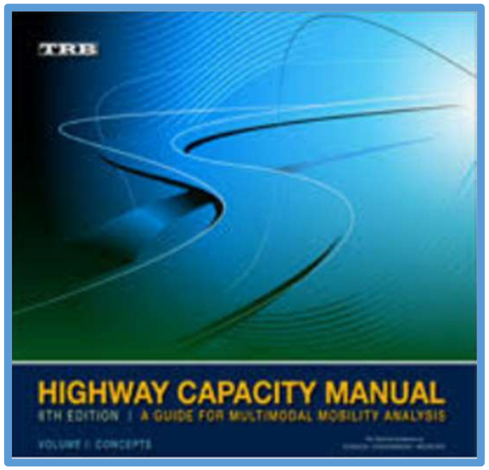
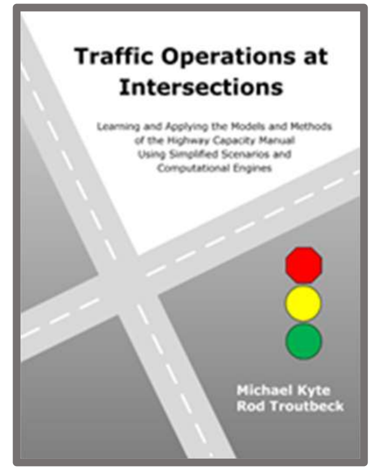


Highway Capacity Manual
6th Edition

Transportation Research Board

Learning and Applying the Methods and Models of the HCM

A Short Course
Day #3



Traffic Operations at Intersections
Learning and Applying
the Models and Methods of the
Highway Capacity Manual
Using Simplified Scenarios and
Computational Engines

Michael Kyte and Rod Troutbeck

Topics for today

- **Check-in**
- Some perspective and context
- Diving in: Exploring the simplified scenarios
- The other scenarios
- Check-out and closure

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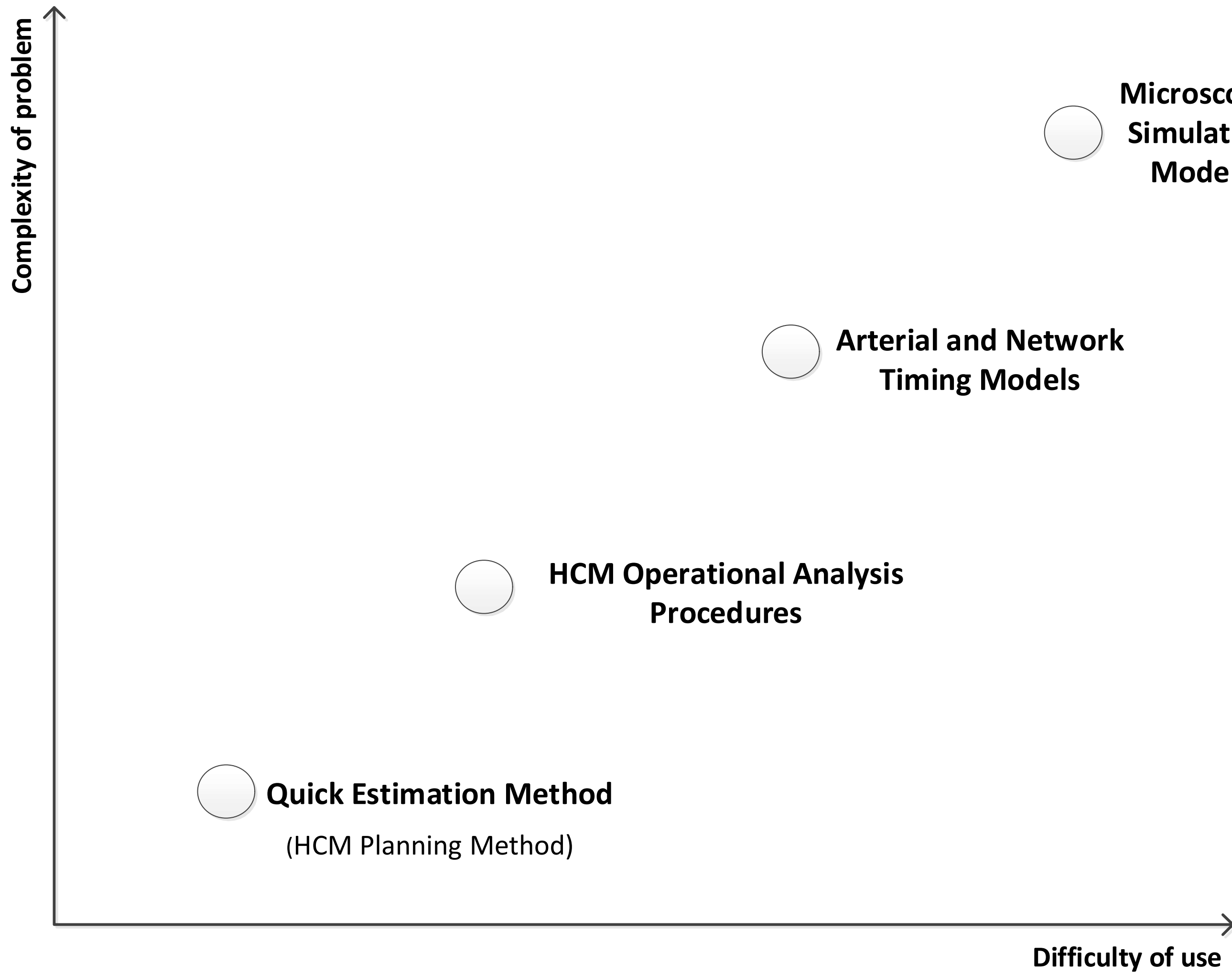
Classification of models



Adapted from "Traffic Signal Timing Manual"

Computational: Directly computes results from equations or tables	**Simulation**: Tracks events and processes
Empirical: Based on field data	**Analytical**: Based on theory
Deterministic: Produces same result for given set of inputs	**Stochastic**: Results can vary based on statistical distributions
Microscopic: Individual driver decisions	**Macroscopic**: Aggregated flow characteristics
Event scan: Based on status of events of interest	**Time scan:** Updates made every time step
Evaluation: Performance data produced	**Optimization**: Objective function optimized based on performance data

HCM Traffic Analysis Tools

Computational: Directly computes results from equations or tables	**Simulation**: Tracks events and processes
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VISSIM microsimulation model

From HCM Chapter 19:

The motorized vehicle methodology does not account for the effect of the following conditions on intersection operation:

- Turn bay overflow
- Multiple advance detectors in the same lane
- Demand starvation due to a closely spaced upstream intersection
- Queue spillback into the subject intersection from a downstream intersection
- Queue spillback from the subject intersection into an upstream intersection
- Premature phase termination due to short detection length, passage time, or both
- Right-turn-on-red (RTOR) volume prediction or resulting right-turn delay
- Turn movements served by more than two exclusive lanes
- Delay to traffic movements that are not under signal control
- Through lane (or lanes) added just upstream of the intersection or dropped just downstream of the intersection
- Storage of shared-lane left-turning vehicles within the intersection to permit bypass by through vehicles in the same lane

From HCM Chapter 19:

In addition to the above conditions, the methodology does not directly account for the following controller functions:

- Rest-in-walk mode for actuated and non-coordinated phases
- Preemption or priority modes
- Phase overlap (see discussion in text)
- Gap reduction or variable initial settings for actuated phases

Topics for today

- Check-in
- Some perspective and context
- Diving in: Exploring the simplified scenarios
  - **Scenario 4.3 - permitted LTs**
  - Scenario 4-6 - upstream signals
- The other scenarios
- Check-out and closure

8. Scenario 4-3. Calculating the Capacity of an Exclusive LT Lane with Permitted LT Phasing

- Pretimed
- Demand < capacity
- Permitted LTs
- Uniform arrivals
- Isolated

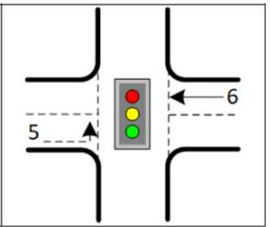

Figure 4-44. Scenario 4-3

The Big Picture

- Permitted LTs must wait for suitable headways in the opposing traffic stream.
- The saturation flow rate for permitted LTs is lower than for protected LTs.
- Part of the green that could be available for permitted LTs is not because of the clearing of the opposing queue.

Terms We Will Use

- Permitted LT phasing
- Exclusive LT lane
- Opposing queue

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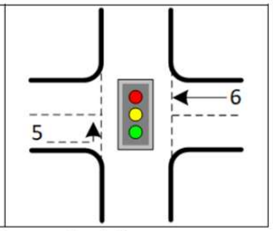

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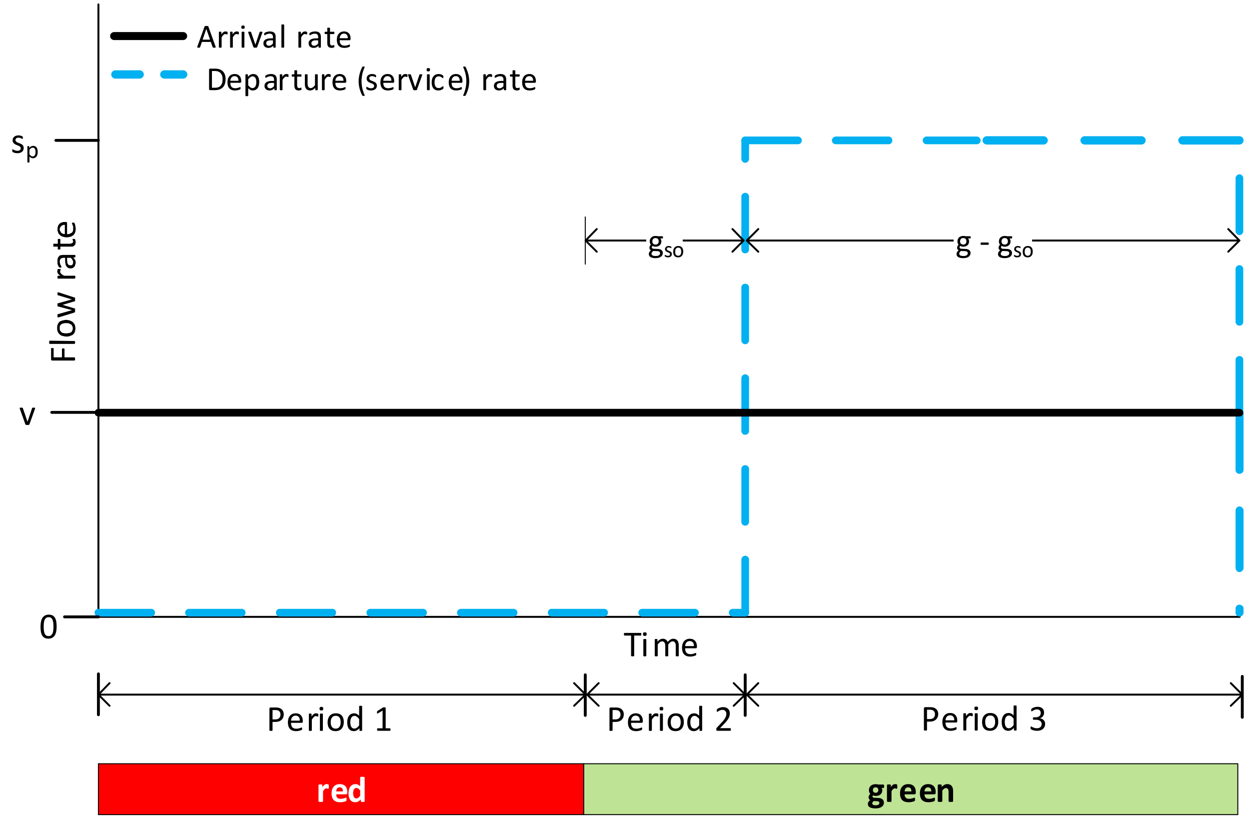

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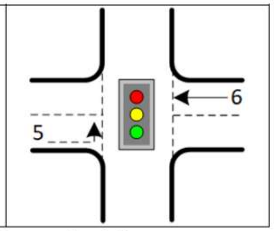

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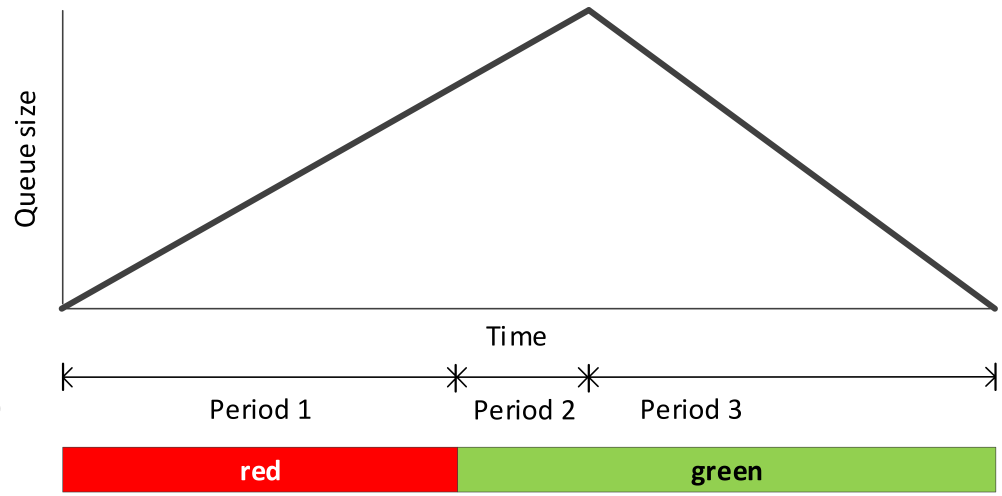

$$s_p = \frac{v_o e^{-v_0 t_c/3600}}{1 - e^{-v_0 t_f/3600}}$$

c = capacity (veh/hr)
v_c = conflicting flow (veh/hr)
t_c = critical headway (sec)
t_f = follow up headway (sec)

$$g_{so} = \frac{v_o r}{s - v_o}$$

time for opposing queue to clear

$$g - g_{so}$$

subject green time available after opposing queue clears

$$c = s_p\left(\frac{g - g_{so}}{C}\right)$$

capacity of permitted LT movement from exclusive lane

8. Scenario 4-3. Calculating the Capacity of an Exclusive LT Lane with Permitted LT Phasing

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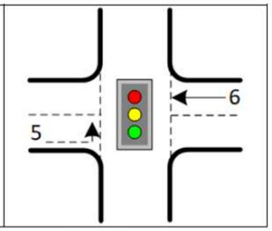

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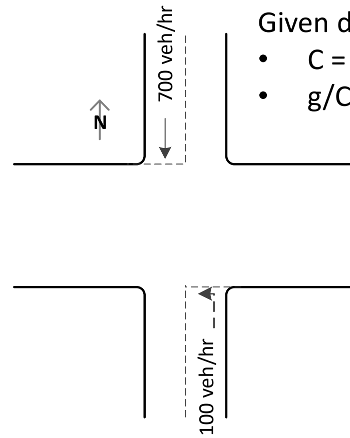
Example Calculation 4-12. Calculating the Capacity of a Permitted LT movement from an Exclusive LT lane



Given data
- C = 60 sec
- g/C = 0.5

$$g_{so} = \frac{v_o r}{s - v_o} = \frac{(700)(30)}{1900 - 30} = 17.5\ sec$$

time for opposing queue to clear

$$g - g_{so} = 30 - 17.5 = 12.5\ sec$$

subject green time available after opposing queue clears

$$s_p = \frac{v_o e^{-v_0 t_c/3600}}{1 - e^{-v_0 t_f/3600}} = \frac{700 e^{-(700)(4.5)/3600}}{1 - e^{-(700)(2.5)/3600}} = 758\ veh/hr$$

saturation flow rate for permitted LT movement from exclusive lane

$$c = (758)\left(\frac{30 - 17.5}{60}\right) = 158\ veh/hr$$

capacity of permitted LT movement from exclusive lane

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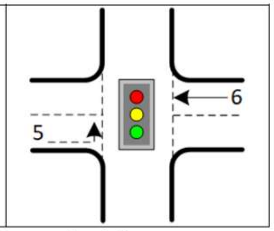

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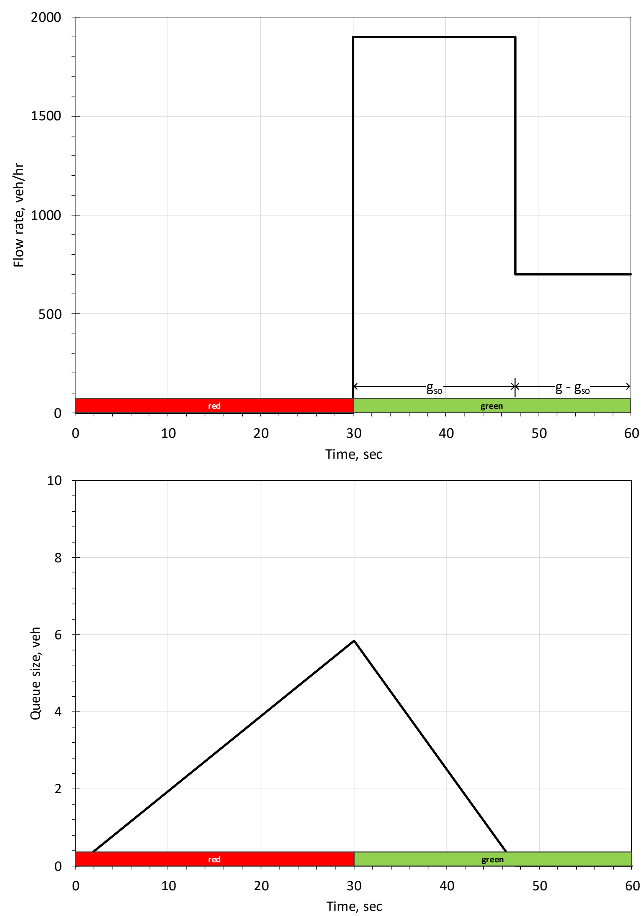

Opposing approach

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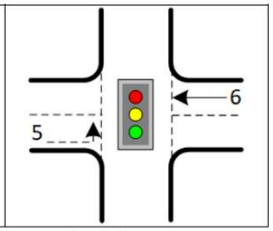

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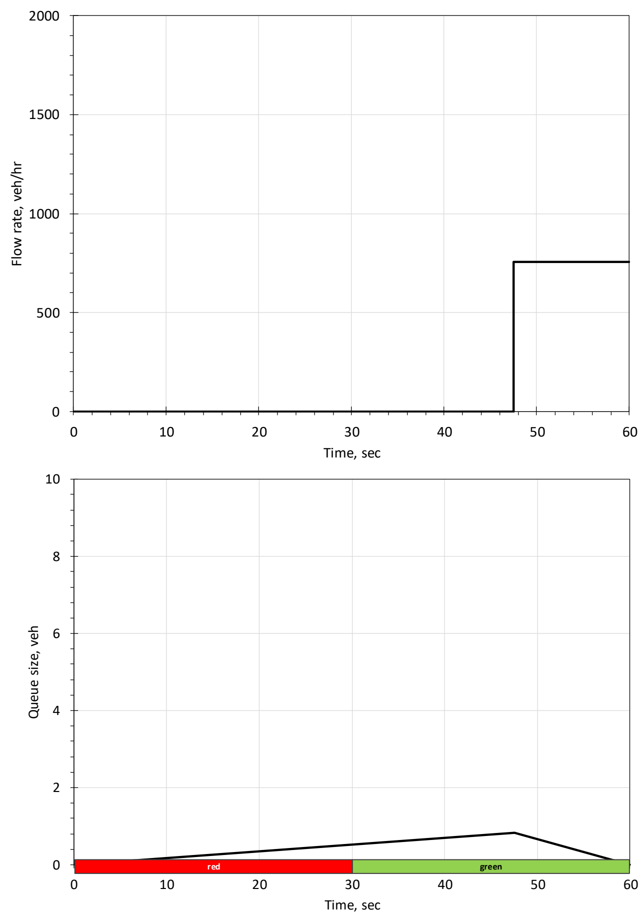
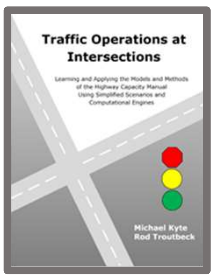
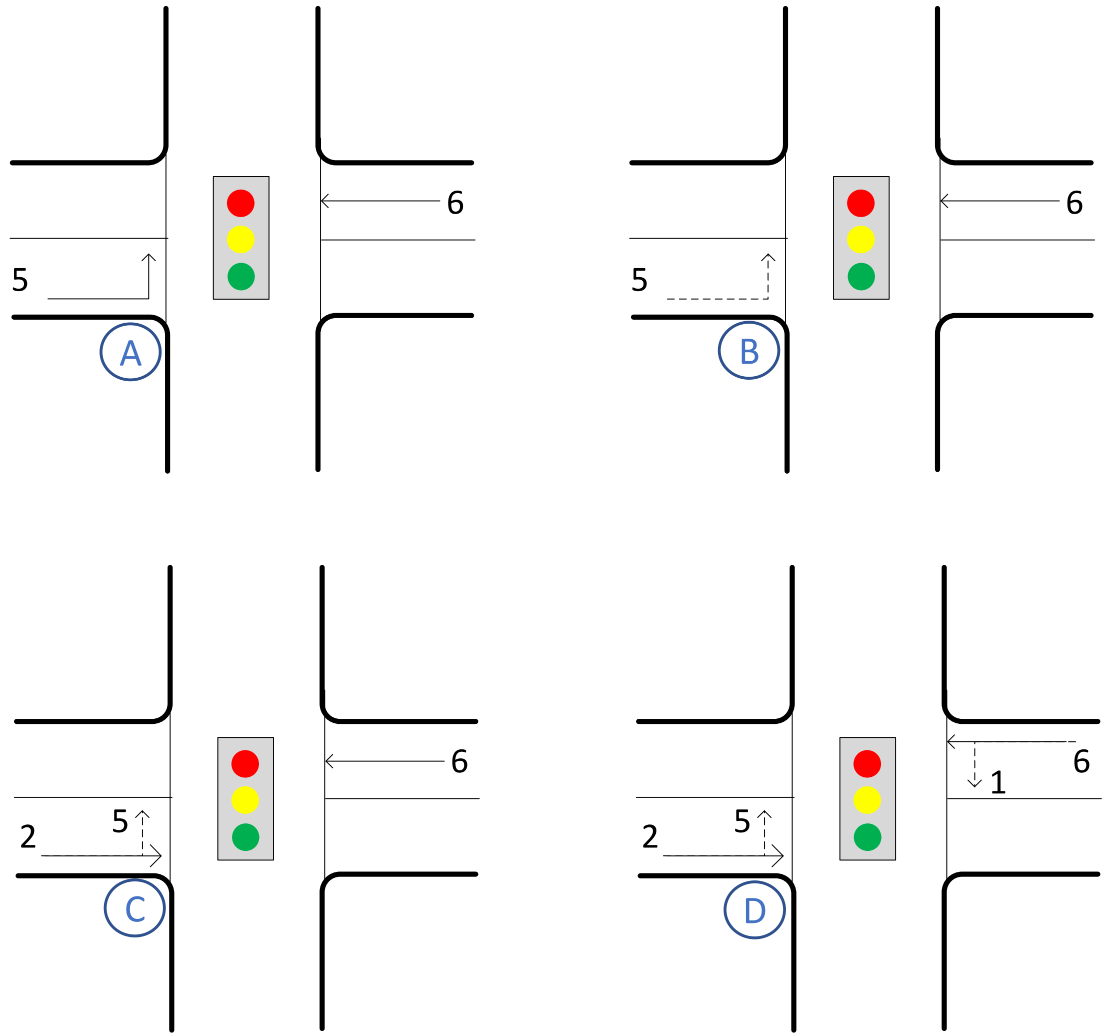


Subject approach

8. Scenario 4-3. Calculating the Capacity of an Exclusive LT Lane with Permitted LT Phasing





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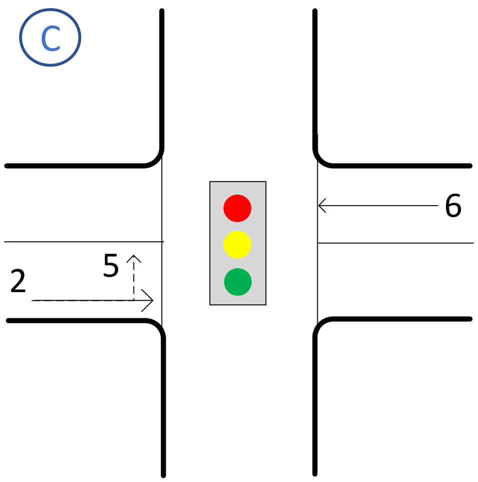

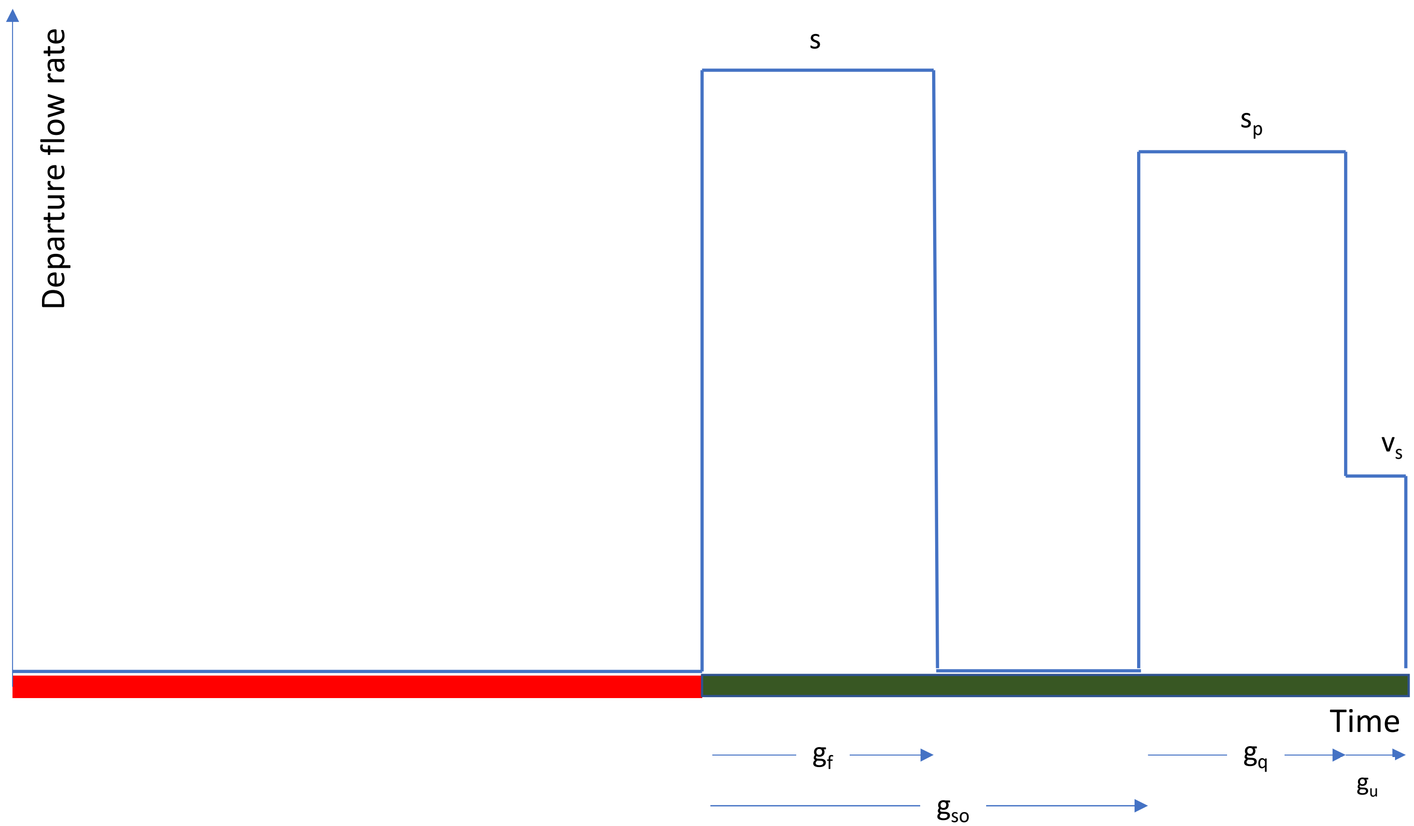

- g_f = time until arrival of first subject LT vehicle
- g_{so} = queue service time for opposing queue
- g_q = time for second subject queue to clear
- g_u = unsaturated green for subject approach after clearance of second queue

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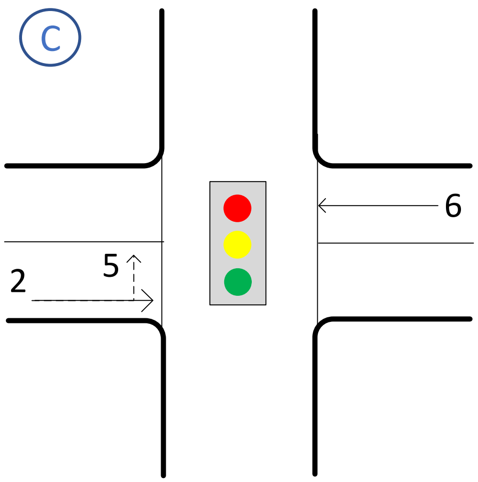

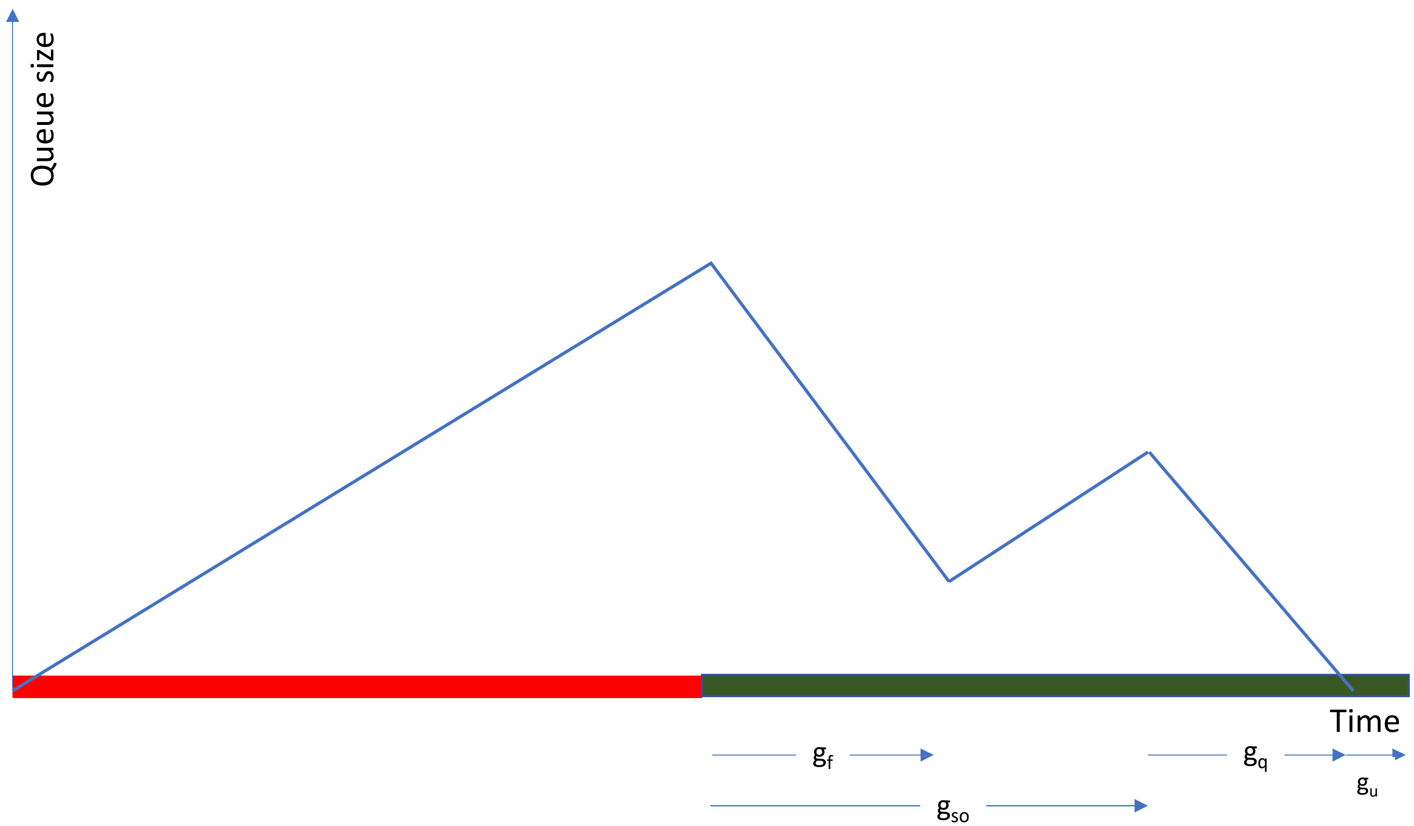

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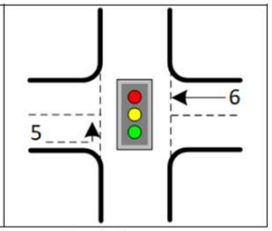

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11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

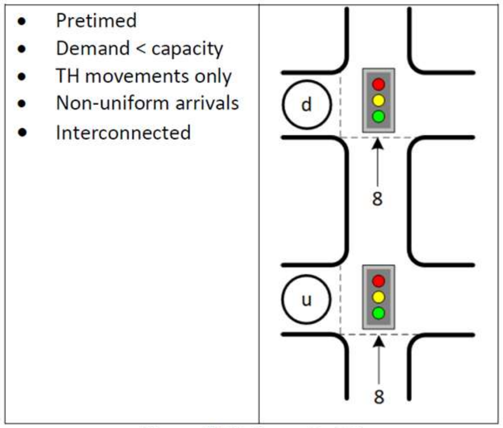


Figure 4-71. Scenario 4-6

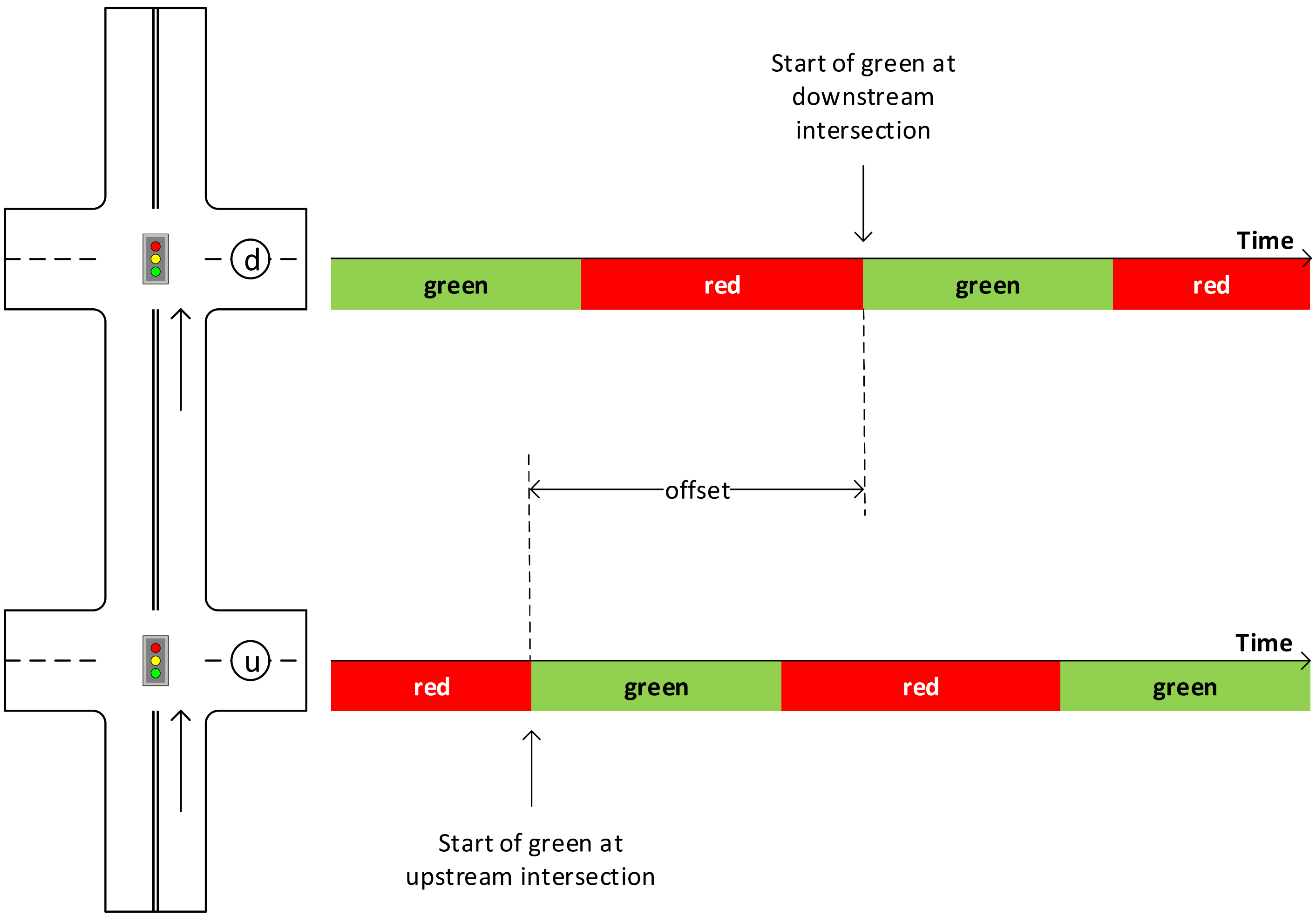
Terms We Will Use

- Offset
- Arrival flow profile
- Departure flow profile
- Time step
- Average travel time
- Queue size

The Big Picture

- We've previously assumed uniform arrivals.
- What happens if there is an upstream signal affecting the arrival pattern by creating platoons?
- How do we model a dispersing platoon traveling from one intersection to the next?
- How does the departure flow profile at the upstream intersection transition to the arrival flow profile at the downstream intersection?
- What is the signal offset?

11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform



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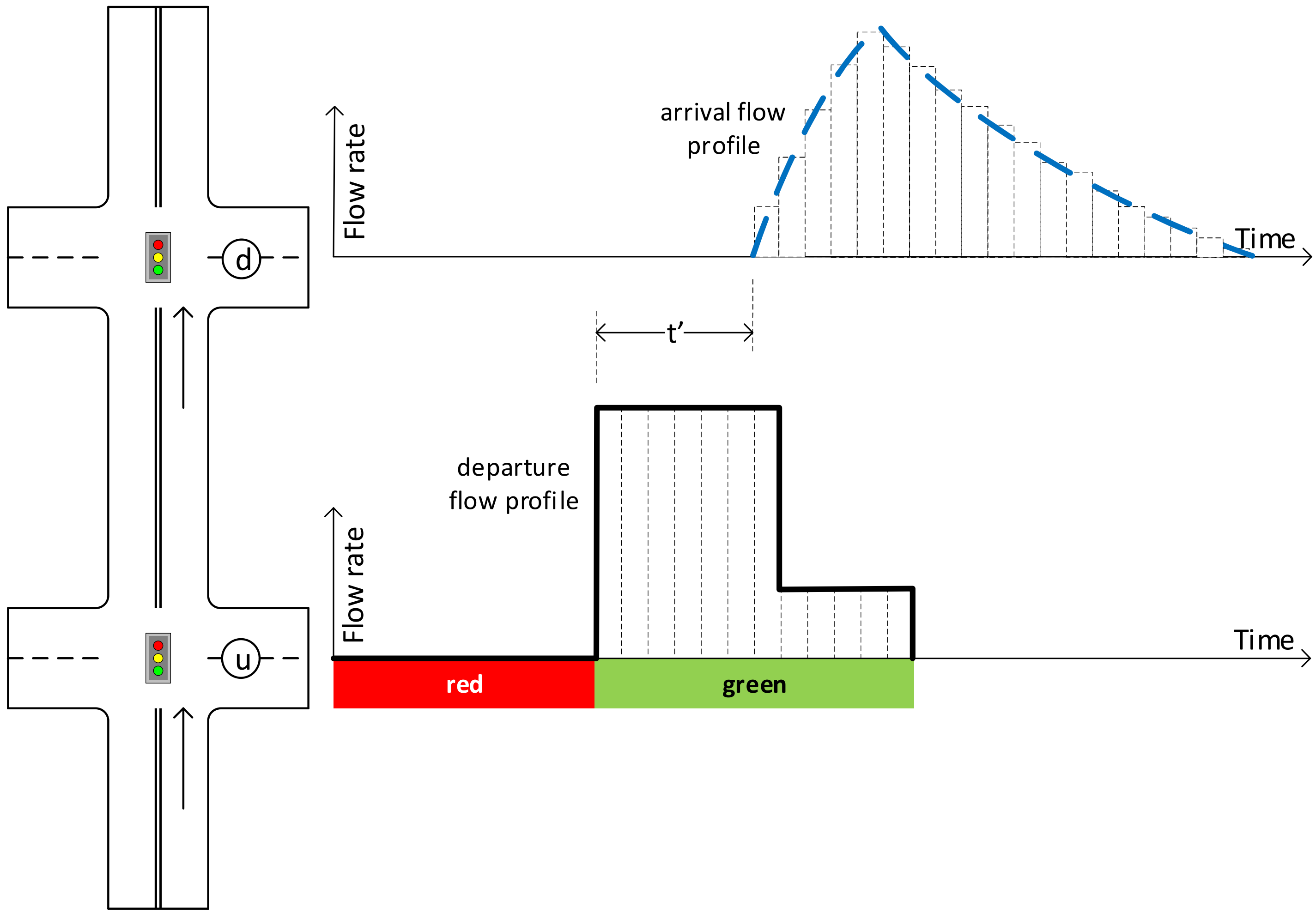


11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

Predicted downstream flow at time step i:

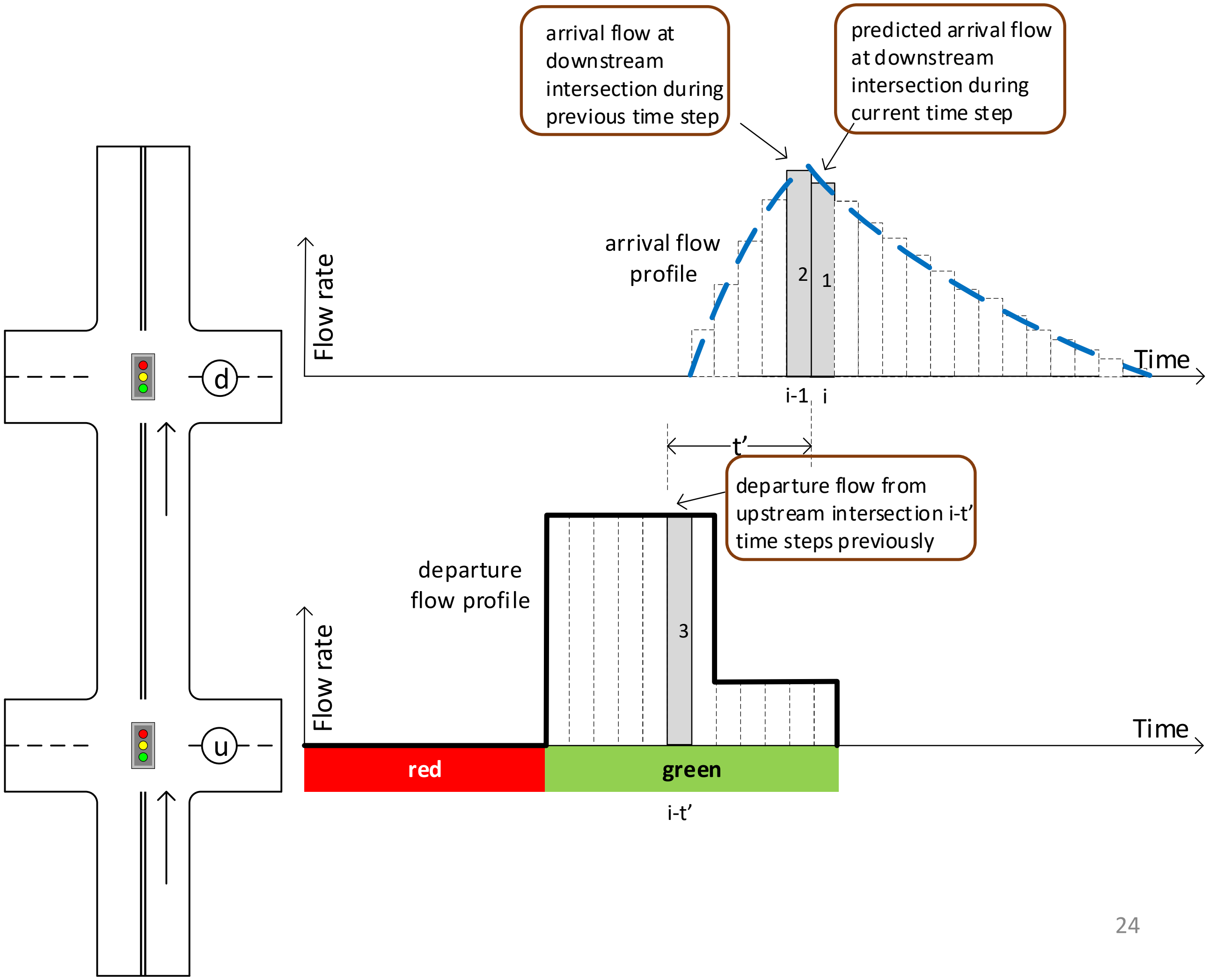
- Upstream flow t' time steps earlier
- Downstream flow one time step earlier

$$q_{d,i} = Fq_{u,i-t'} + (1-F)q_{d,i-1}$$

$$F = \frac{1}{1.315 + 0.138t_R}$$

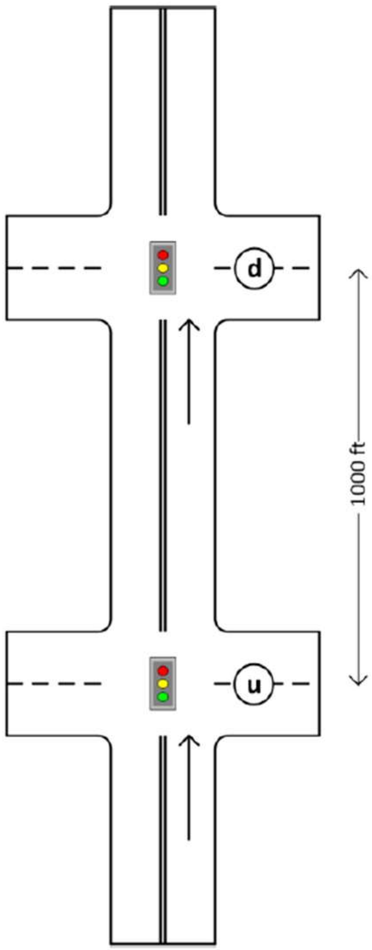
$$t' = t_R - \frac{1}{F} + 1.25$$

Predicted time for front of platoon to travel from upstream to downstream intersection



11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

Example Calculation 4-18. Calculating the Arrival Pattern at the Downstream Intersection



- Arrival flow rate is 600 veh/hr
- Intersection spacing is 1000 ft
- C = 60 sec
- g/C = 0.5
- s = 1900 veh/hr
- Average vehicle speed = 25 mi/hr or 36.75 ft/sec

11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

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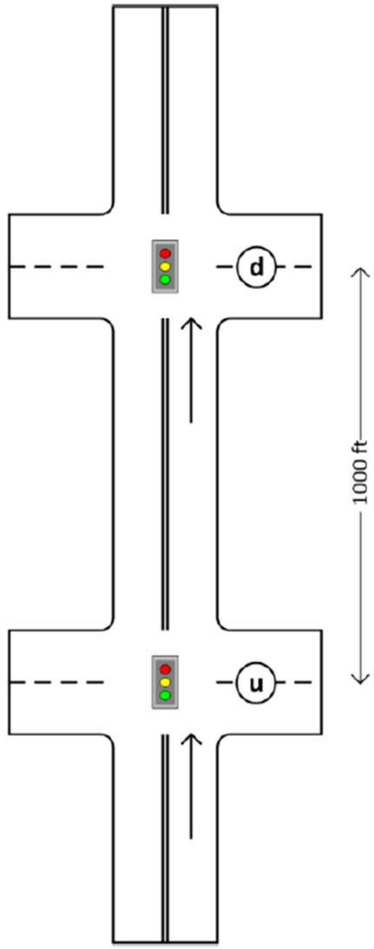

$$g_s = \frac{vr}{s - v} = \frac{(600\frac{veh}{hr})(30\,sec)}{1900\frac{veh}{hr} - 600\ \frac{veh}{hr}} = 13.8\,sec$$

$$t_R = \frac{distance}{average\ travel\ speed} = \frac{1000\,ft}{36.75\,ft/sec} = 27.2\,sec$$

$$F = \frac{1}{1.315 + 0.138t_R} = \frac{1}{1.315 + (0.138)(27.2)} = 0.197$$

$$t' = t_R - \frac{1}{F} + 1.25 = 27.2 - \frac{1}{0.197} + 1.25 = 23\,sec$$

11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

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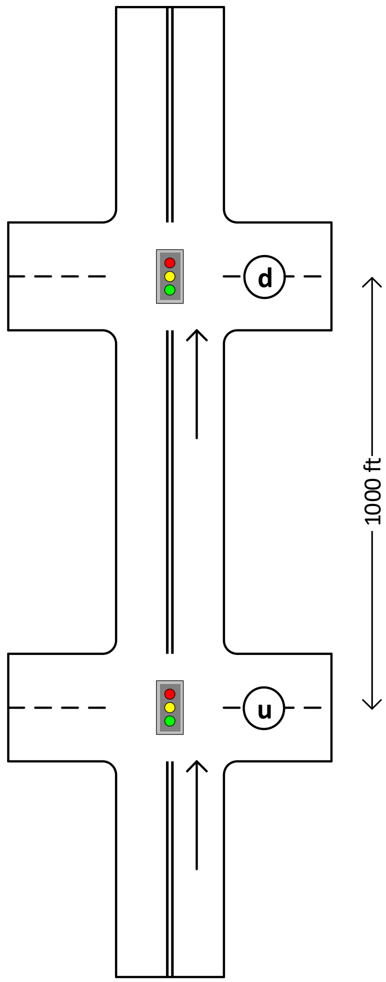

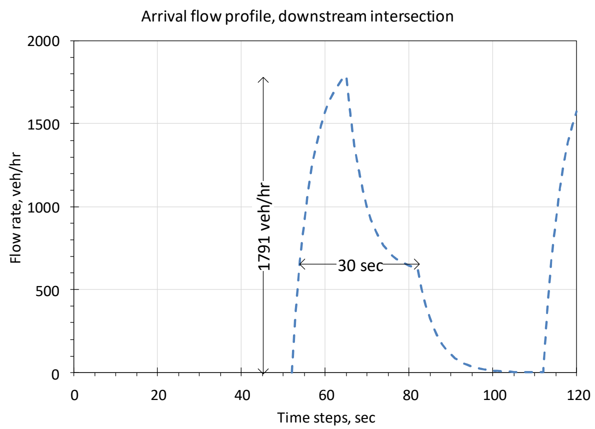

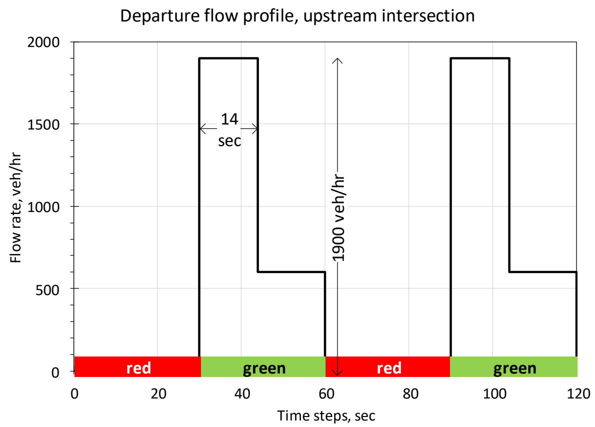

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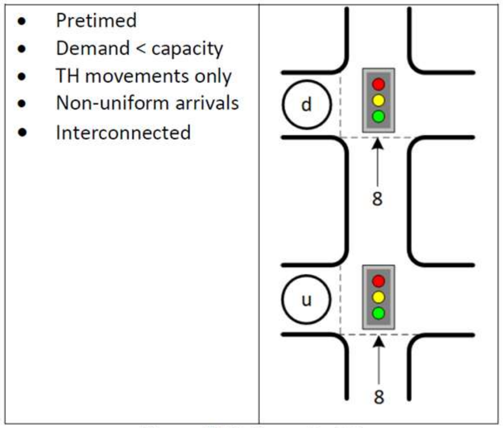


Figure 4-71. Scenario 4-6

$$q_{d,i} = F q_{u,i-t'} + (1-F) q_{d,i-1}$$

$$q_{d,54} = F q_{u,31} + (1-F) q_{d,53}$$

$$q_{d,54} = (0.197)(1900) + (0.803)(0) = 375 \text{ veh/hr}$$

$$q_{d,55} = F q_{u,32} + (1-F) q_{d,54}$$

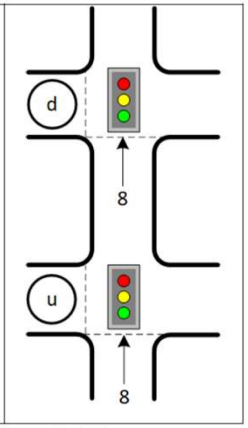
$$q_{d,55} = (0.197)(1900) + (0.803)(375) = 676 \text{ veh/hr}$$

Example Calculation 4-18. Calculating the Arrival Pattern at the Downstream Intersection

Time step (sec)	Upstream departure flow rate (veh/hr)	Downstream arrival flow rate (veh/hr)
1-30	0	0
31-43	1900	0
44-53	600	0
54	600	375
55	600	676
56	600	917
57	600	1111
58	600	1267
59	600	1392
60	600	1492

11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

- Pretimed
- Demand < capacity
- TH movements only
- Non-uniform arrivals
- Interconnected



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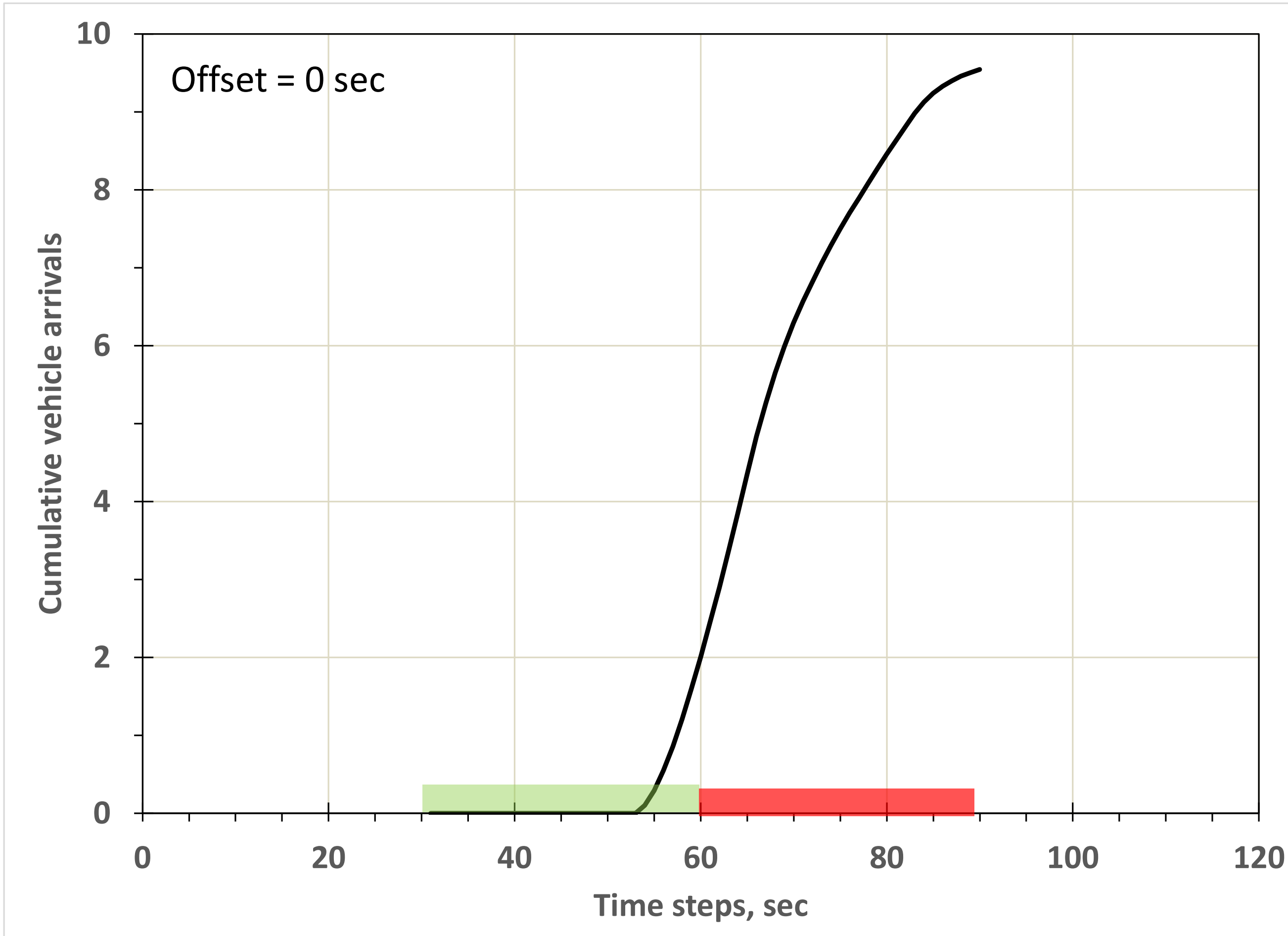

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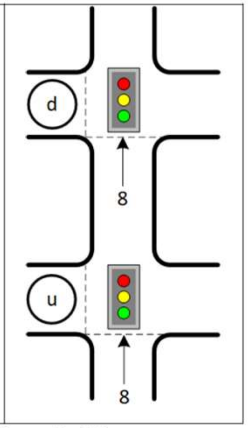

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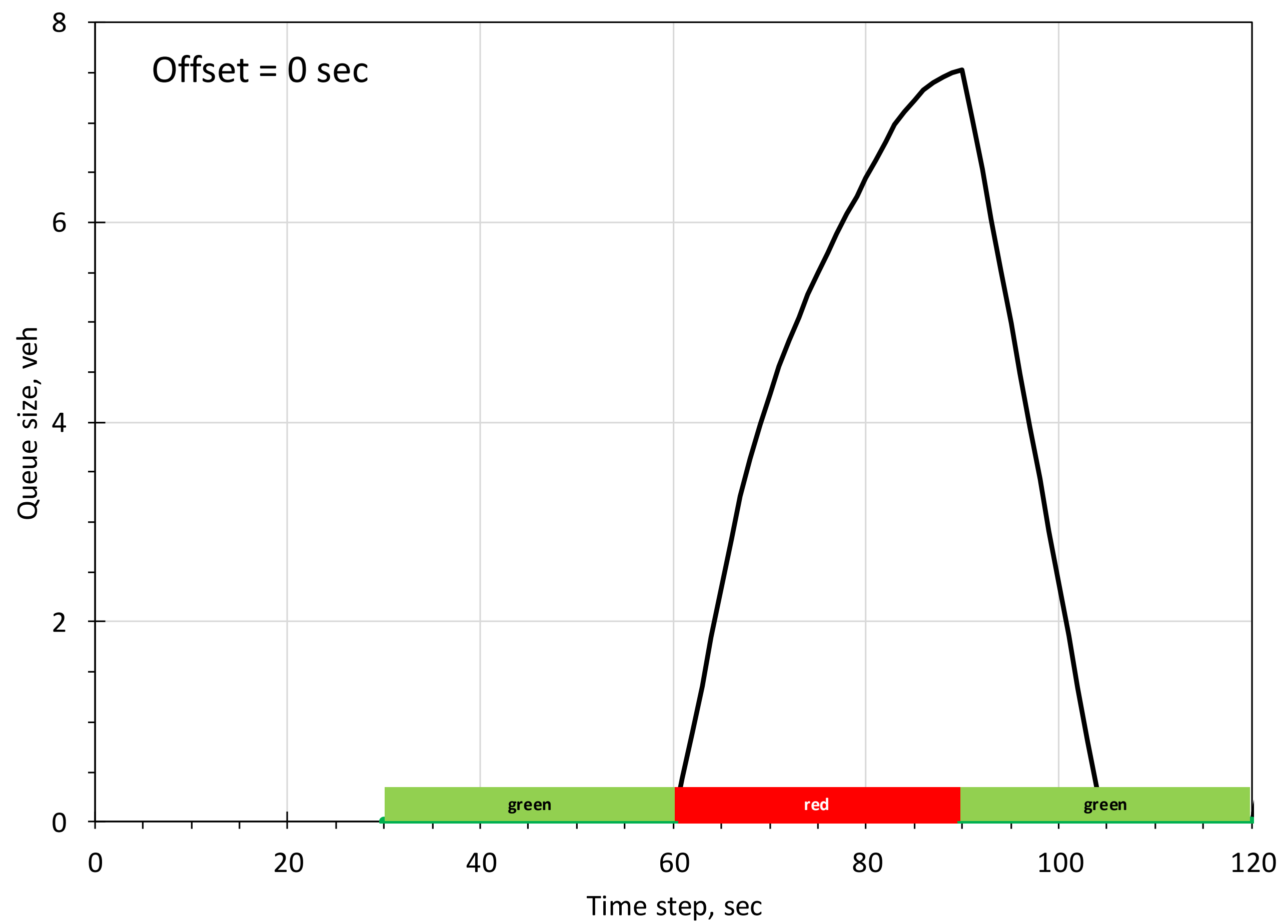

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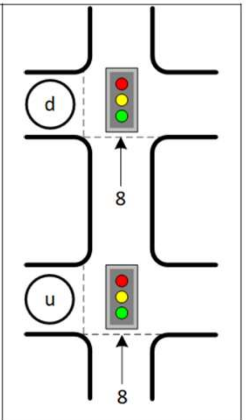

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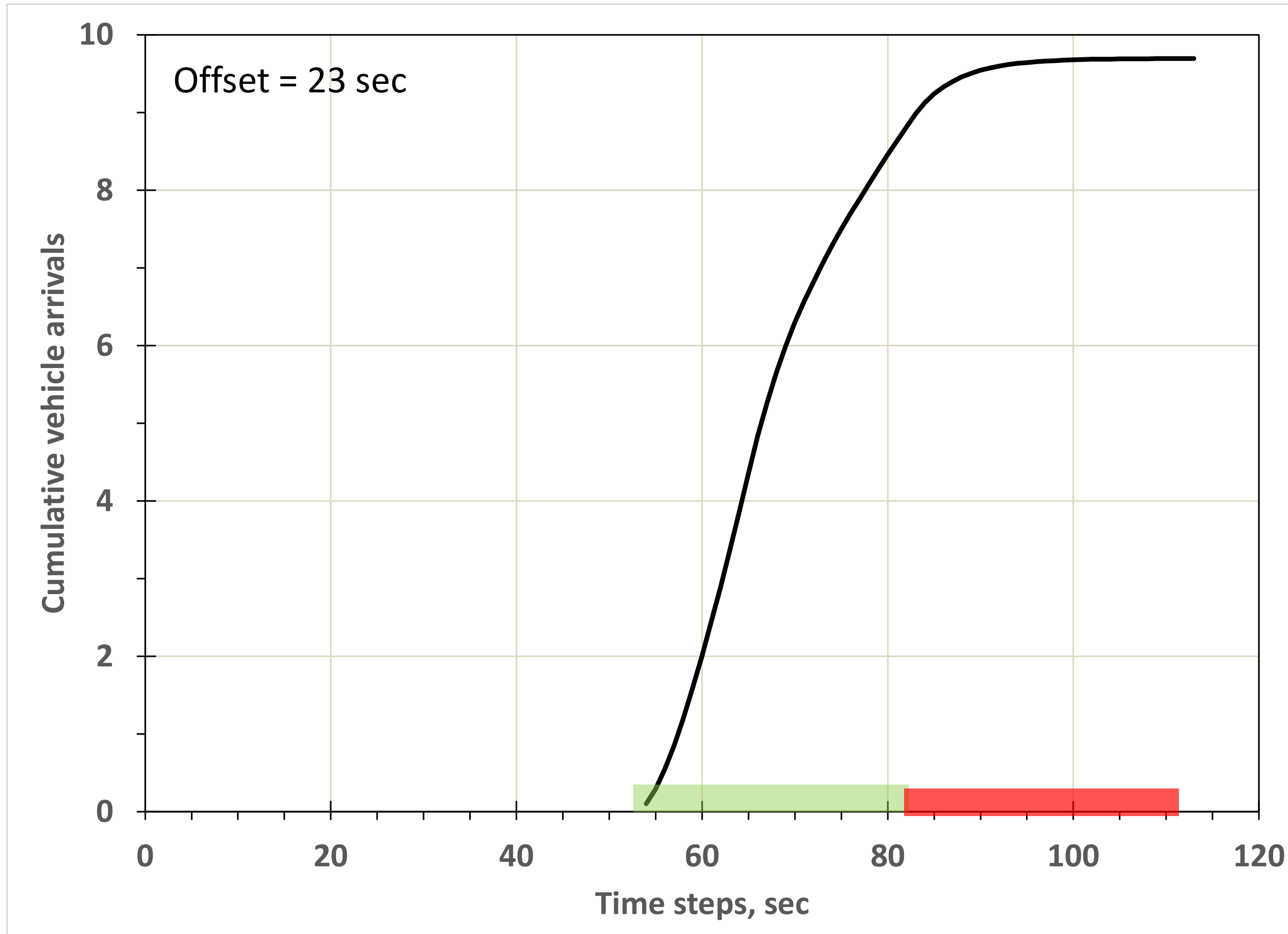

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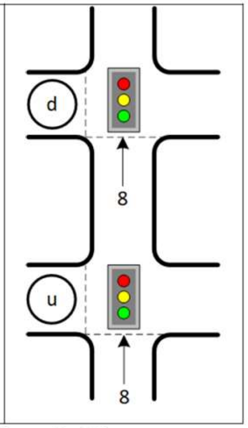

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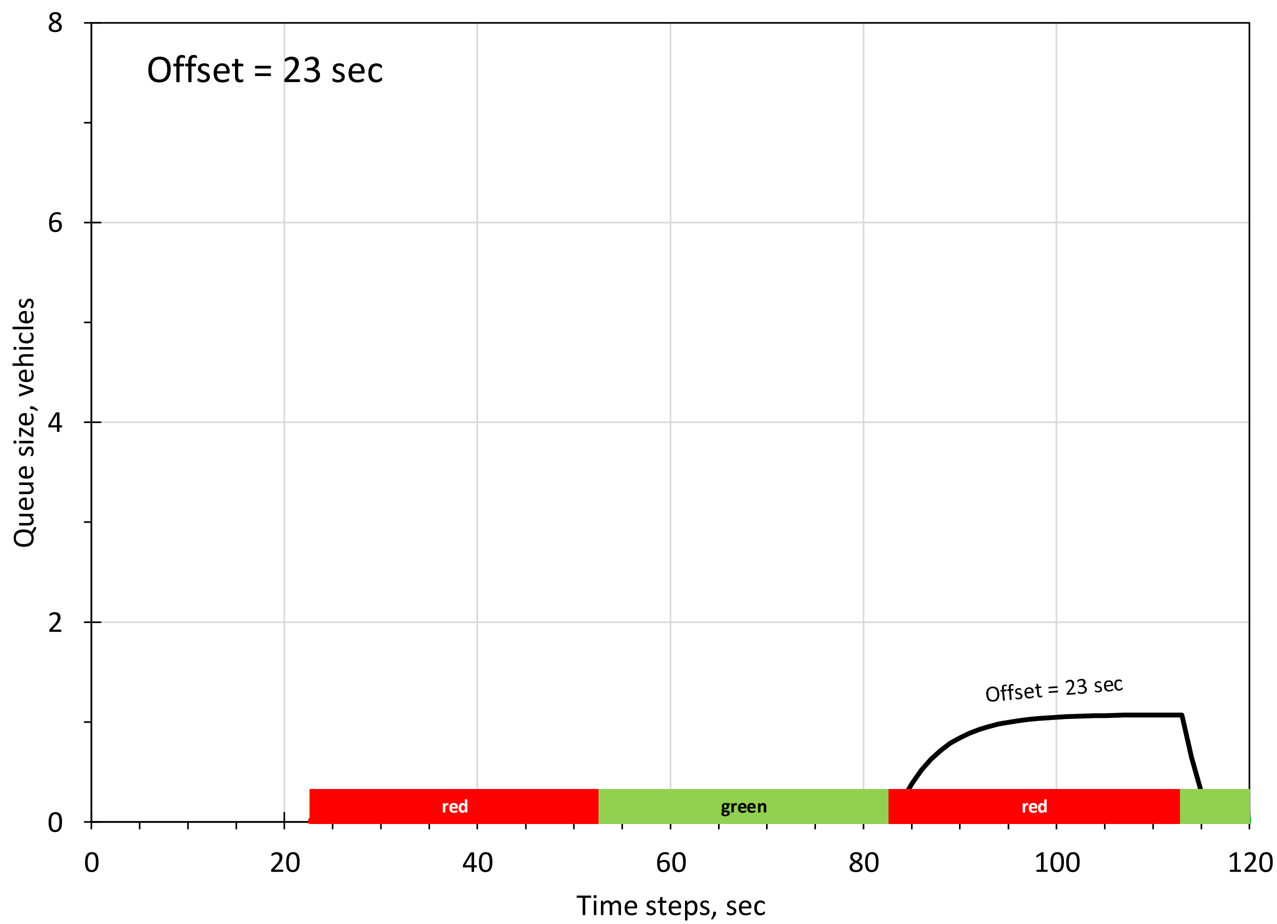

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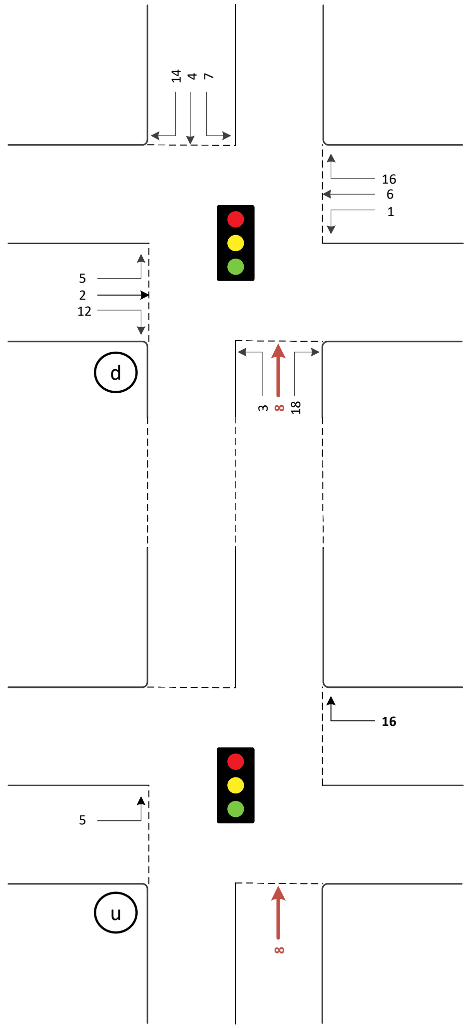
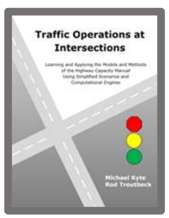
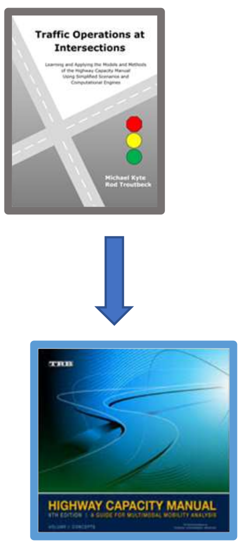
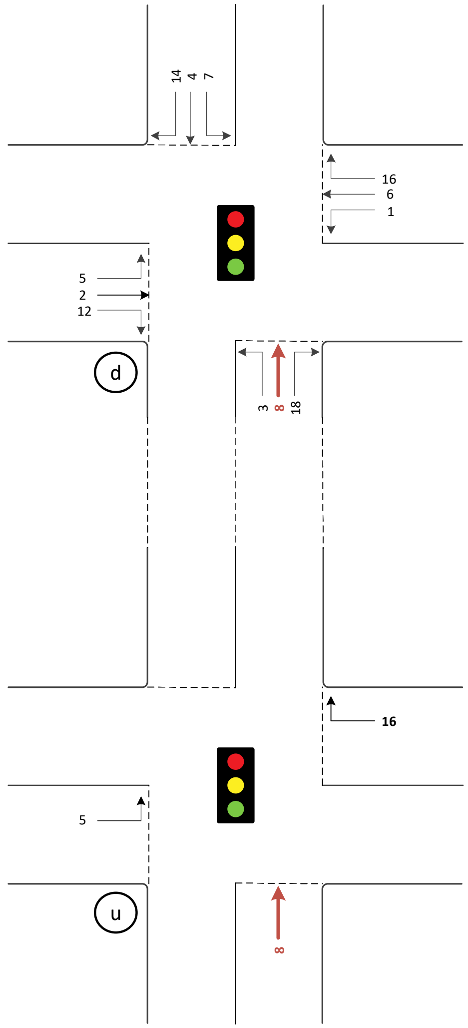
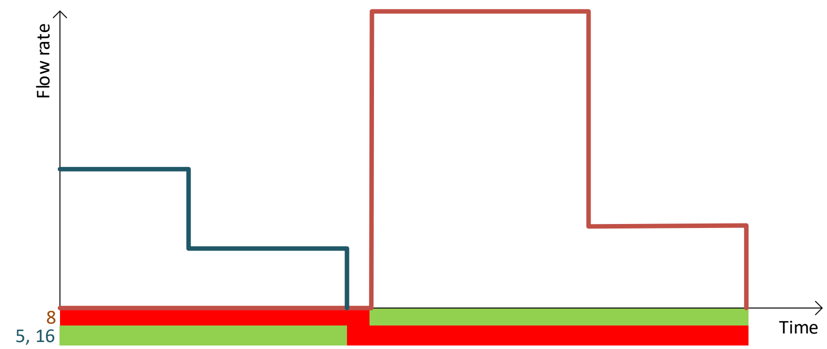




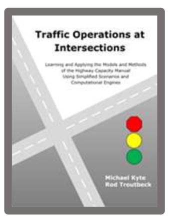
11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

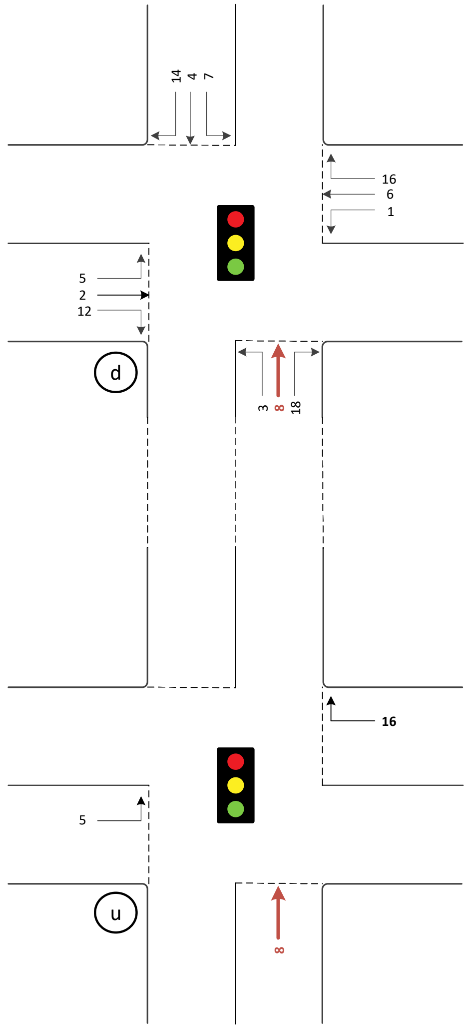






11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform





Arrival Type	Progression Quality	Proportion Arriving During Green
1	Very poor	.17
2	Unfavorable	.33
3	Random (or uniform) arrivals	.50
4	Favorable	.67
5	Highly favorable	.83
6	Exceptionally favorable	1.00

11. Scenario 4-6. Calculating Delay on a Lane When the Arrival Pattern is Non-Uniform

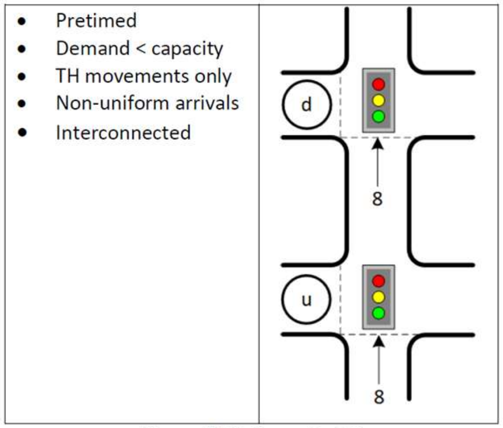


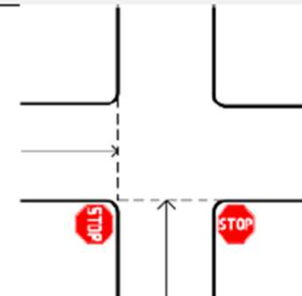
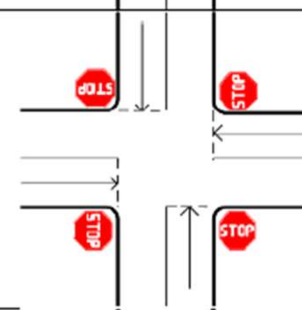
Figure 4-71. Scenario 4-6

The Big Picture

- We've previously assumed uniform arrivals.
- What happens if there is an upstream signal affecting the arrival pattern by creating platoons?
- How do we model a dispersing platoon traveling from one intersection to the next?
- How does the departure flow profile at the upstream intersection transition to the arrival flow profile at the downstream intersection?
- What is the signal offset?

Topics for today

- Check-in
- Some perspective and context
- Diving in: Exploring the simplified scenarios
- **The other scenarios**
- Check-out and closure

Intersection Control	Scenario	Conditions	Illustration
AWSC intersections 	2-1. Calculating the capacity of each lane for an intersection of two one-lane one-way streets	• Two one-way streets • TH movements	
	2-2. Calculating the capacity of each lane for a standard 4-leg intersection	• Four approaches • TH movements	

Scenario 4-5

- Pretimed control
- Demand>capacity
- TH movements
- Uniform arrivals
- Isolated

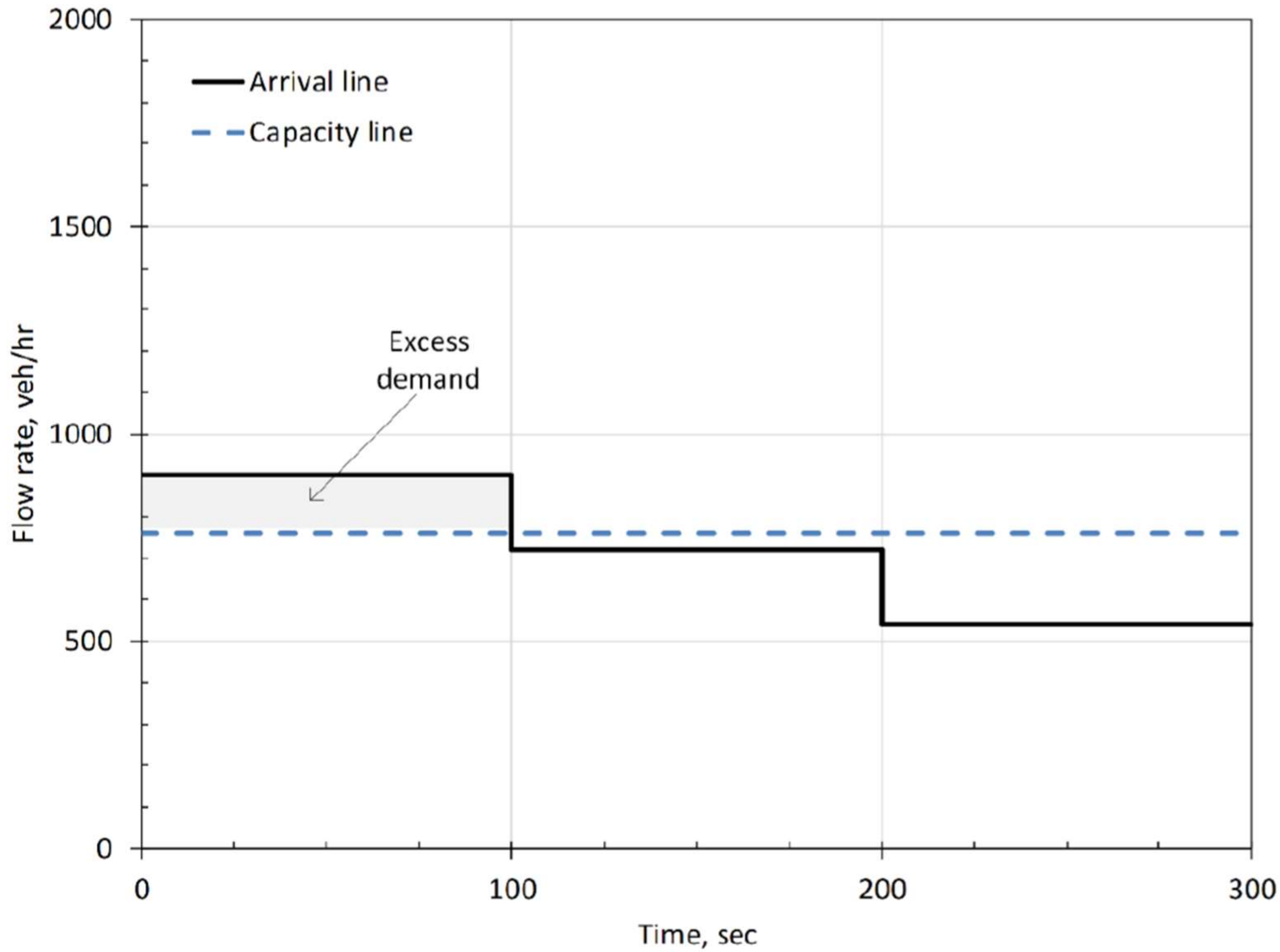


Figure 4-67. Flow profile diagram for Example Calculation 4-17

Scenario 4-5

- Pretimed control
- Demand>capacity
- TH movements
- Uniform arrivals
- Isolated

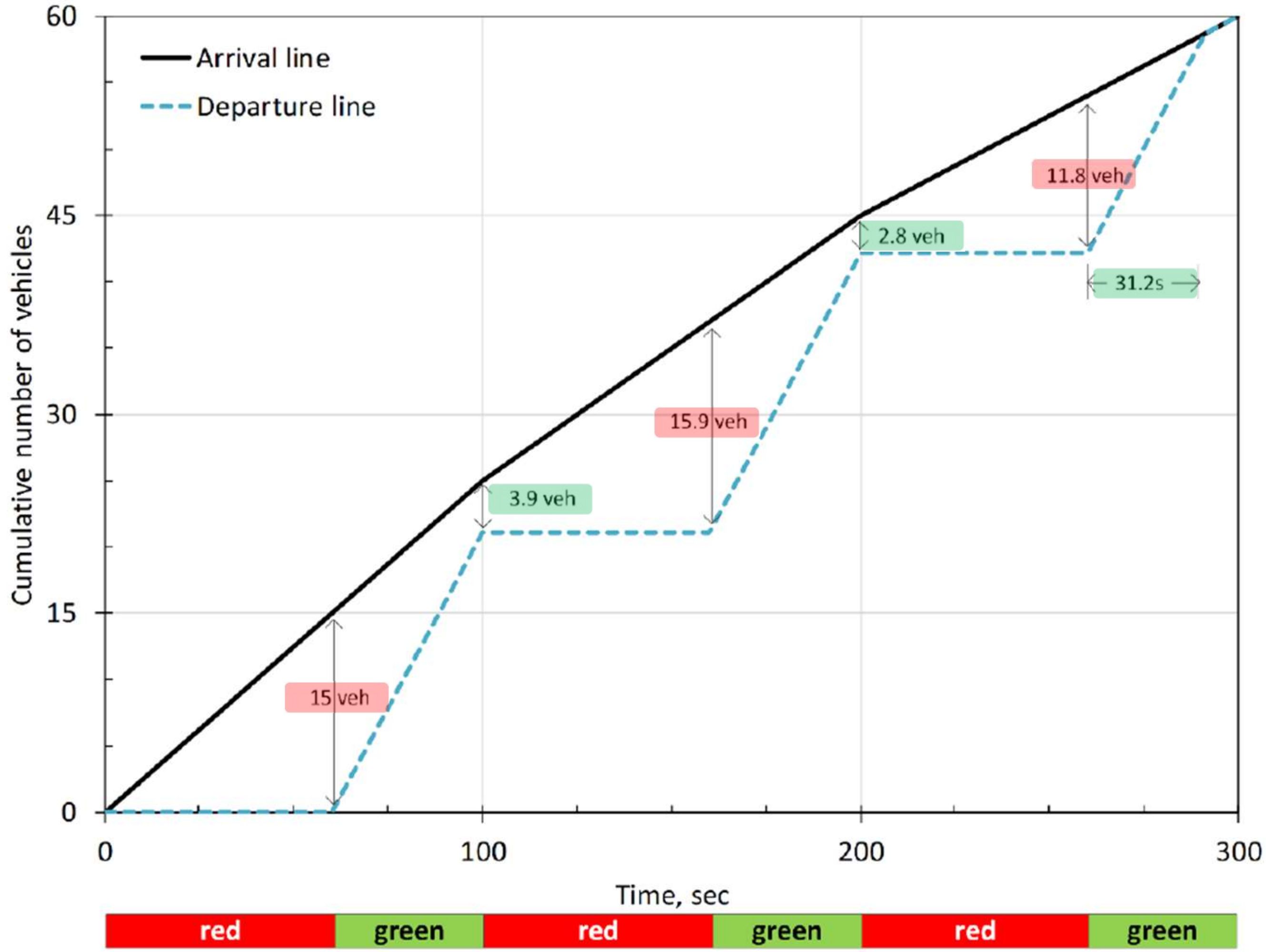


Figure 4-68. Cumulative vehicle diagram for Example Calculation 4-17

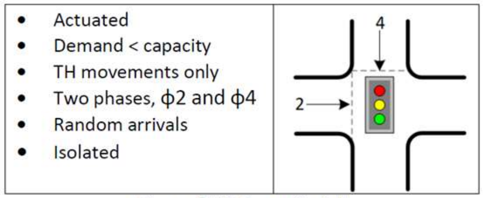


Figure 4-79. Scenario 4-7

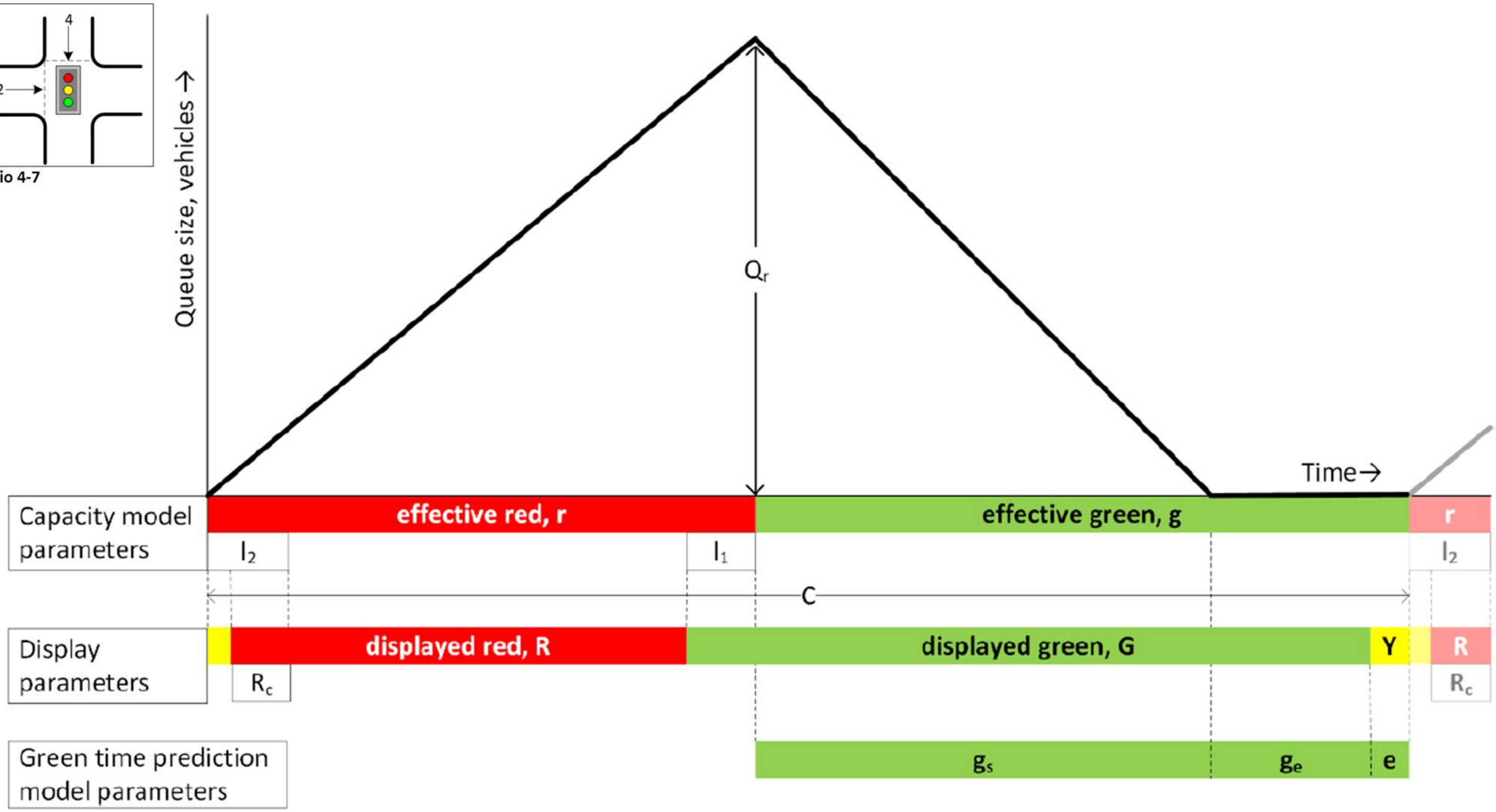


Figure 4-80. Capacity model, display model, and predicted green time prediction model parameters

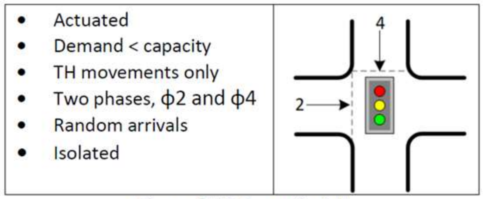


Figure 4-79. Scenario 4-7

- Occupancy time, t_o
- Unoccupancy time, t_u
- Passage time
- Maximum allowable headway

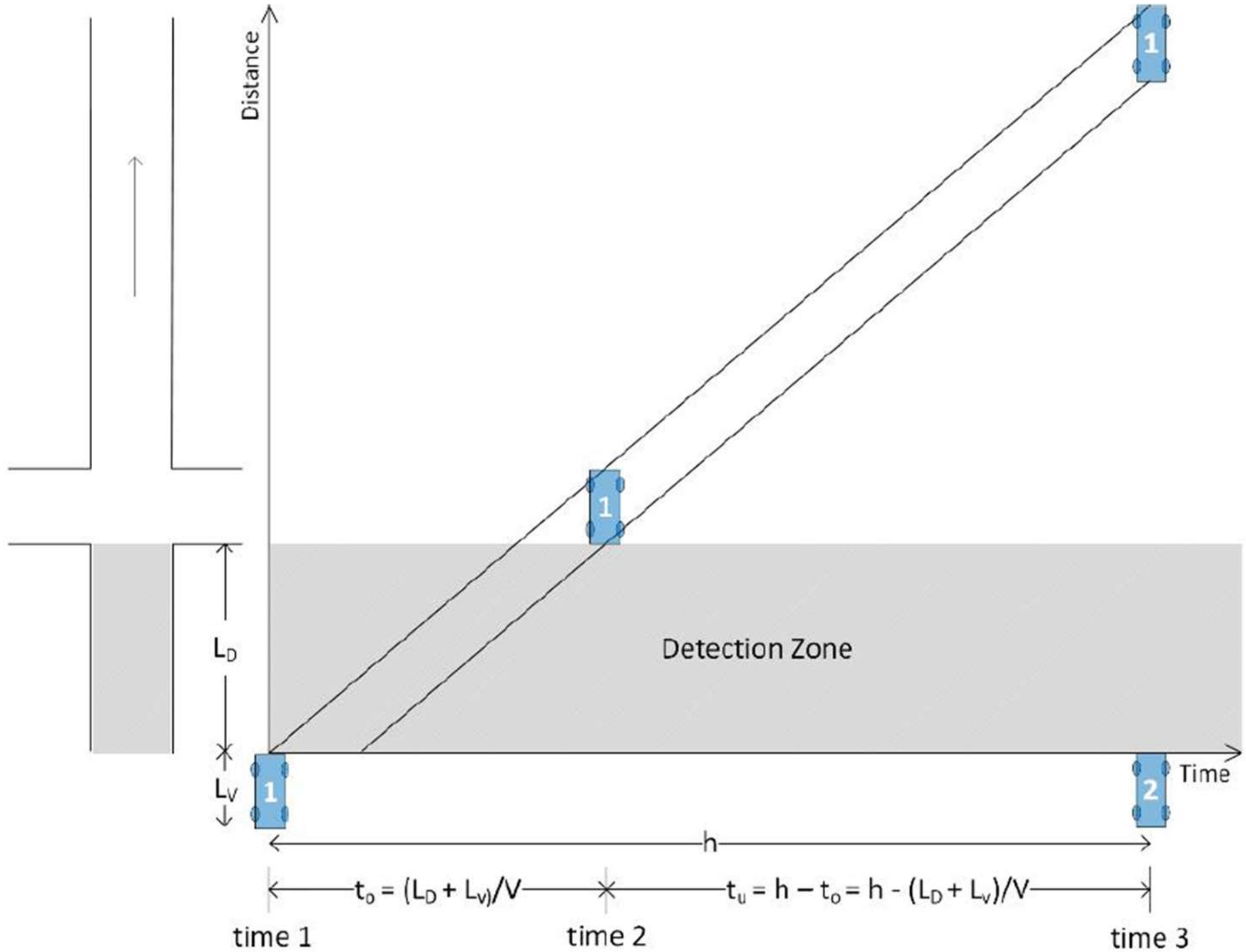


Figure 4-82. Headway, occupancy time, and unoccupancy time

Topics for today

- Check-in
- Some perspective and context
- Diving in: Exploring the simplified scenarios
- The other scenarios
- **Check-out and closure**

Final Questions