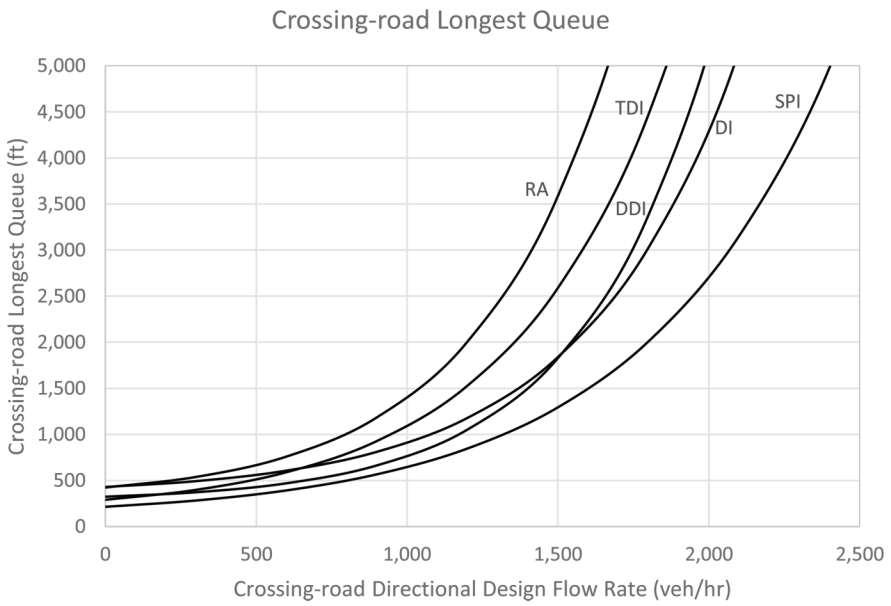




F 7 Geometric and Traffic Conditions

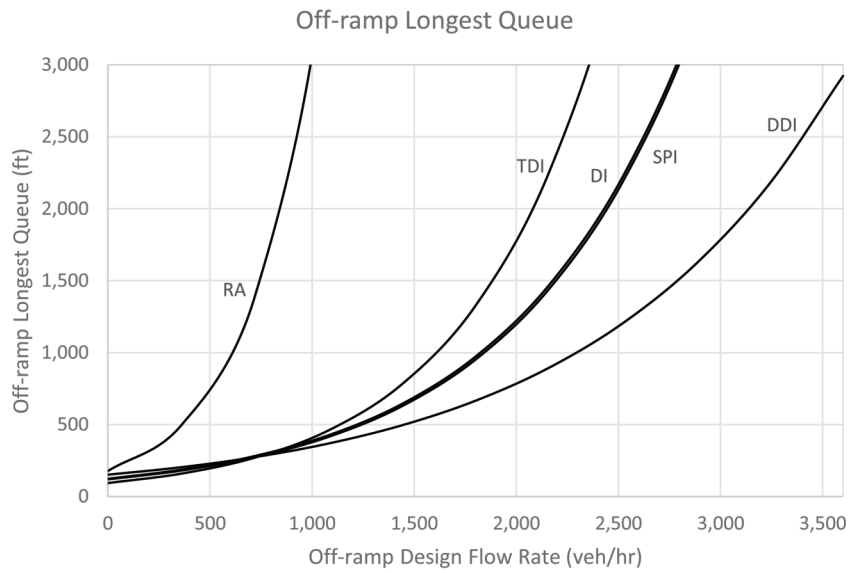
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	5,000

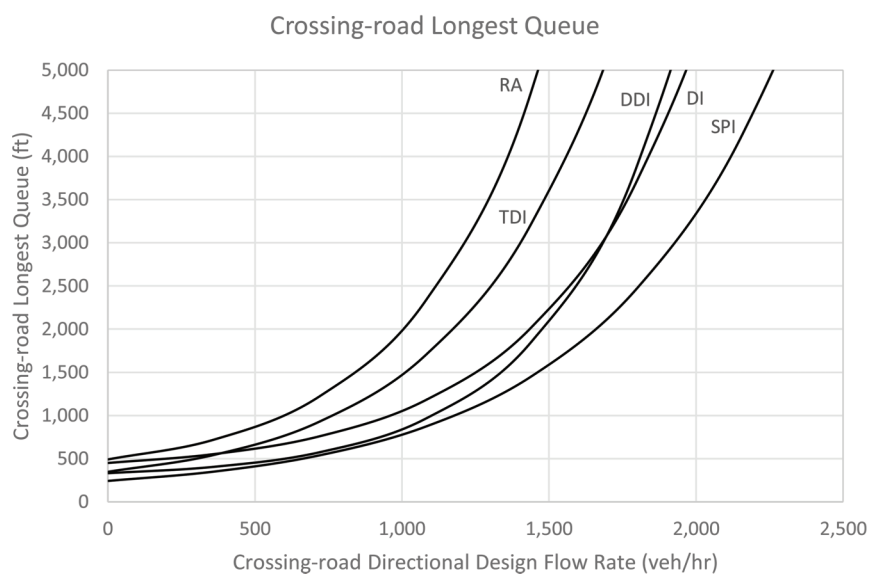




F 8 Geometric and Traffic Conditions

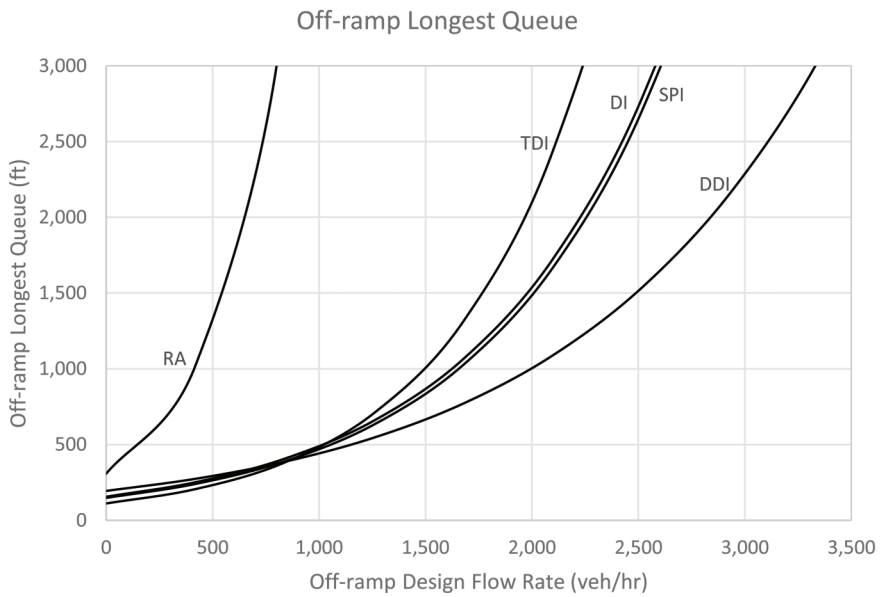
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	6,000

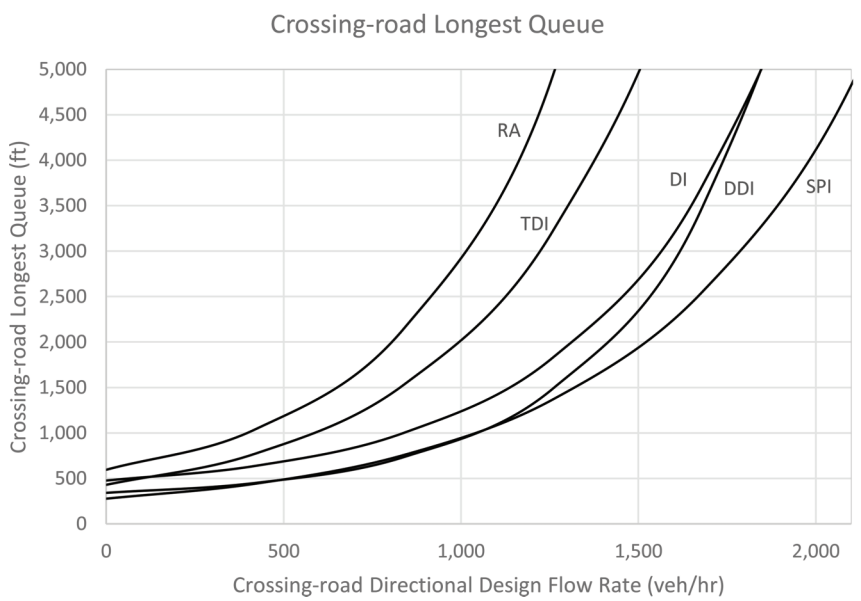




F 9 Geometric and Traffic Conditions

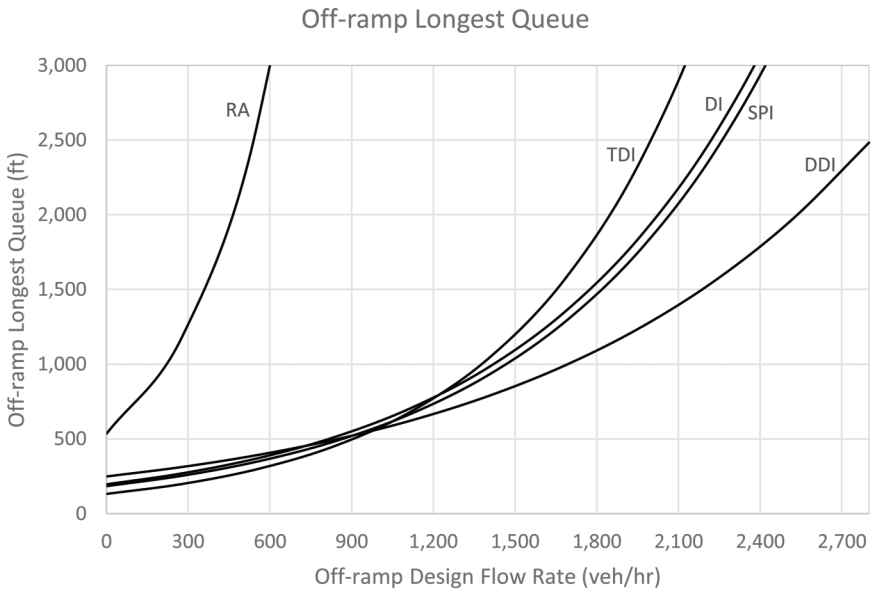
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	7,000

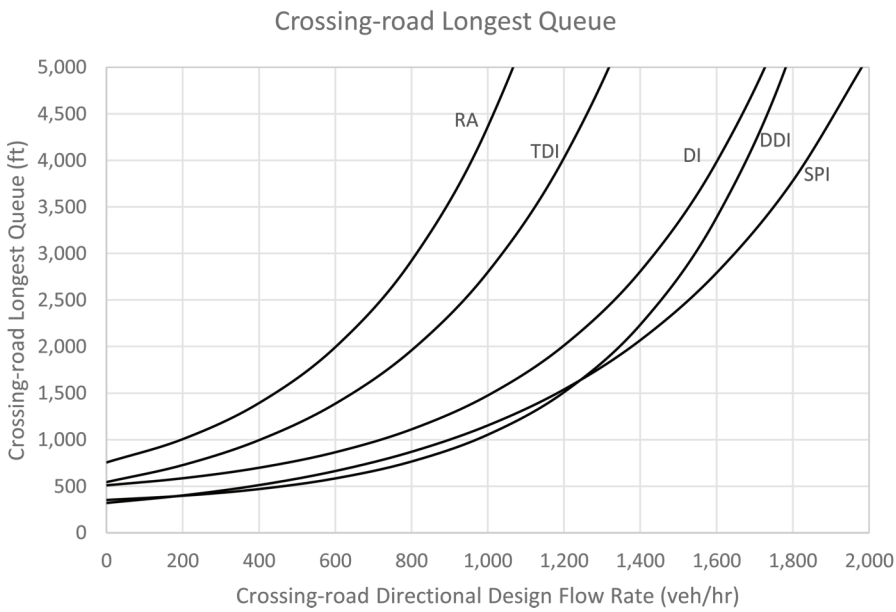




F 10 Geometric and Traffic Conditions

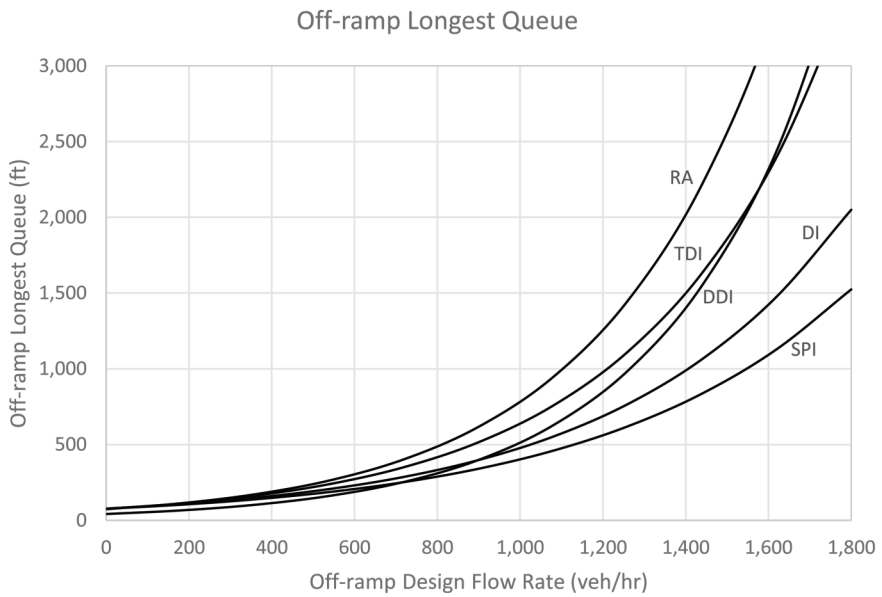
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	1
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	8,000

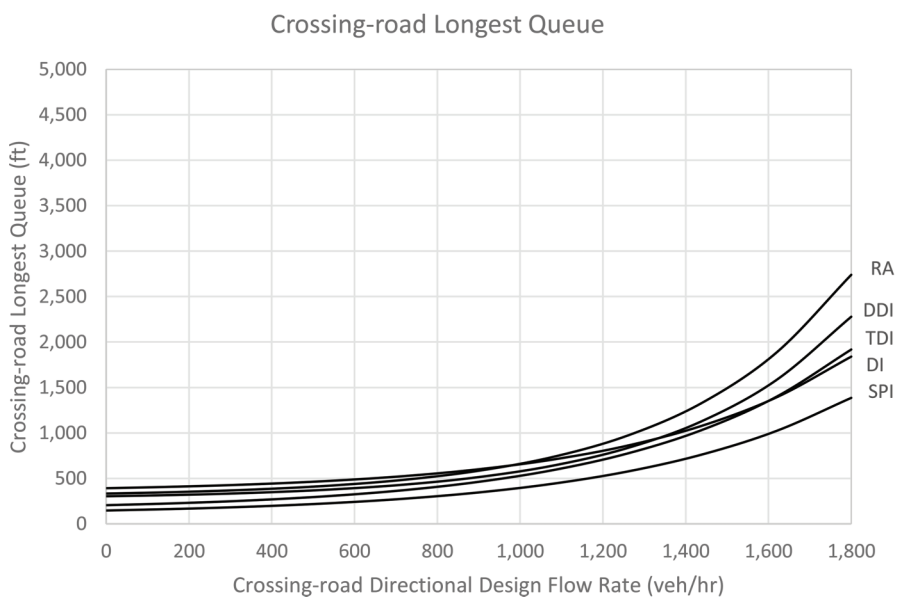




F 11 Geometric and Traffic Conditions

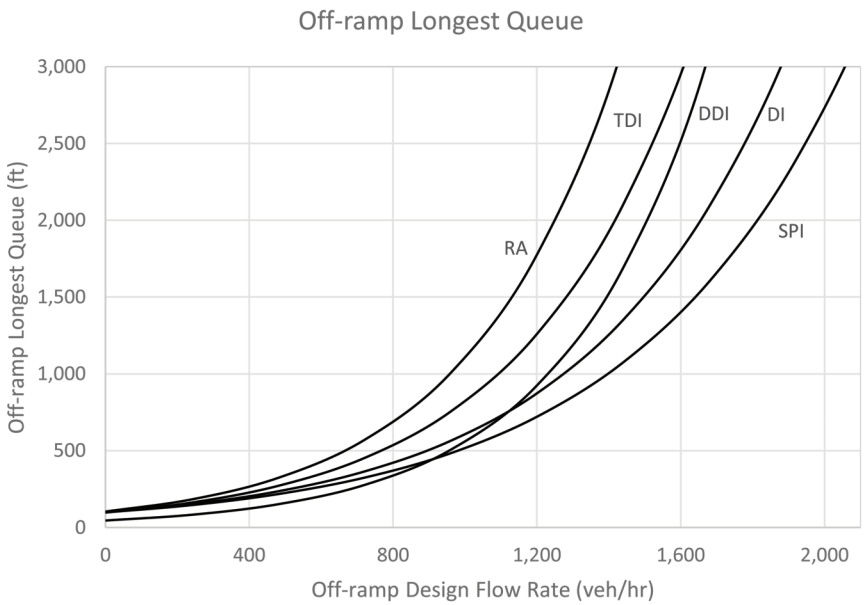
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	3,000

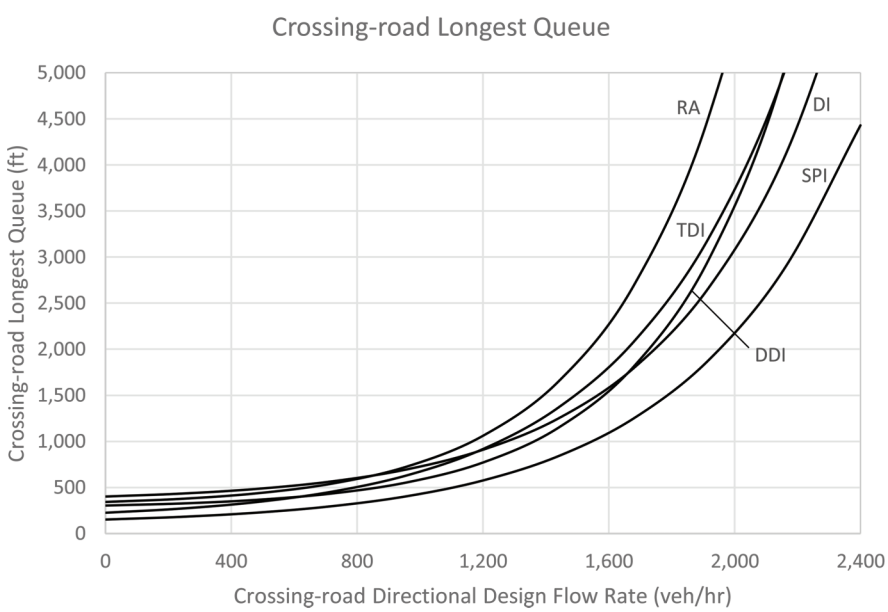




F 12 Geometric and Traffic Conditions

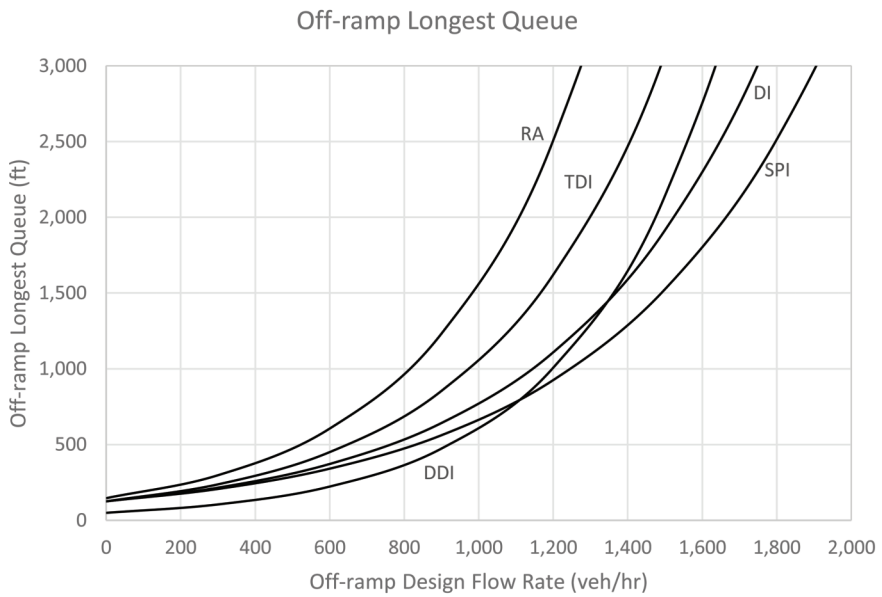
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	4,000

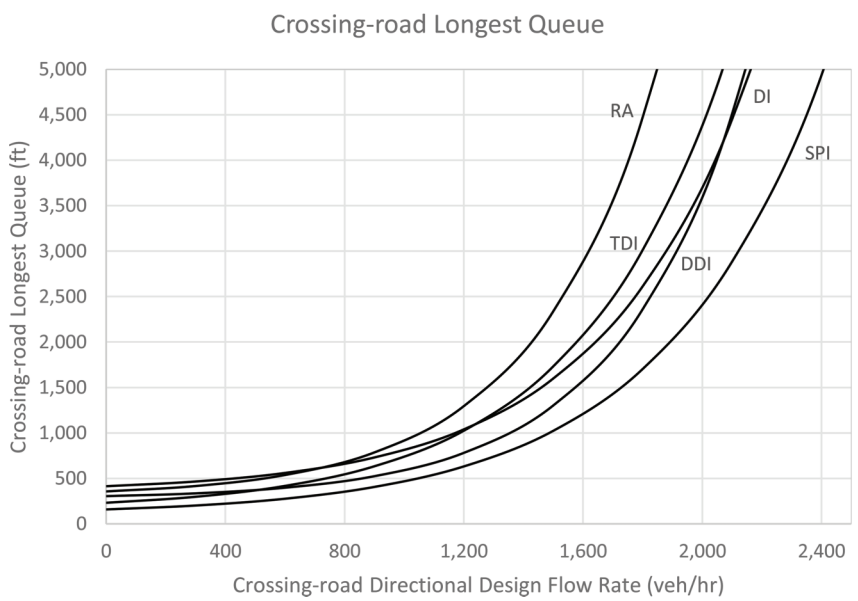




F 13 Geometric and Traffic Conditions

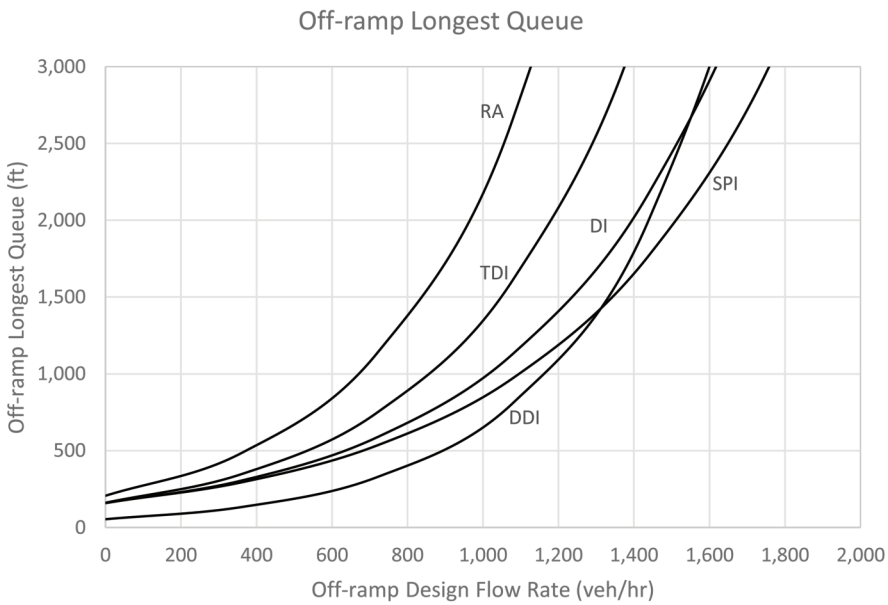
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	5,000

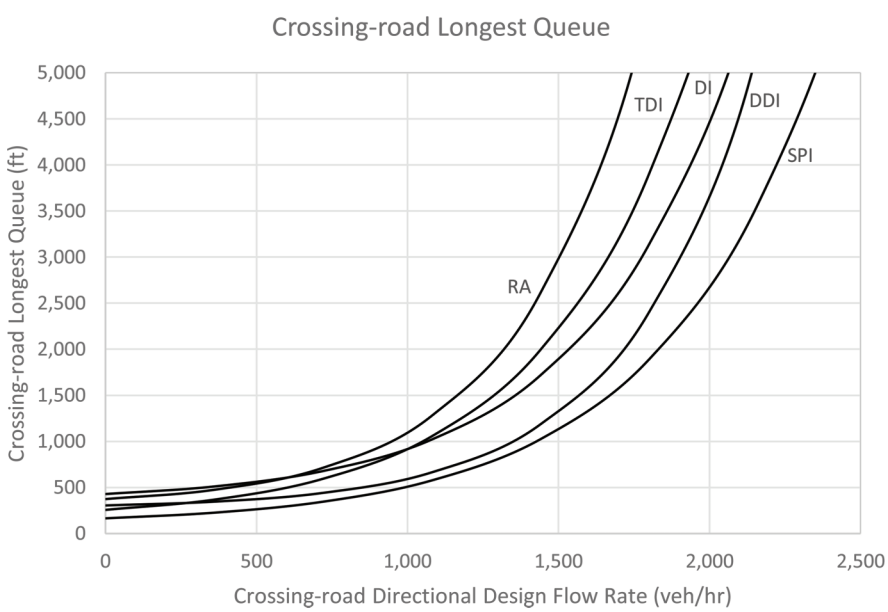




F 14 Geometric and Traffic Conditions

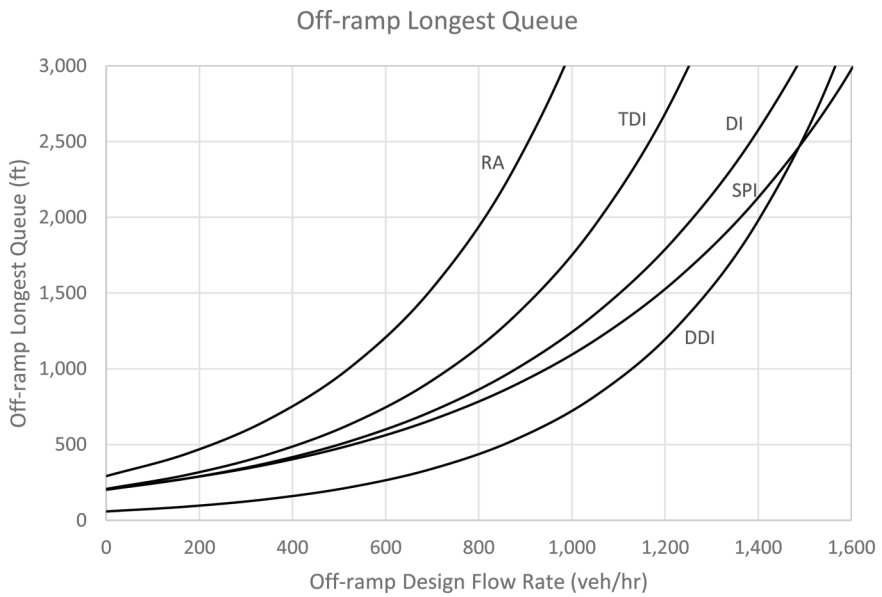
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	6,000

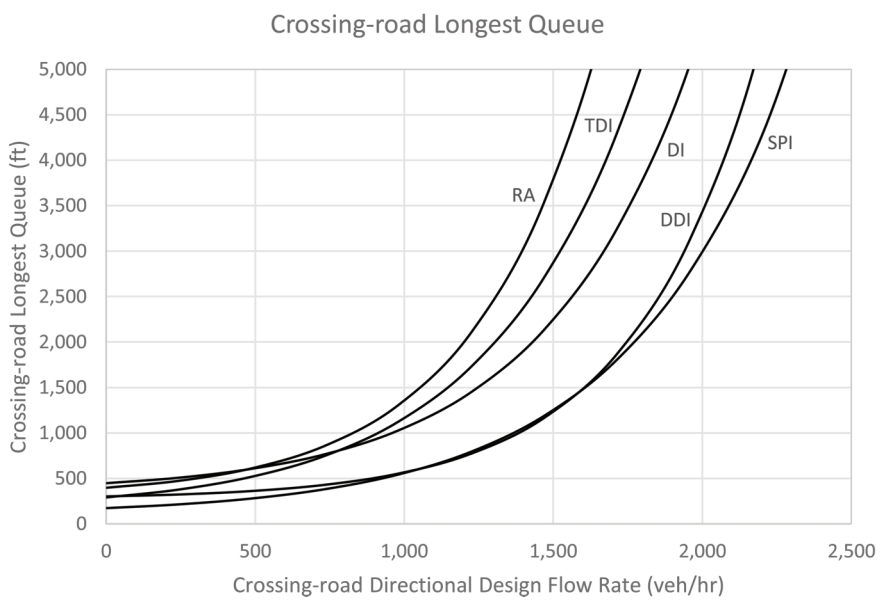




F 15 Geometric and Traffic Conditions

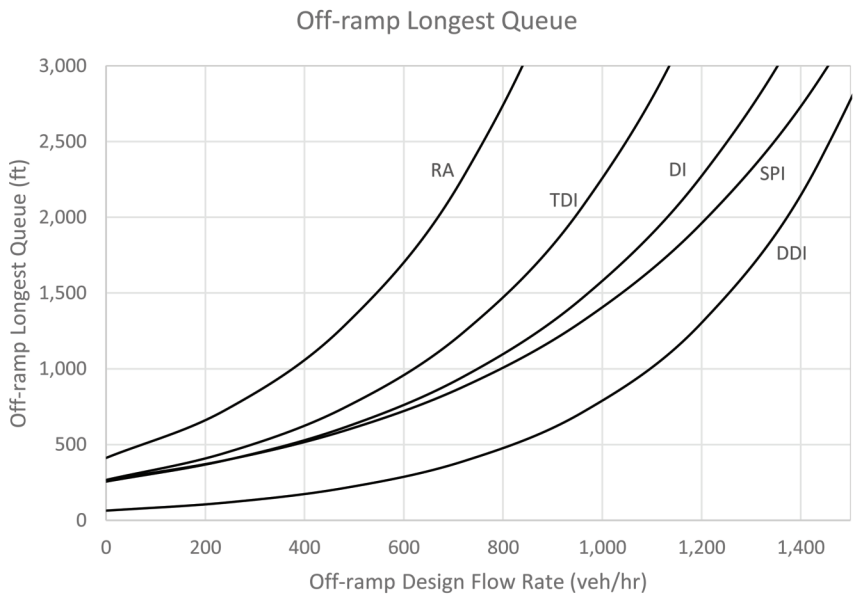
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	7,000

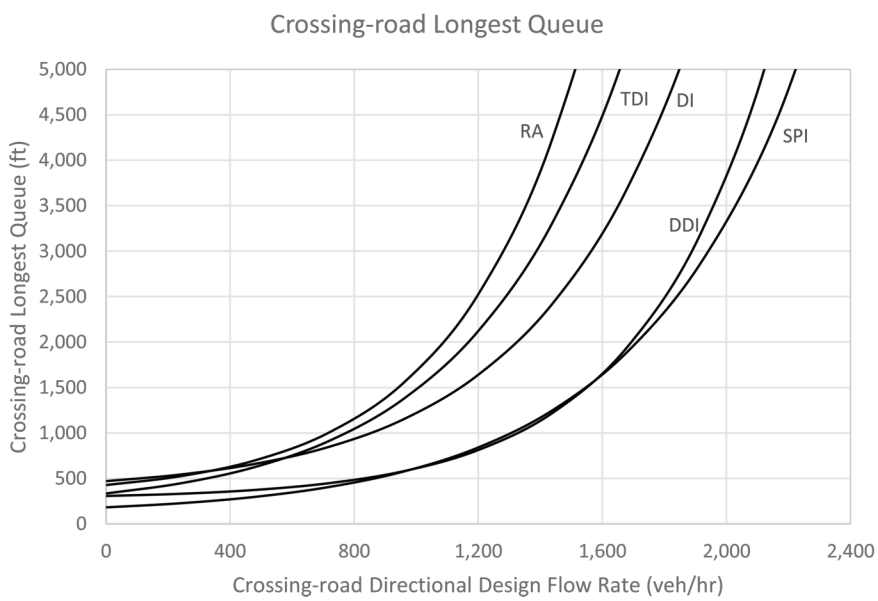




F 16 Geometric and Traffic Conditions

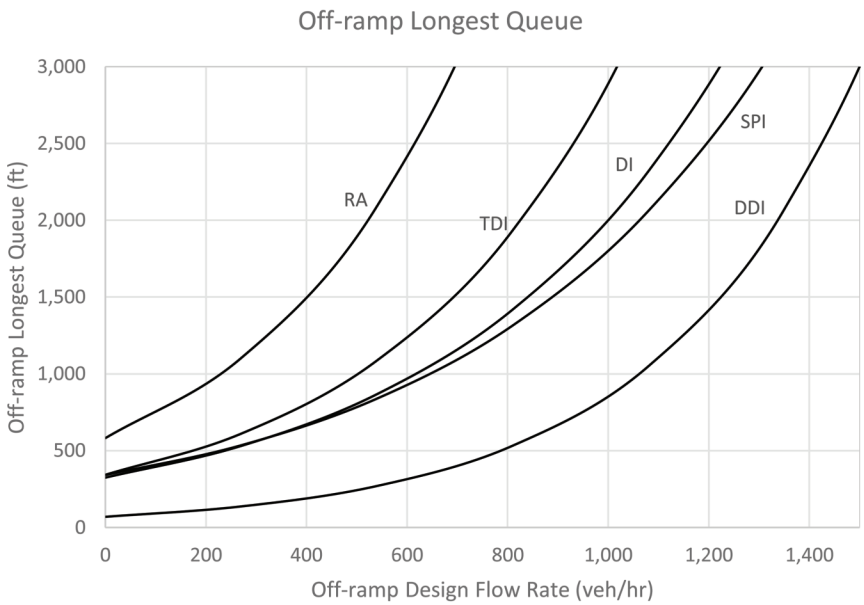
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	8,000

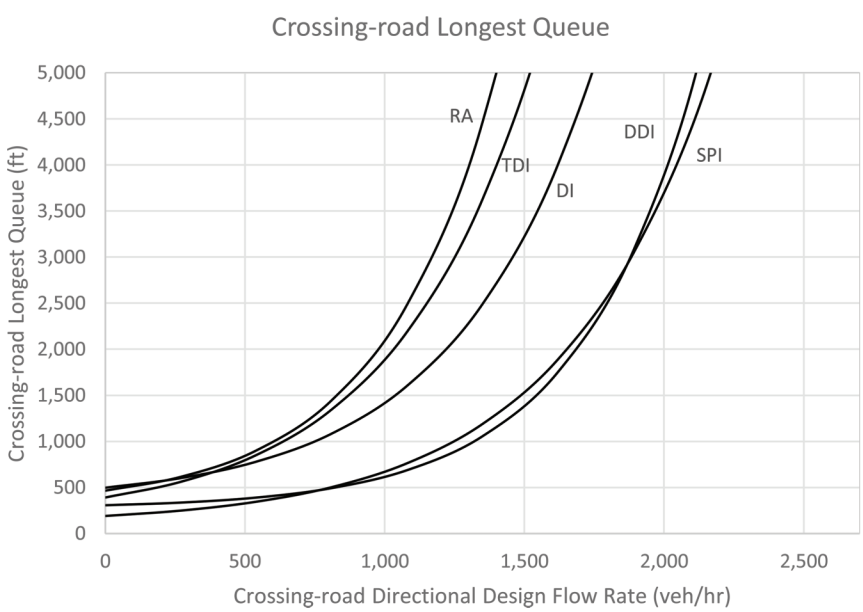




F 17 Geometric and Traffic Conditions

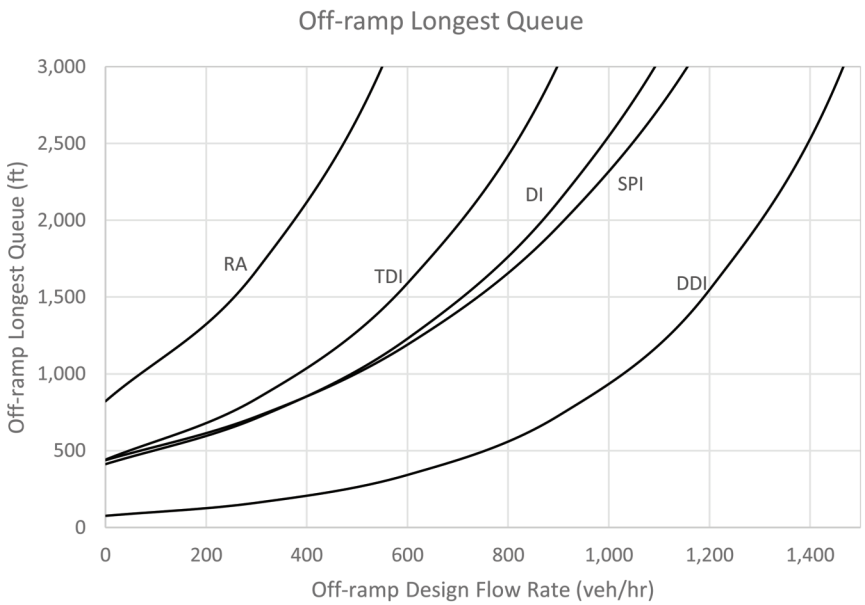
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	9,000

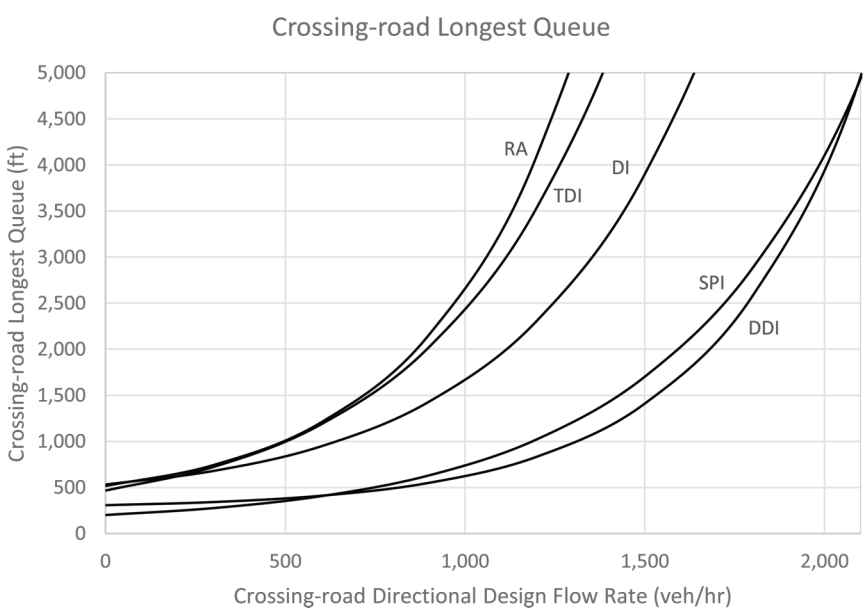




F 18 Geometric and Traffic Conditions

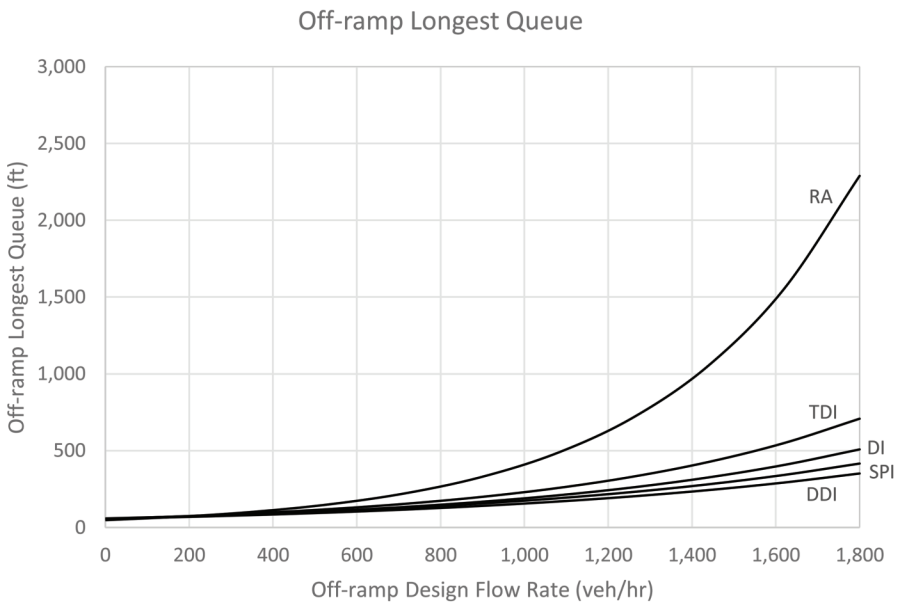
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	2
Non-freeway design flow rate (veh/hr)	10,000

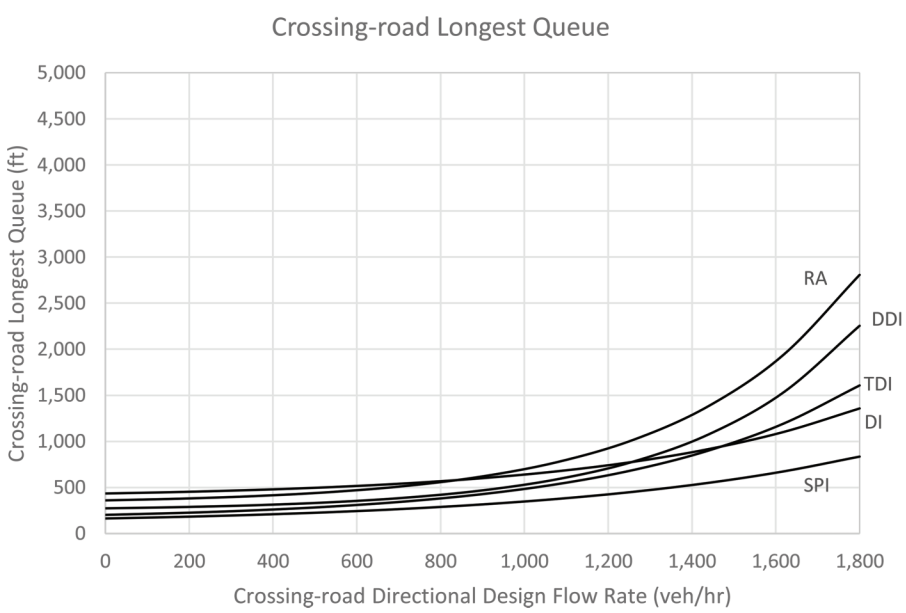




F 19 Geometric and Traffic Conditions

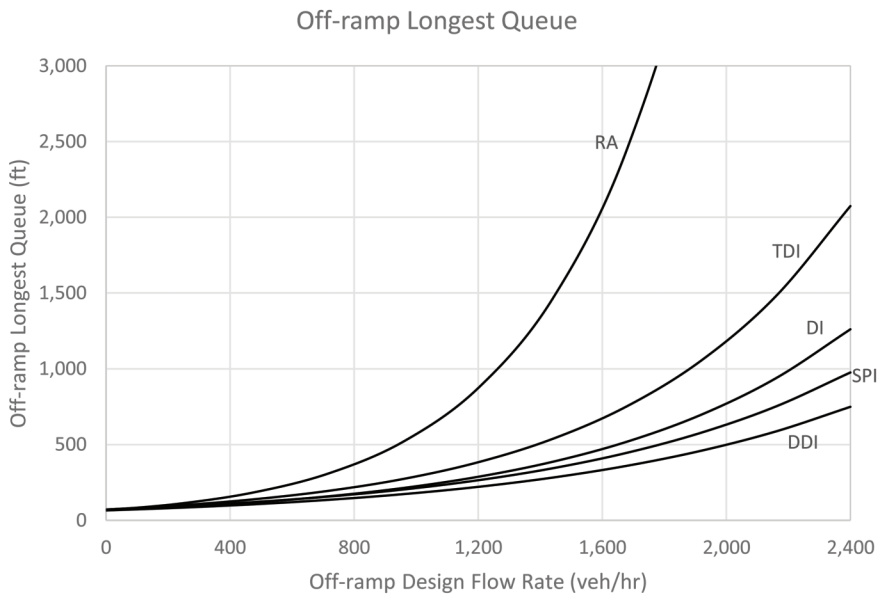
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	3,000

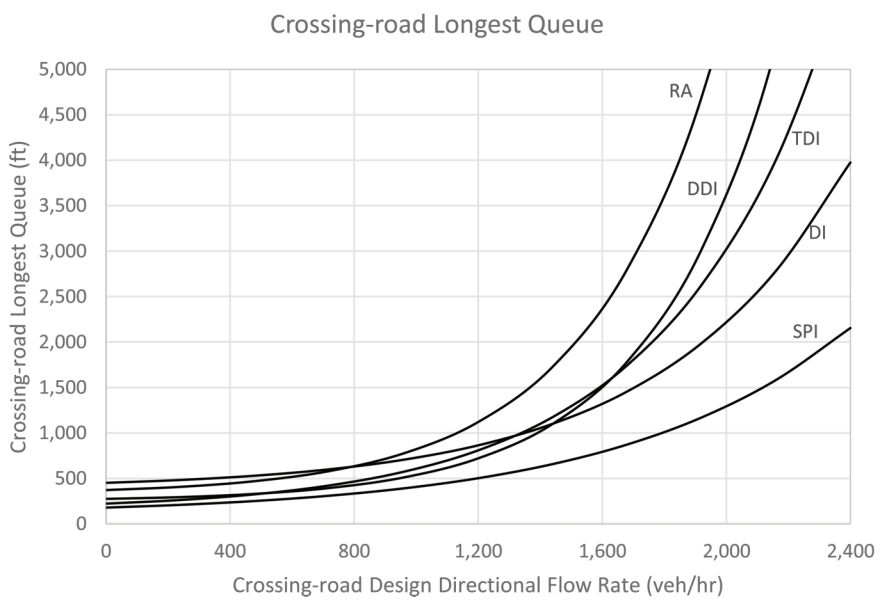




F 20 Geometric and Traffic Conditions

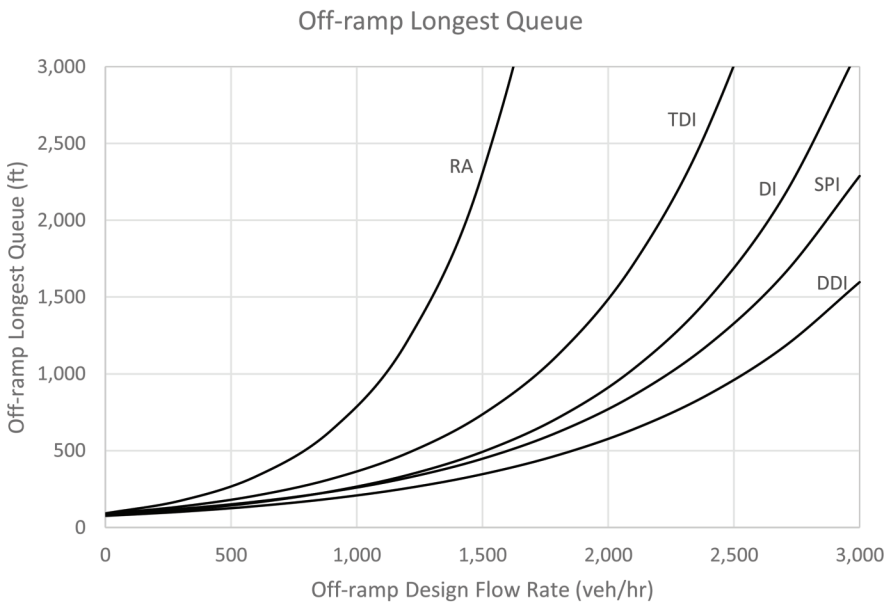
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	4,000

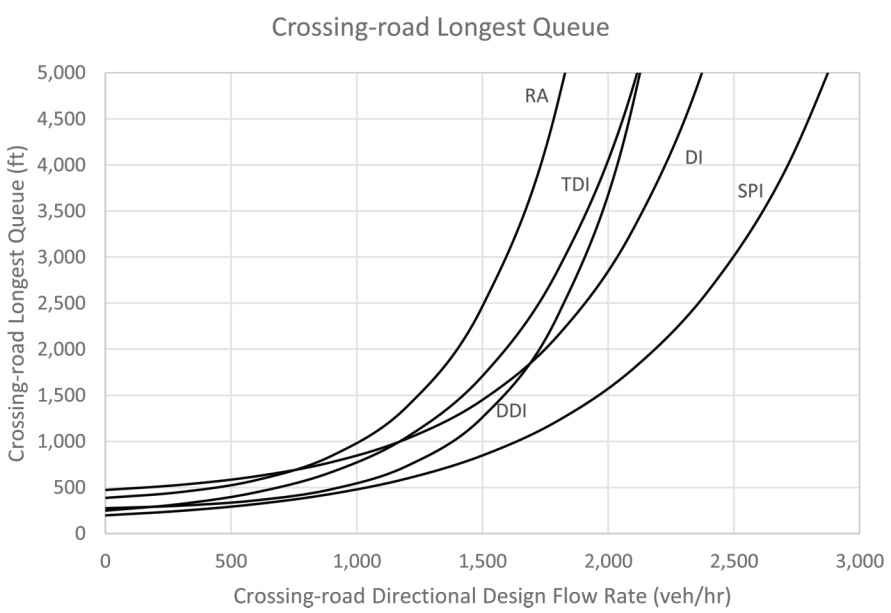




F 21 Geometric and Traffic Conditions

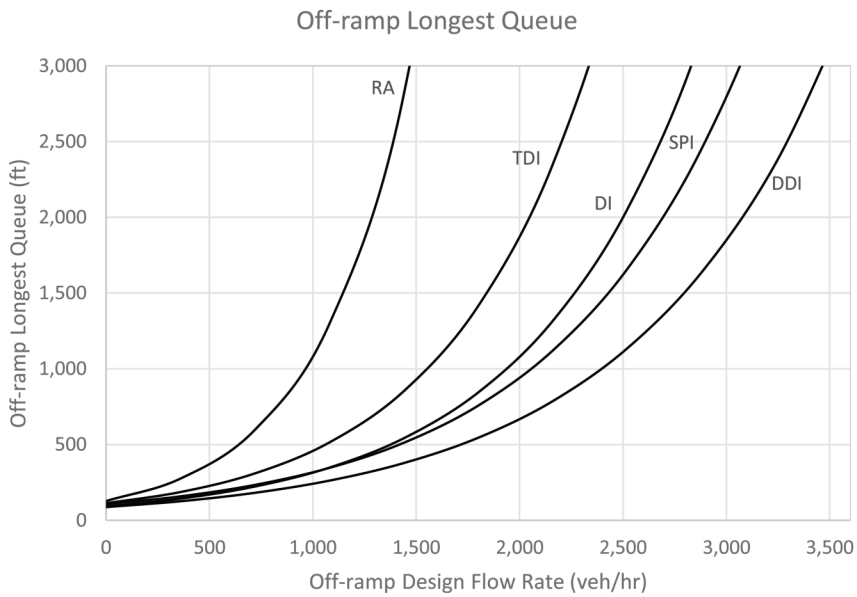
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	5,000

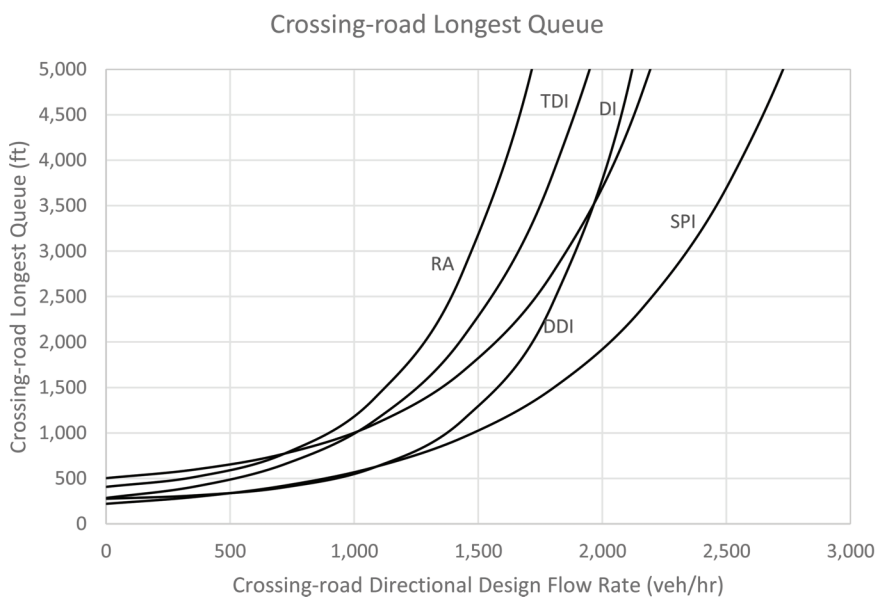




F 22 Geometric and Traffic Conditions

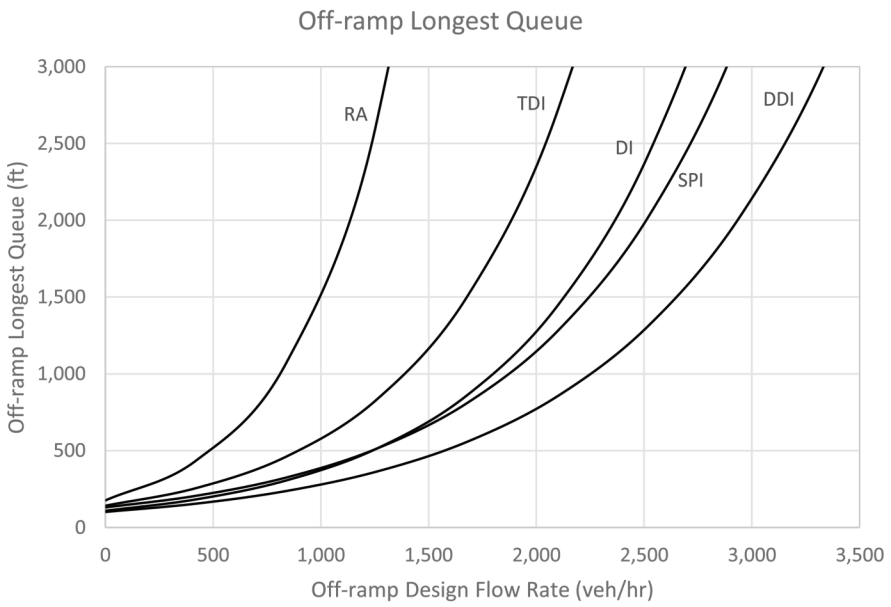
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	6,000

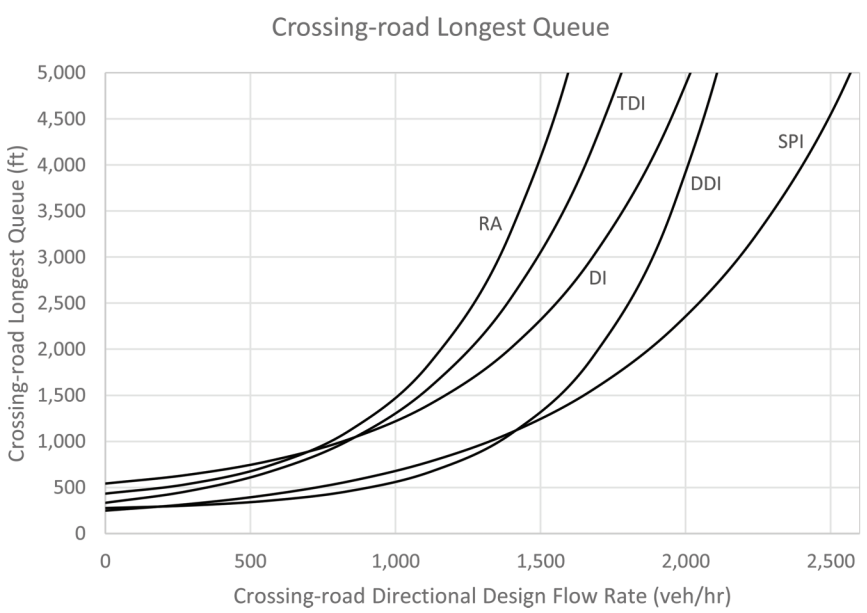




F 23 Geometric and Traffic Conditions

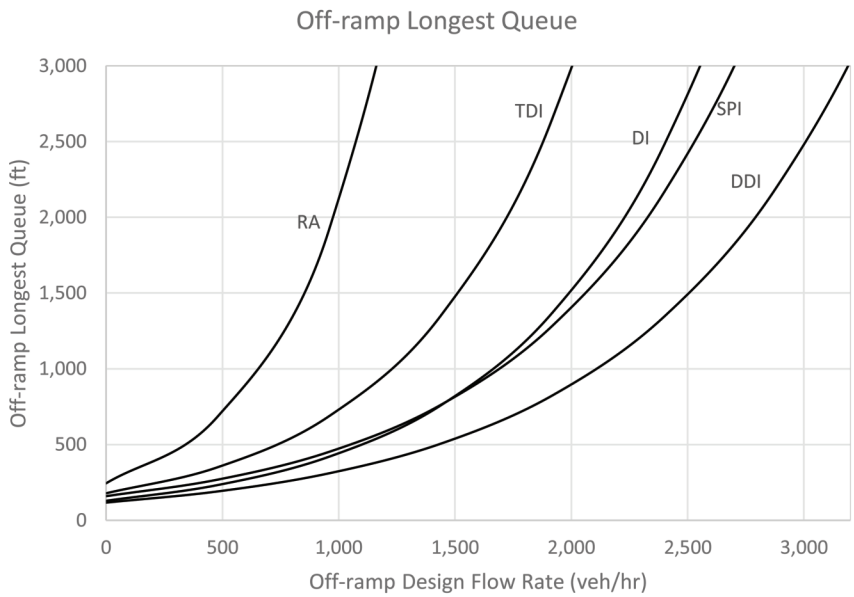
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	7,000

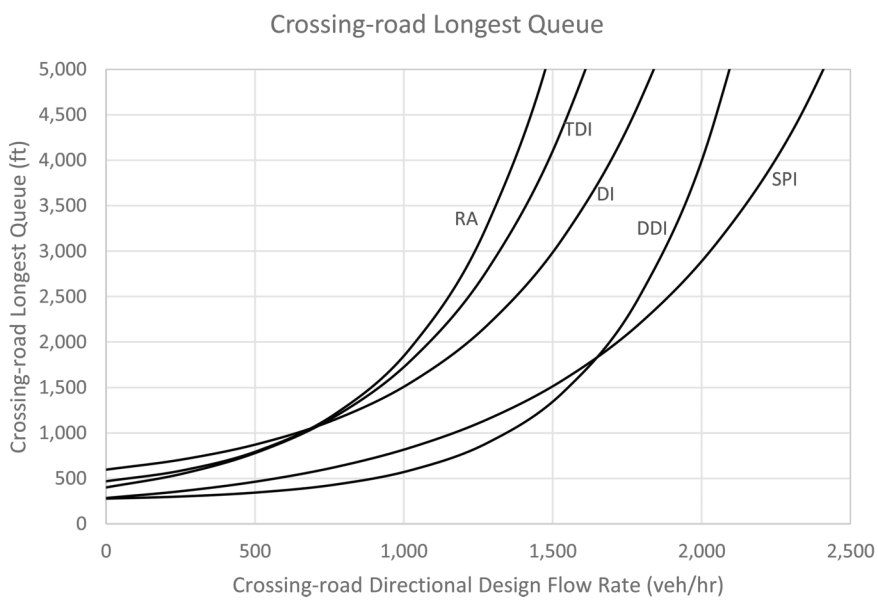




F 24 Geometric and Traffic Conditions

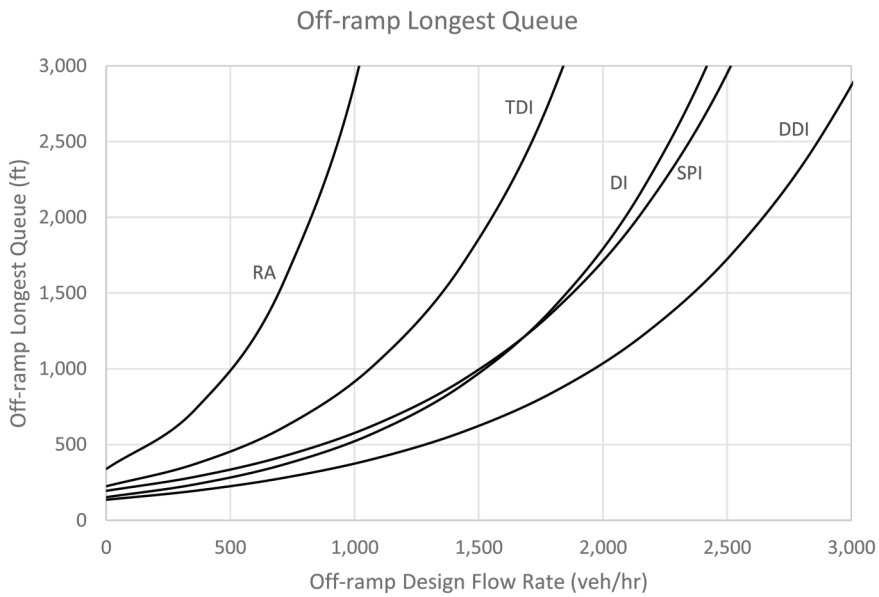
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	8,000

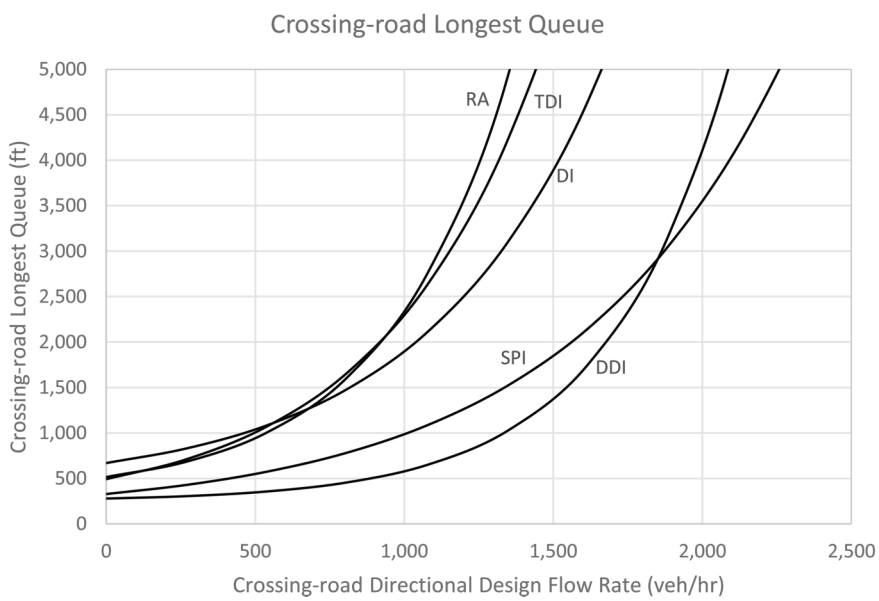




F 25 Geometric and Traffic Conditions

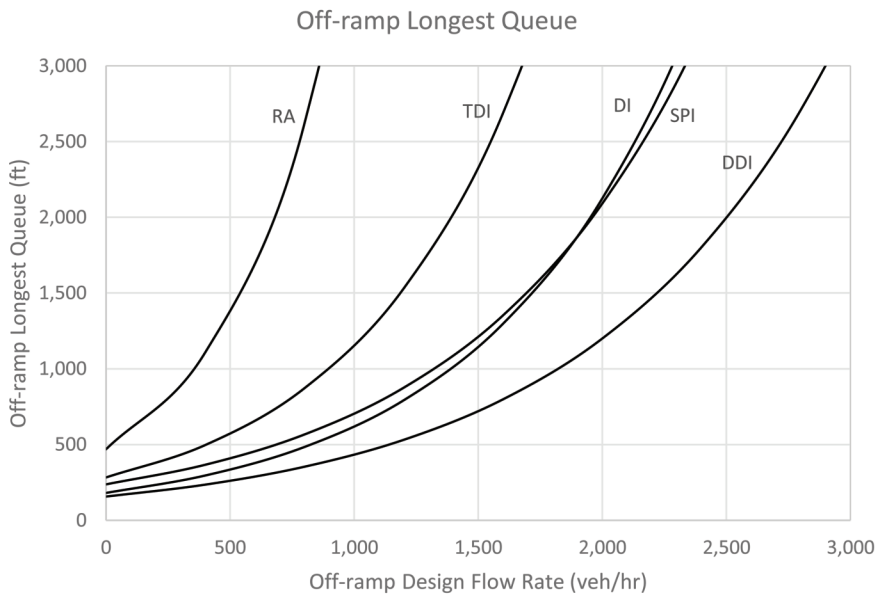
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	9,000

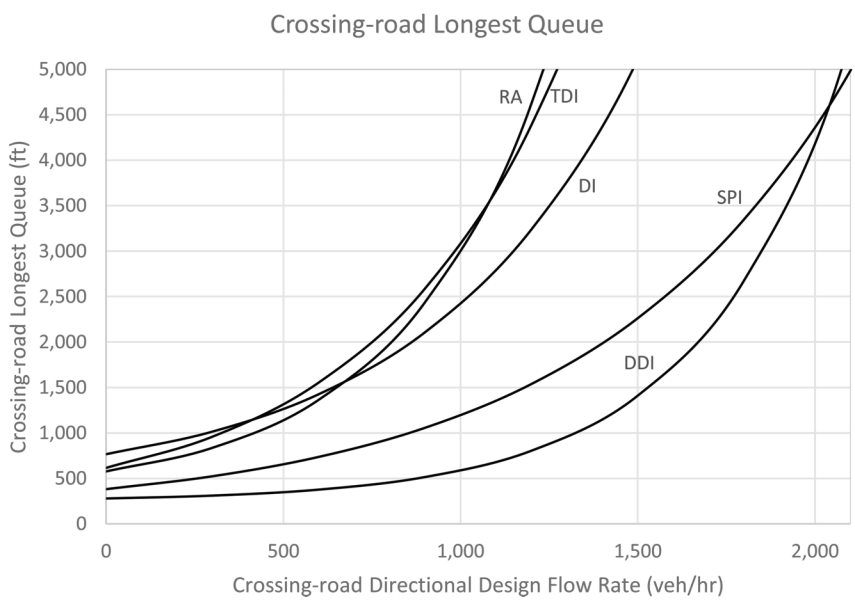




F 26 Geometric and Traffic Conditions

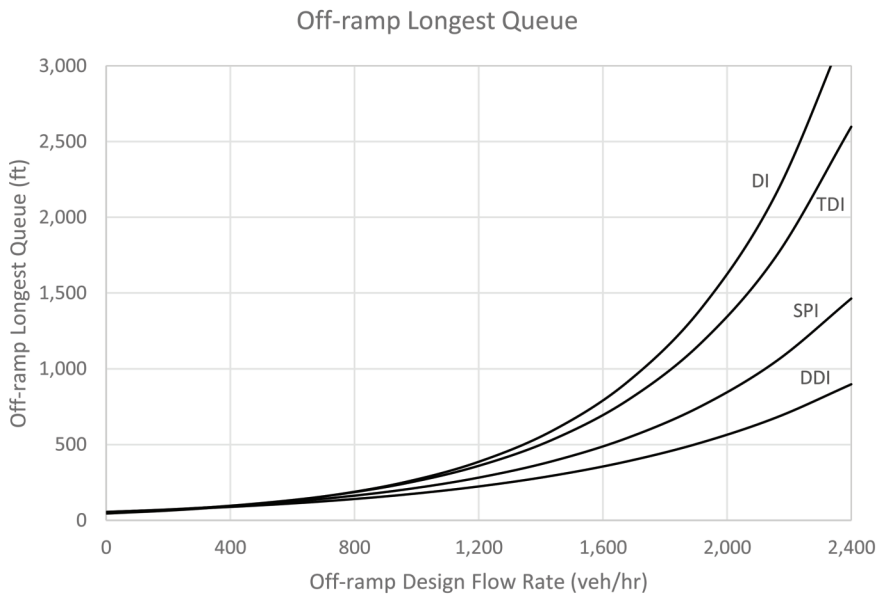
Number of continuous lanes on crossing-road	4
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	10,000

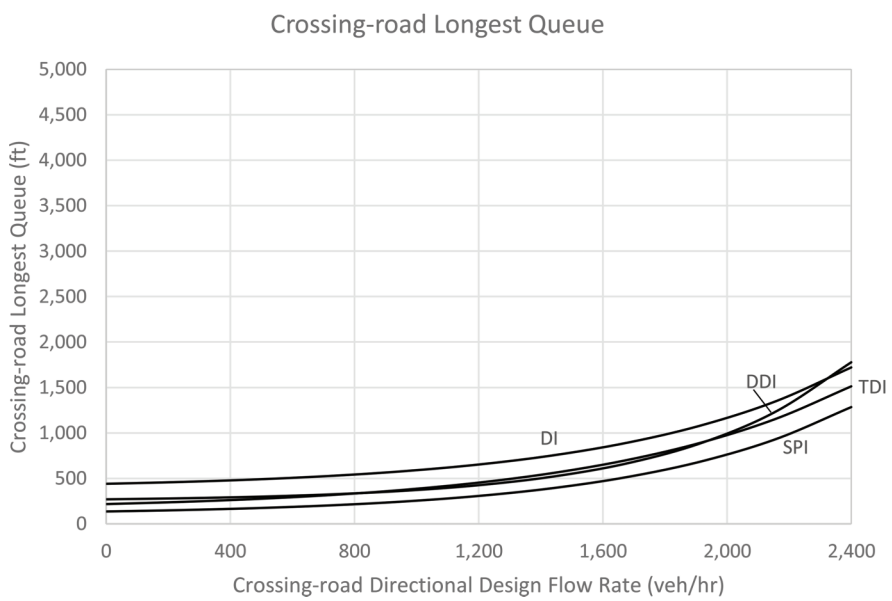




F 27 Geometric and Traffic Conditions

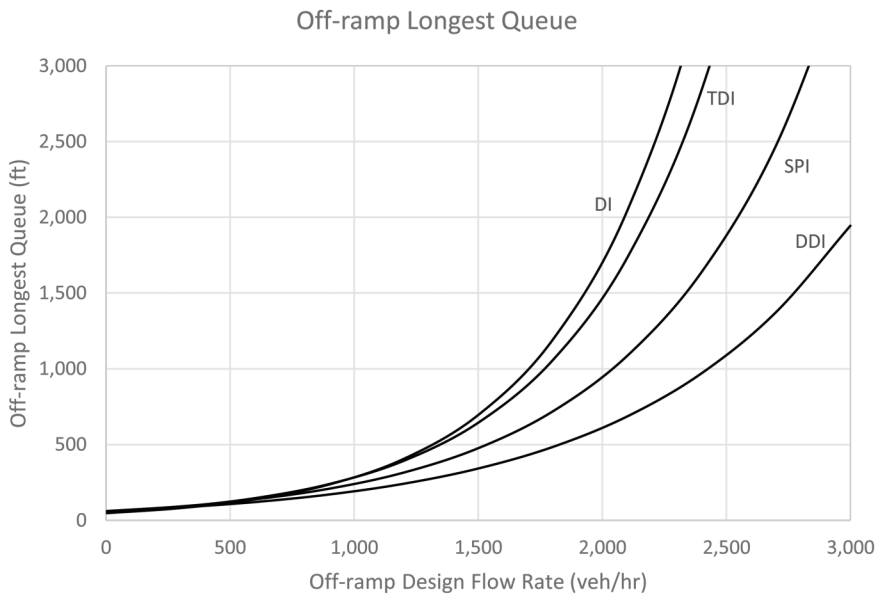
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	4,000

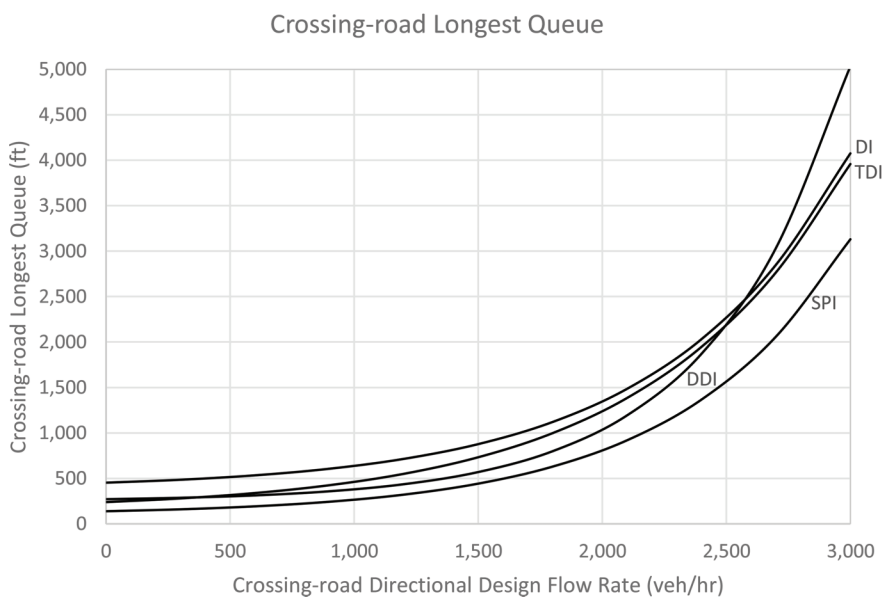




F 28 Geometric and Traffic Conditions

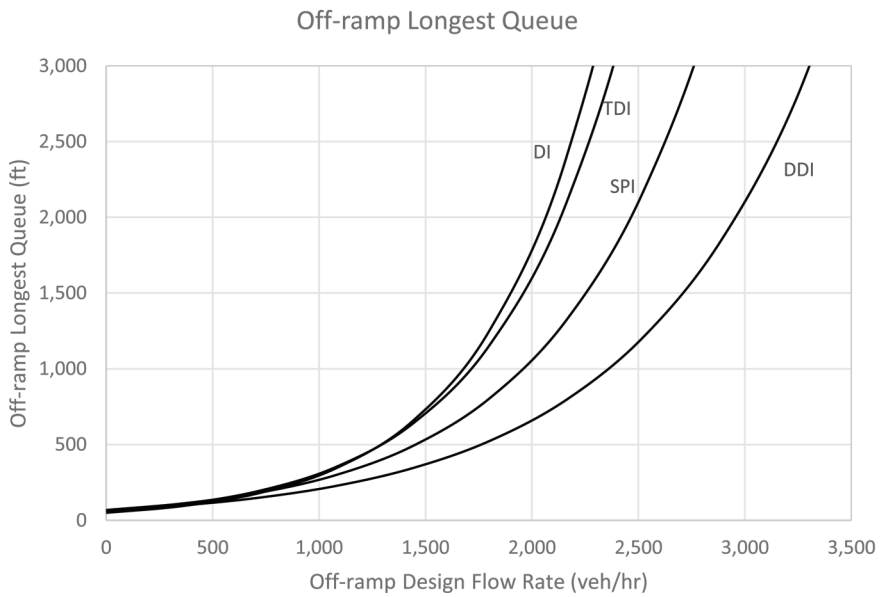
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	5,000

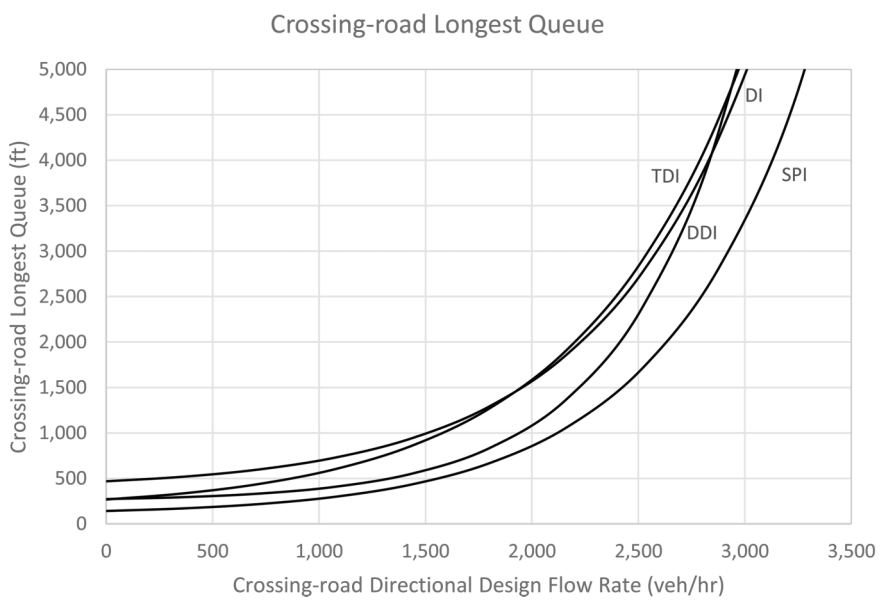




F 29 Geometric and Traffic Conditions

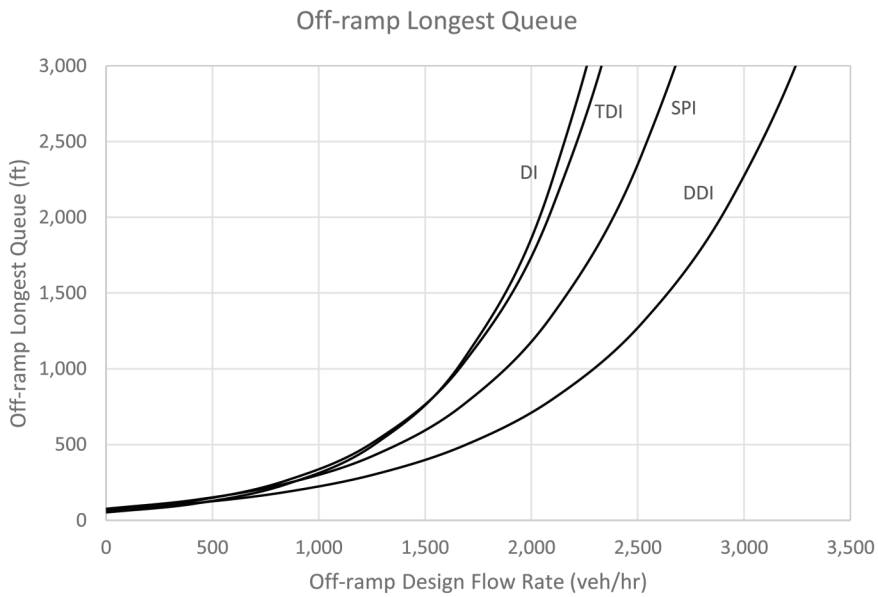
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	6,000

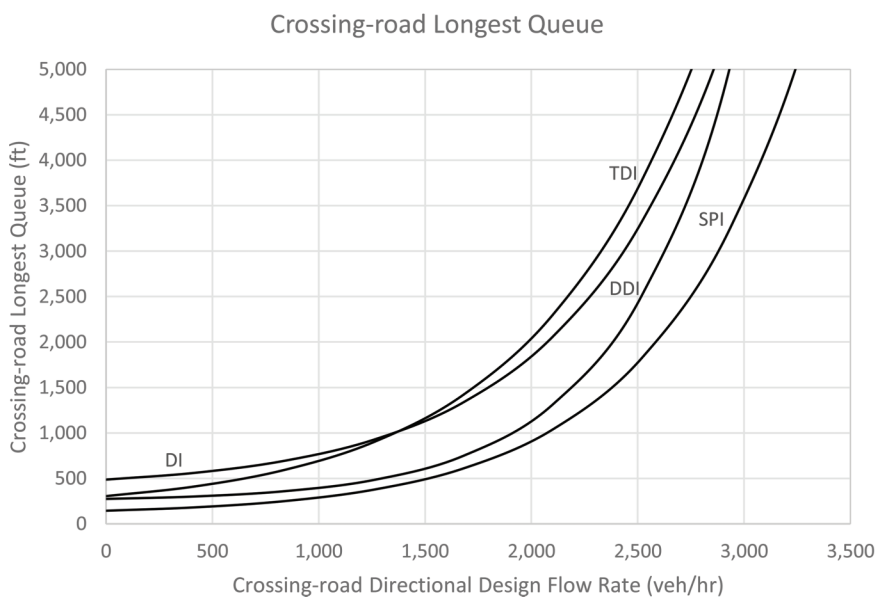




F 30 Geometric and Traffic Conditions

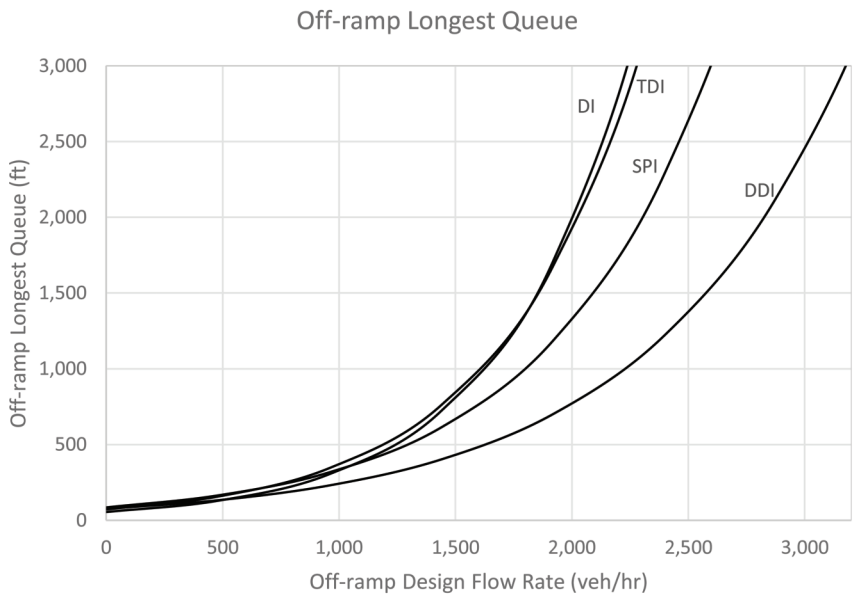
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	7,000

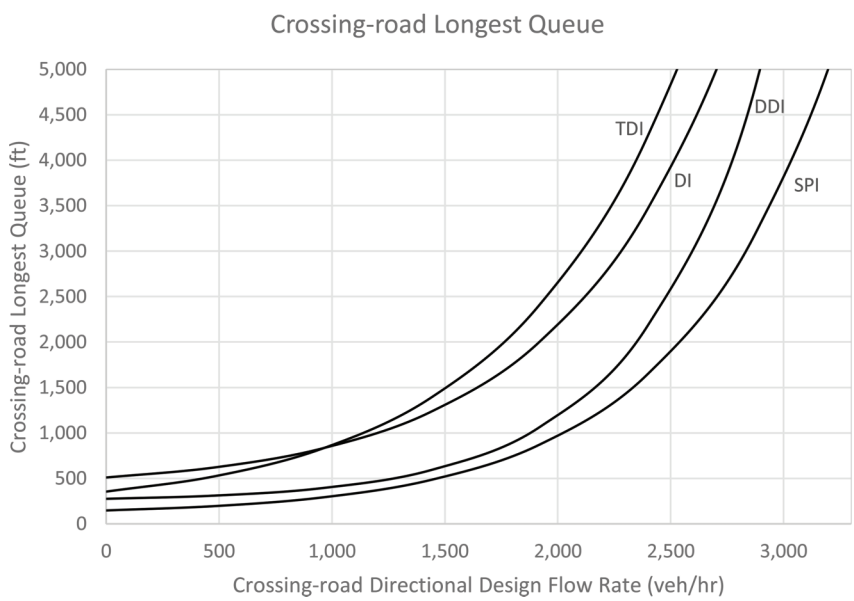




F 31 Geometric and Traffic Conditions

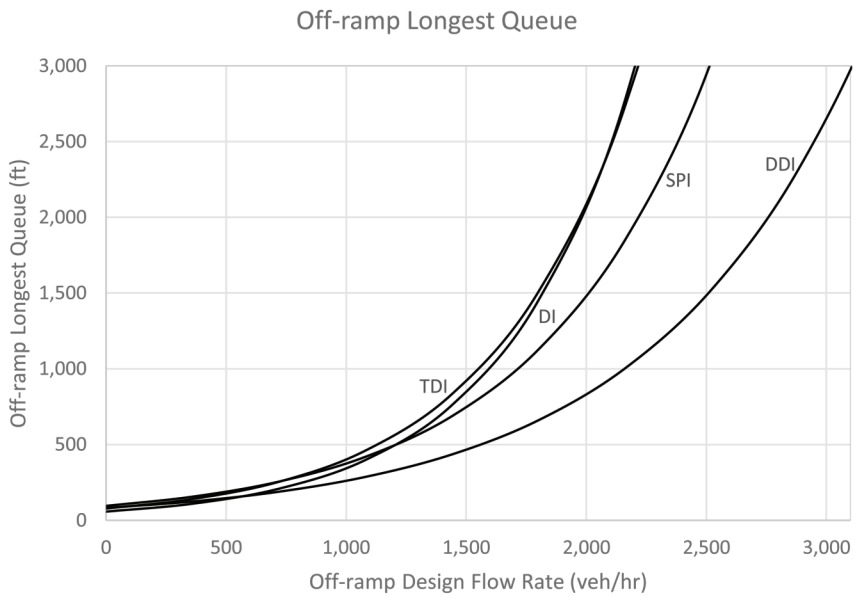
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	8,000

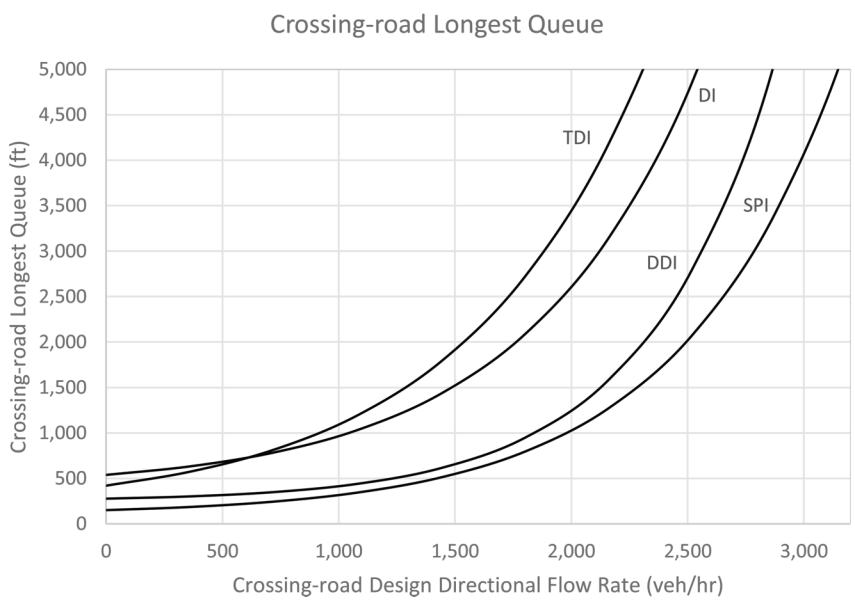




F 32 Geometric and Traffic Conditions

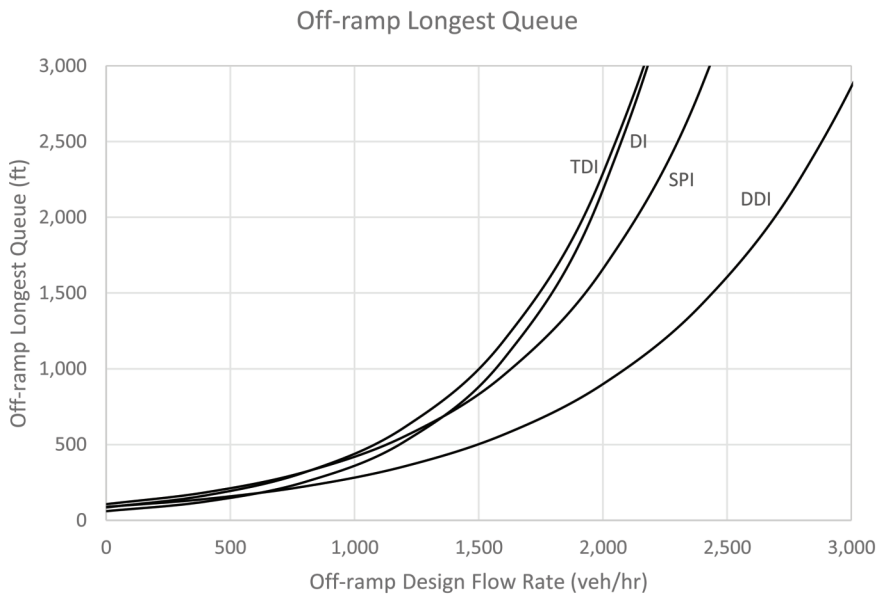
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	9,000

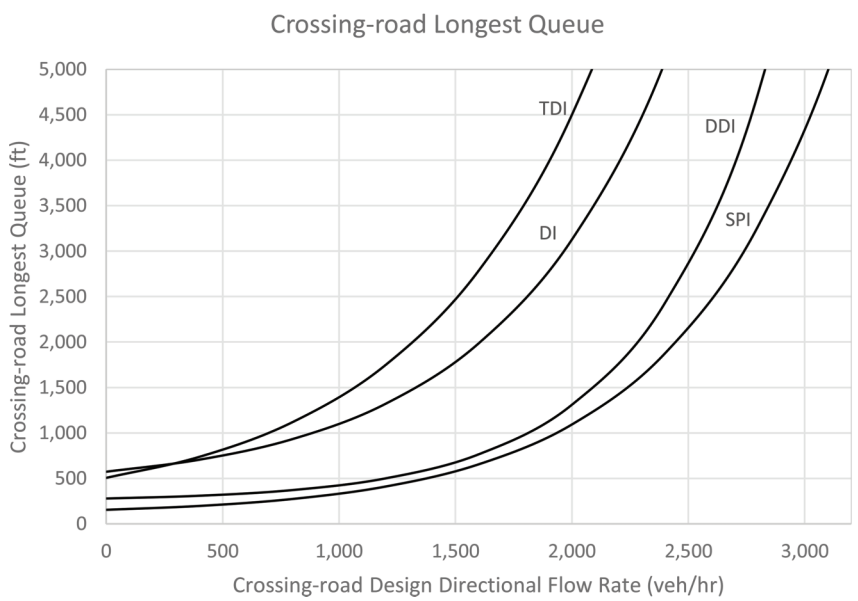




F 33 Geometric and Traffic Conditions

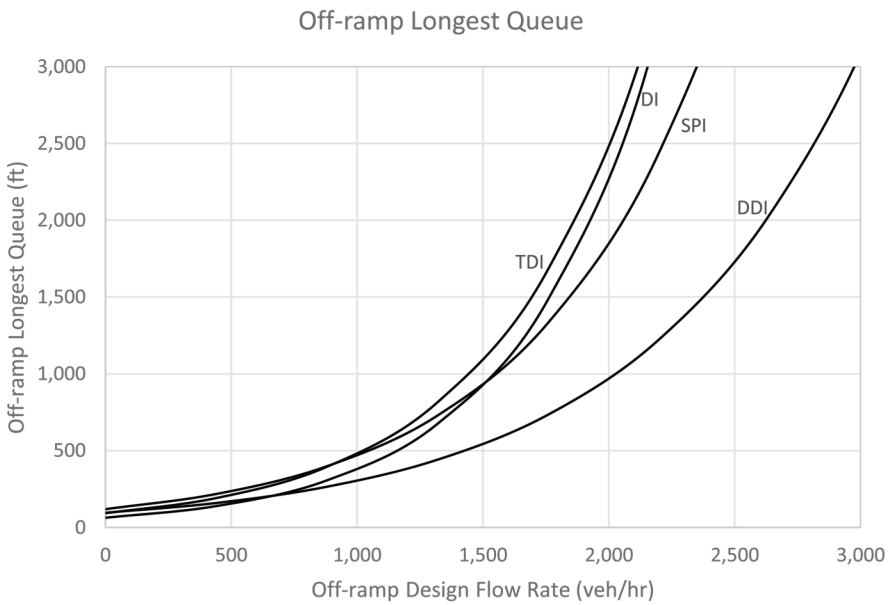
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	10,000

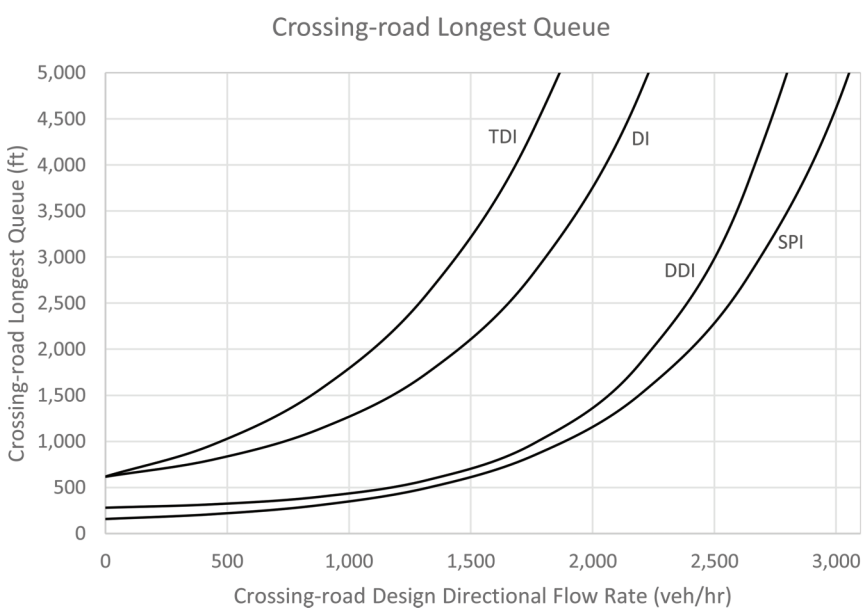




F 34 Geometric and Traffic Conditions

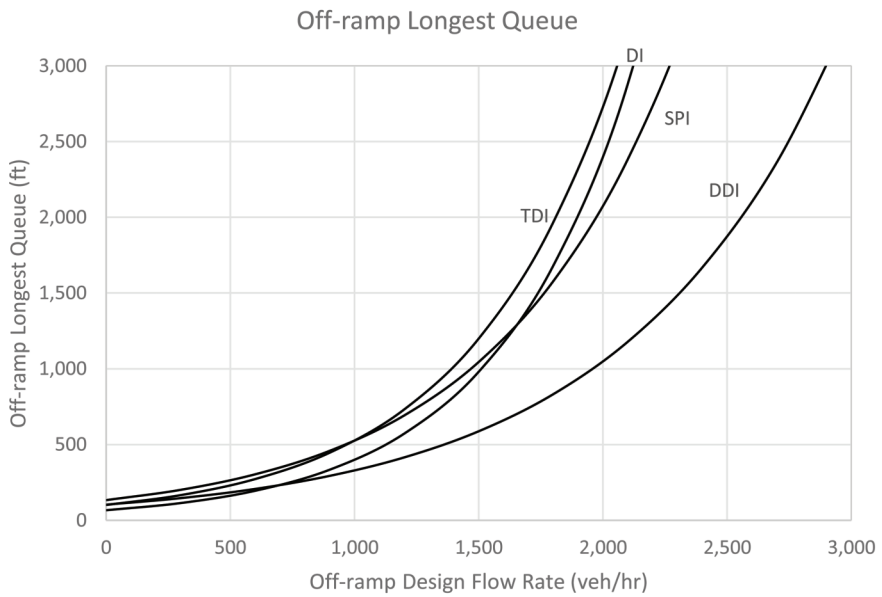
Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	11,000

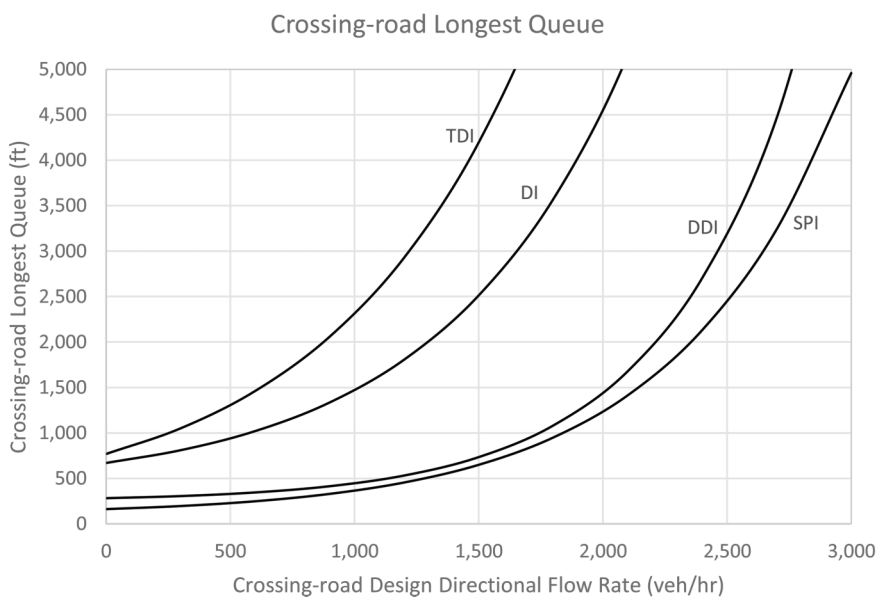




F 35 Geometric and Traffic Conditions

Number of continuous lanes on crossing-road	6
Number of continuous lanes on off-ramps	2
Number of approach lanes on off-ramps	4
Non-freeway design flow rate (veh/hr)	12,000





About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

Further information about JTRP and its current research program is available at: http://www.purdue.edu/jtrp

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