CEE 551 - Traffic Science

Topic: Traffic Signal Control (5)

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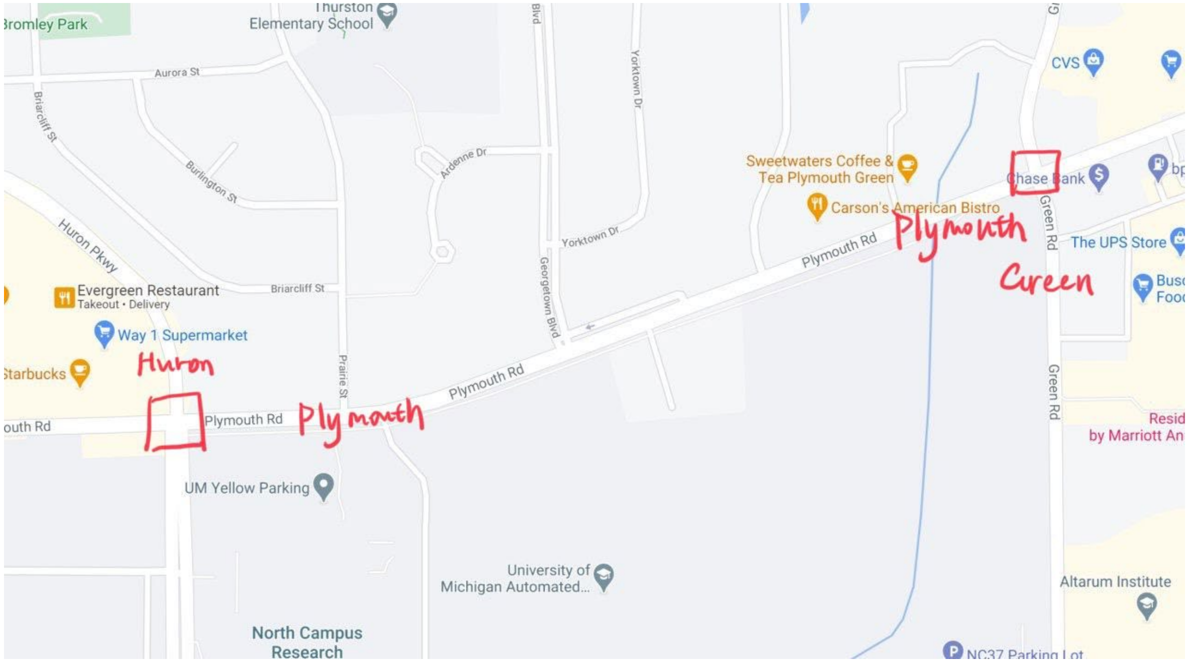
Outline

- Homework assignment 6 (due Dec. 11)
- SUMO tutorial Part II
- Traffic coordination
  - Basic concept and design principle
  - Coordinated actuated control: force-offs

Homework Assignment 6

- Design the fixed-time traffic signal for two consecutive traffic signals including the cycle, splits, and offset in SUMO simulation and perform the evaluation



Course Project Presentation Schedule

	Group	Name	Start Time
Nov. 30	1	Aiden Ascioti	9:00
	2	Garrett Everitt Andrew Hendrie	9:07
	3	Amy Fong Sungho Lim	9:21
	4	Karsten Van Fossan Joey Ryan	9:35
	5	Maia Gallagher	9:49
	6	Ryan Herster Taewhan Ko	9:56
	7	Seung-Gu Lee	10:10
Dec. 5	8	Shuyang Li Siqi Lian	9:00
	9	Richard Lee Zhijie Qiao	9:14
	10	Jason Lu Ben Rosenblad	9:28
	11	Sakie Kawsar	9:42
	12	Yuyang Zhao Shiqi Zhang	9:49
	13	Yiyun Zou	10:03
	14	Ruicong Zhang Lingyun Zhong	10:10

Each student has a total of 7 minutes for presentation and Q&A

Signal Coordination

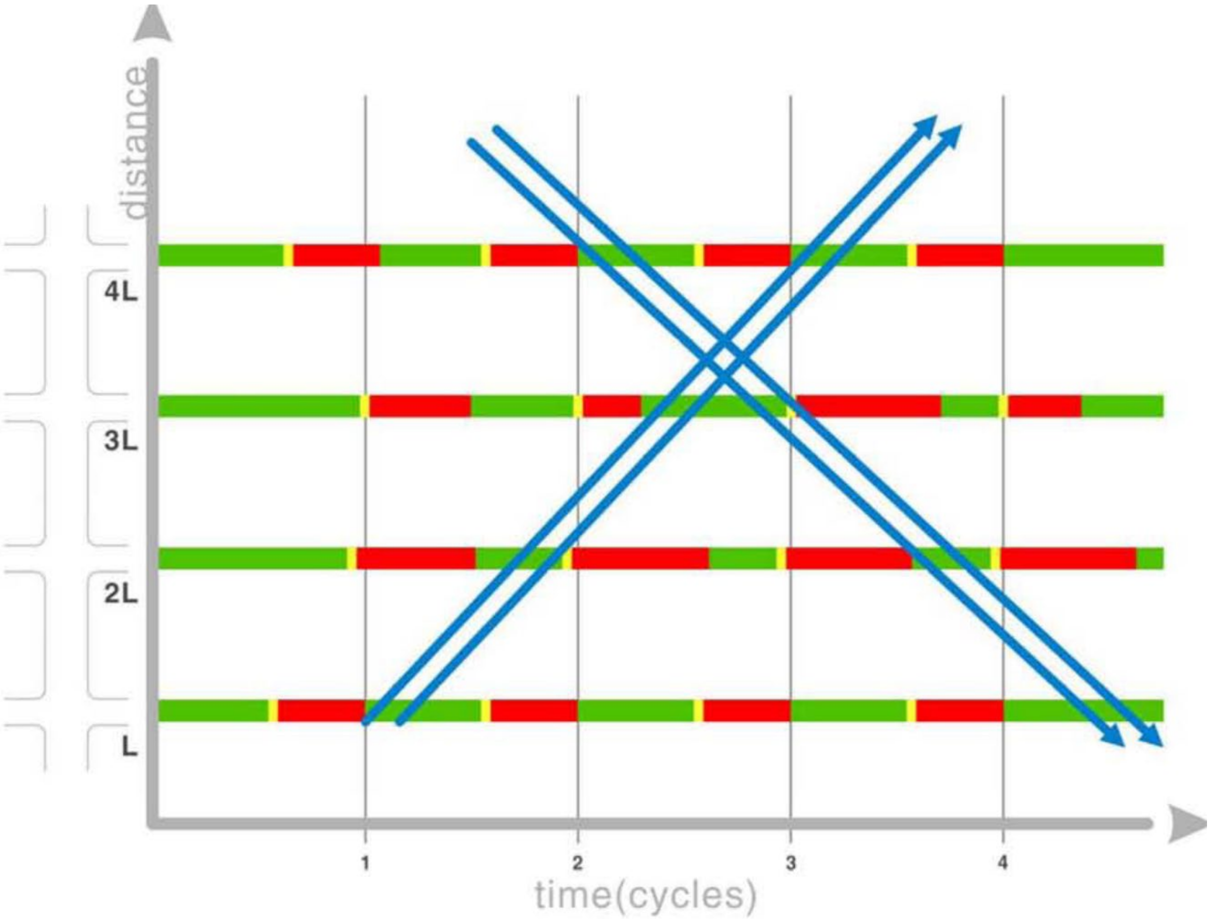
- For situations with relatively closely spaced intersections
- Common practice is to coordinate signals less than ½ mile apart on major streets and highways

Benefits

- Prime benefit: reduction in stops, delays, and energy consumptions

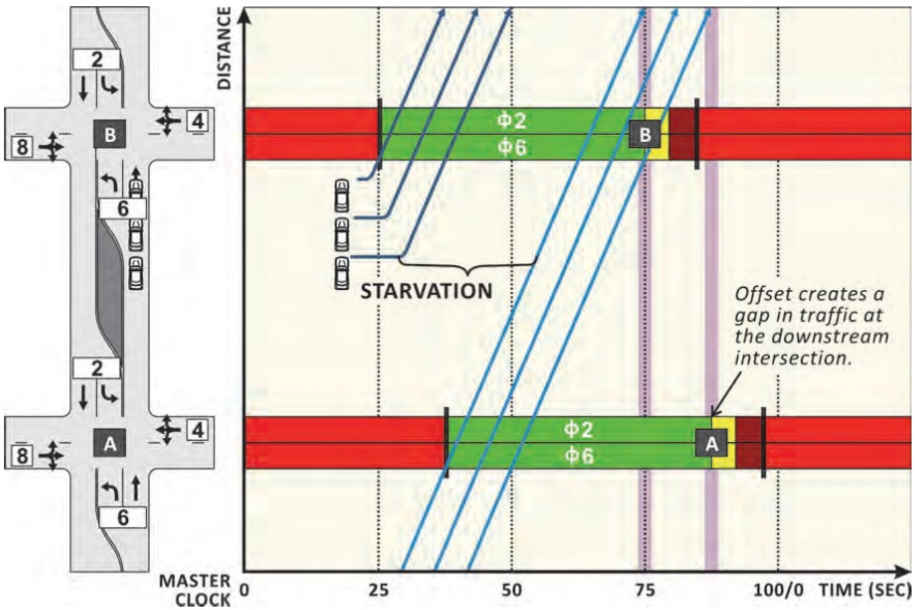
- Encourage preferred speed: signals set such that to incur more stops for speeds faster than the design speed
- Although in many cases the offset does not change the capacity, it could increase the throughput of intersections by preventing the “starvation” & “spillback”

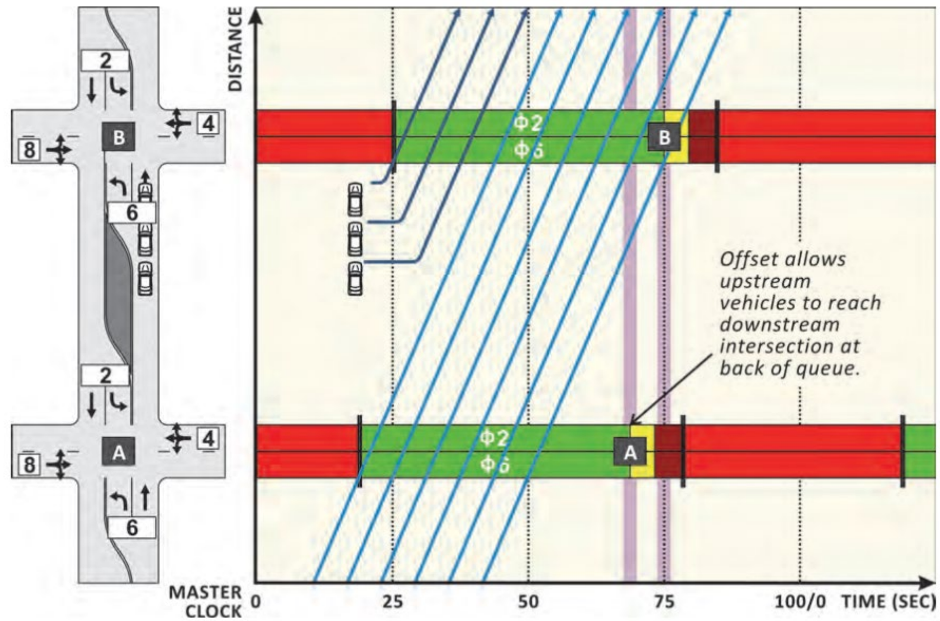
Time-Space Diagram



Offset to Prevent Starvation

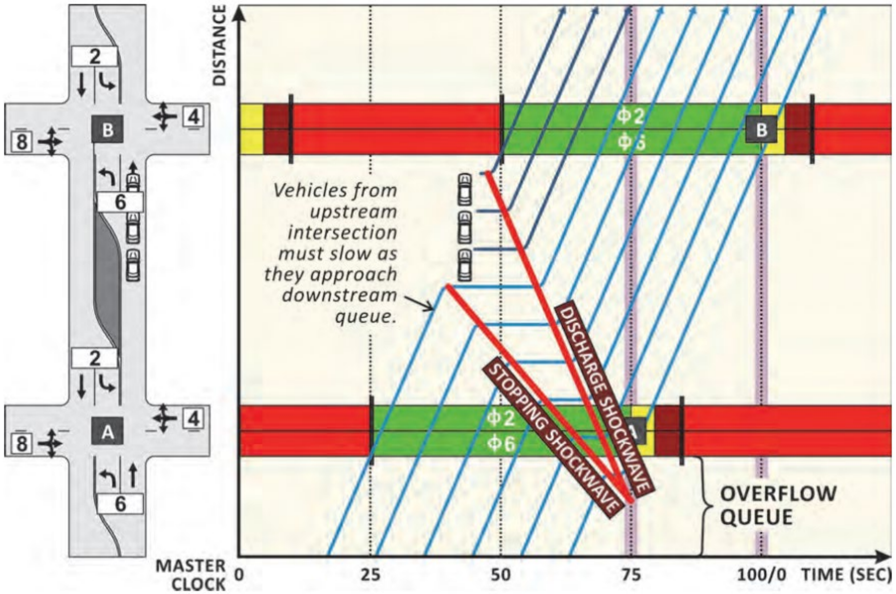
- Starvation & prevention

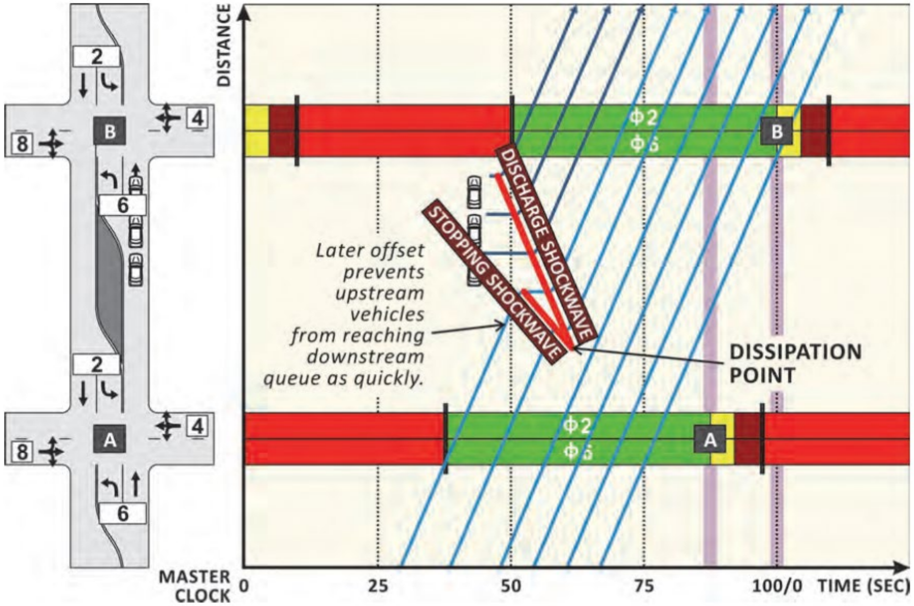




Offset to Prevent Queue Spillback

- Spill-back and the prevention





Factors lessening benefits

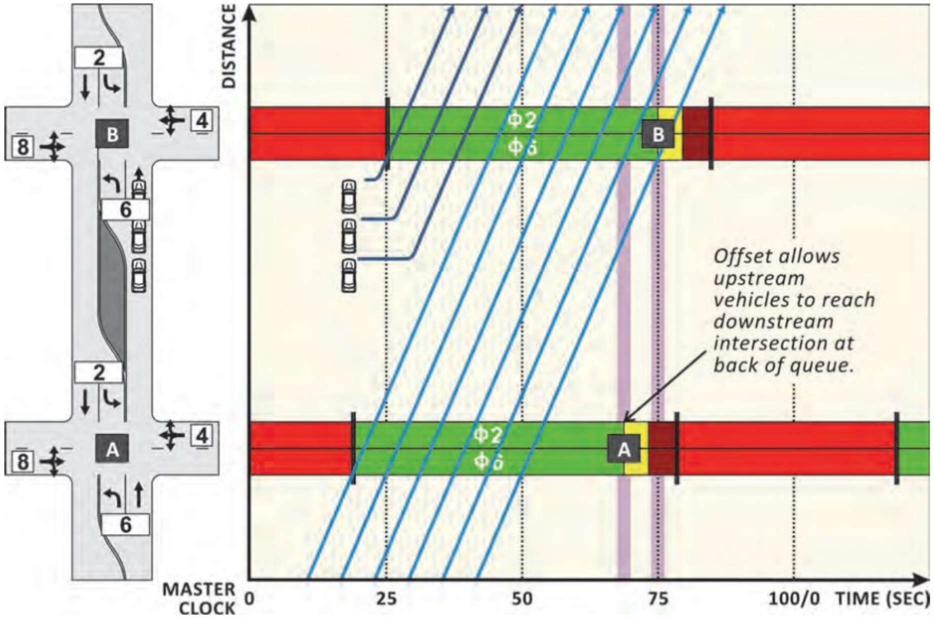
- Existence of side frictions including parking, loading, etc.
- Heavy turn volumes, either into or out of the street

- Easy coordination may not always be possible. For example, a very busy intersection located in not as congested area. The engineer may not want to use the cycle time of the busy intersection as the common cycle time.

Ideal Offsets

- (Relative) offset: the temporal difference between the local reference time (e.g., green initiation times) at two adjacent intersections
- Usually expressed as a positive number between zero and the cycle length.
- Ideal offset: the value such that the first vehicle of a platoon just arrives at the downstream signal, the downstream signal turns green.
  - $t^* = \frac{L}{v}$
  - $\text{Offset} = t^* \% C$
  - L: length between intersections
  - v: vehicle speed
  - C: cycle length

Effect of Vehicles Queued at Signals



$$t^* = \frac{L}{v} - (q \times h + L)$$

- L: length between intersections
- v: vehicle speed
- q: residual queue (# of vehicles)
- h: time headway (sec/veh)
- L: start-up loss time

Offset Optimization

- Define the actual offset and ideal offset by:

$$t(i,j) = t^*(i,j) + e(i,j)$$

  - (i,j): from intersection i to intersection j
  - $t(i,j)$: actual temporal difference of the green start between i and j
  - $e(i,j)$: discrepancy between the actual & ideal temporal differences of the green start time, $e(i,j) \in (-\frac{1}{2}C, \frac{1}{2}C]$

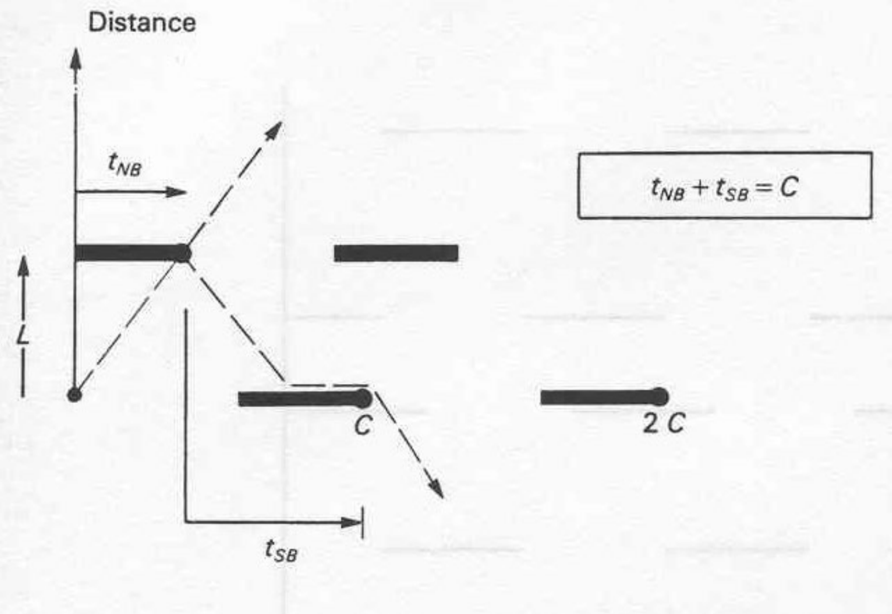
- Offset optimization objective: minimize the squares or of the discrepancies, weighted by the link volumes $Q(i,j)$:

$$\min \sum_{\forall ij} Q(i,j) \cdot e^2(i,j) = \min \sum_{\forall ij} Q(i,j)(t(i,j) - t^*(i,j))^2$$

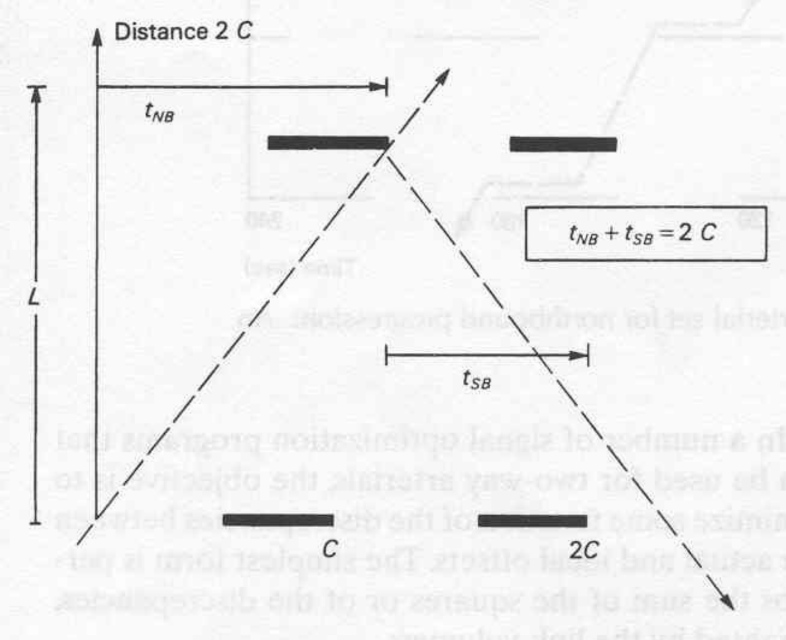
Two-Way Offset Constraint

- For two-way offsets $t(i,j)$ and $t(j,i)$, the constraint is given by

$$t(i,j) + t(j,i) = nC, \qquad n \in \{1,2,\dots\}$$



(a) Offsets add to one cycle length



(b) Offsets add to two cycle lengths

Offset Optimization

- Overall formulation

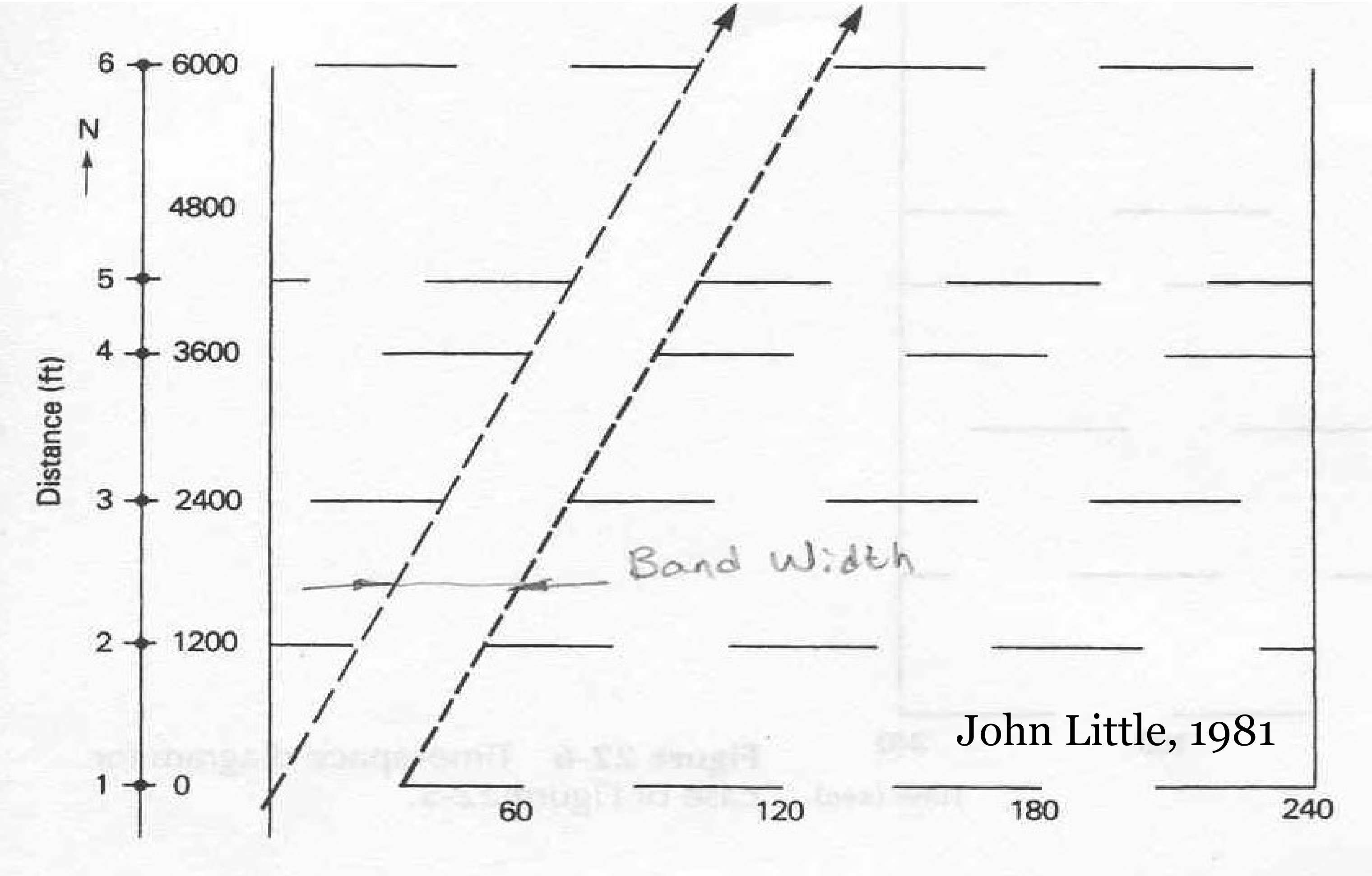
$$\min \sum_{\forall ij} Q(i,j)(t(i,j) - t^*(i,j))^2$$

$$t(i,j) + t(j,i) = n(i,j)C = n(j,i)C, \qquad \forall(i,j)$$

$$n(i,j) \in \{1,2,\dots\}, \qquad \forall(i,j)$$

  - Decision variables: $t(i,j)$ and $n(i,j)$ for each (i,j)
  - Both $t(i,j)$ and $t^*(i,j)$ are temporal differences of the green start time following the free-flow speed. You need to take the remainder by dividing cycle length to get the offsets

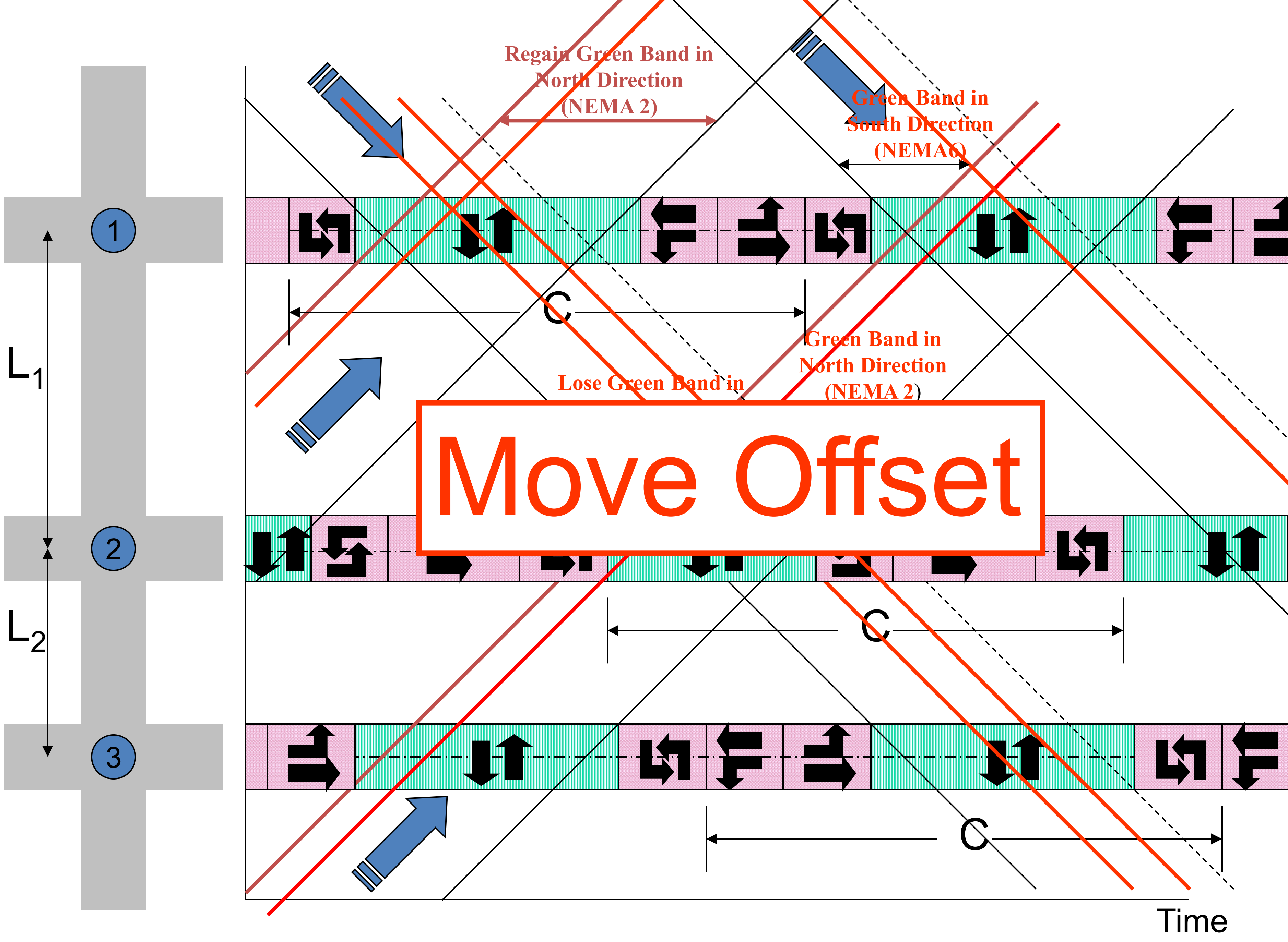
The bandwidth concept and maximum bandwidth



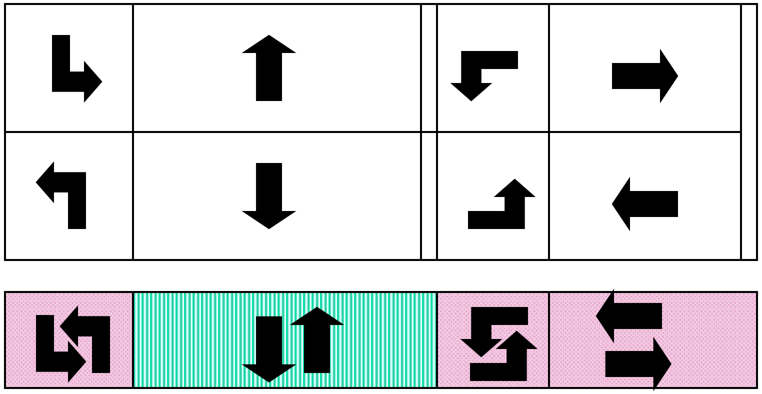
John Little, 1981

Bandwidth and efficiency of a progression

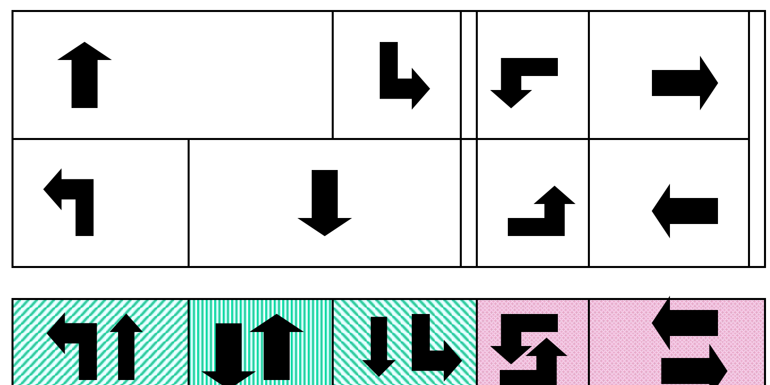
- Efficiency = (bandwidth/cycle length) × 100%
- An efficiency of 40-55% is considered as good.

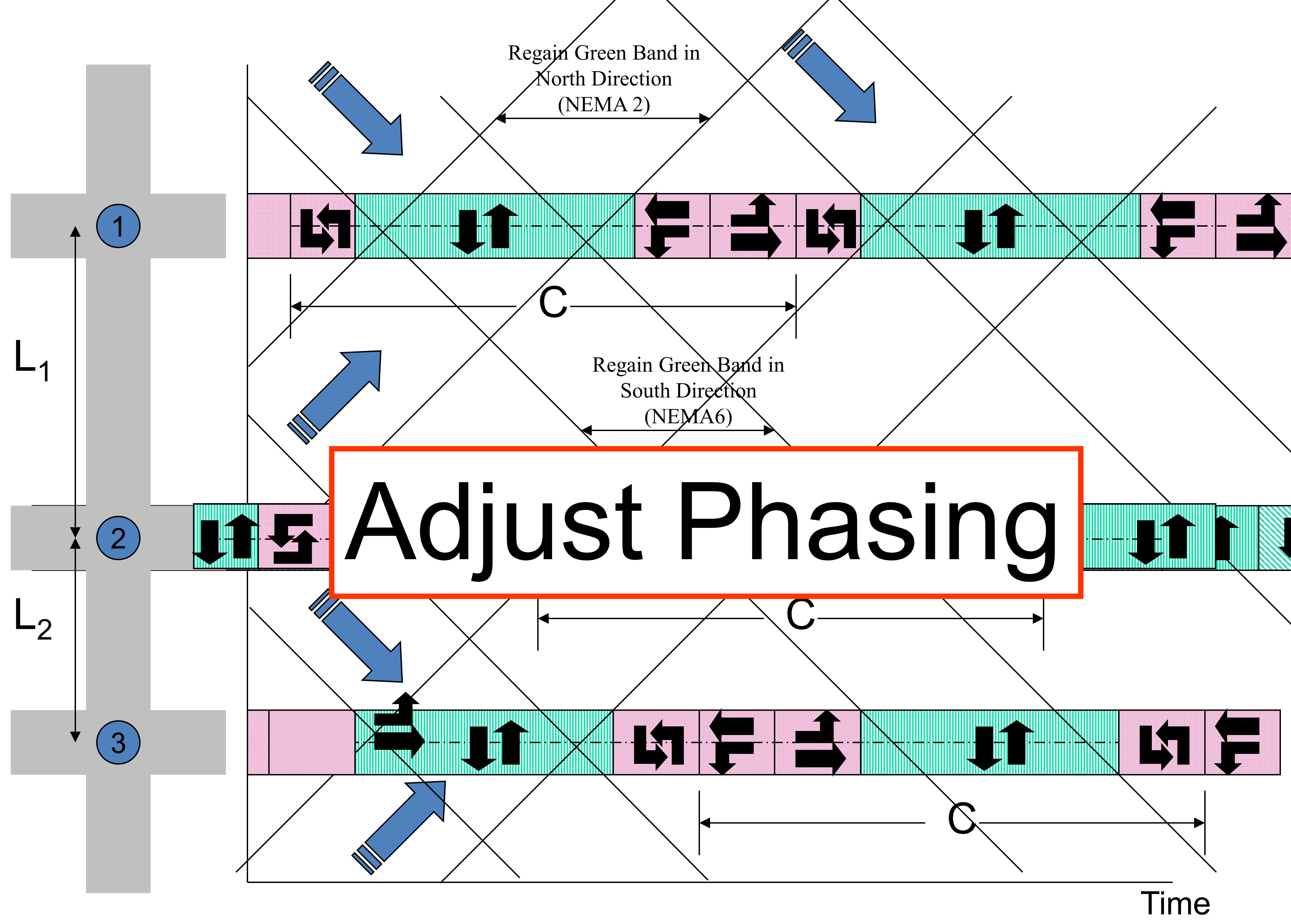

Regain Green Band in
North Direction
(NEMA 2)
Green Band in
South Direction
(NEMA6)
Green Band in
North Direction
(NEMA 2)
Lose Green Band in
Move Offset
1
2
3
L1
L2
C
C
C
Time

ORIGINAL PHASING DIAGRAM
for Intersection 2



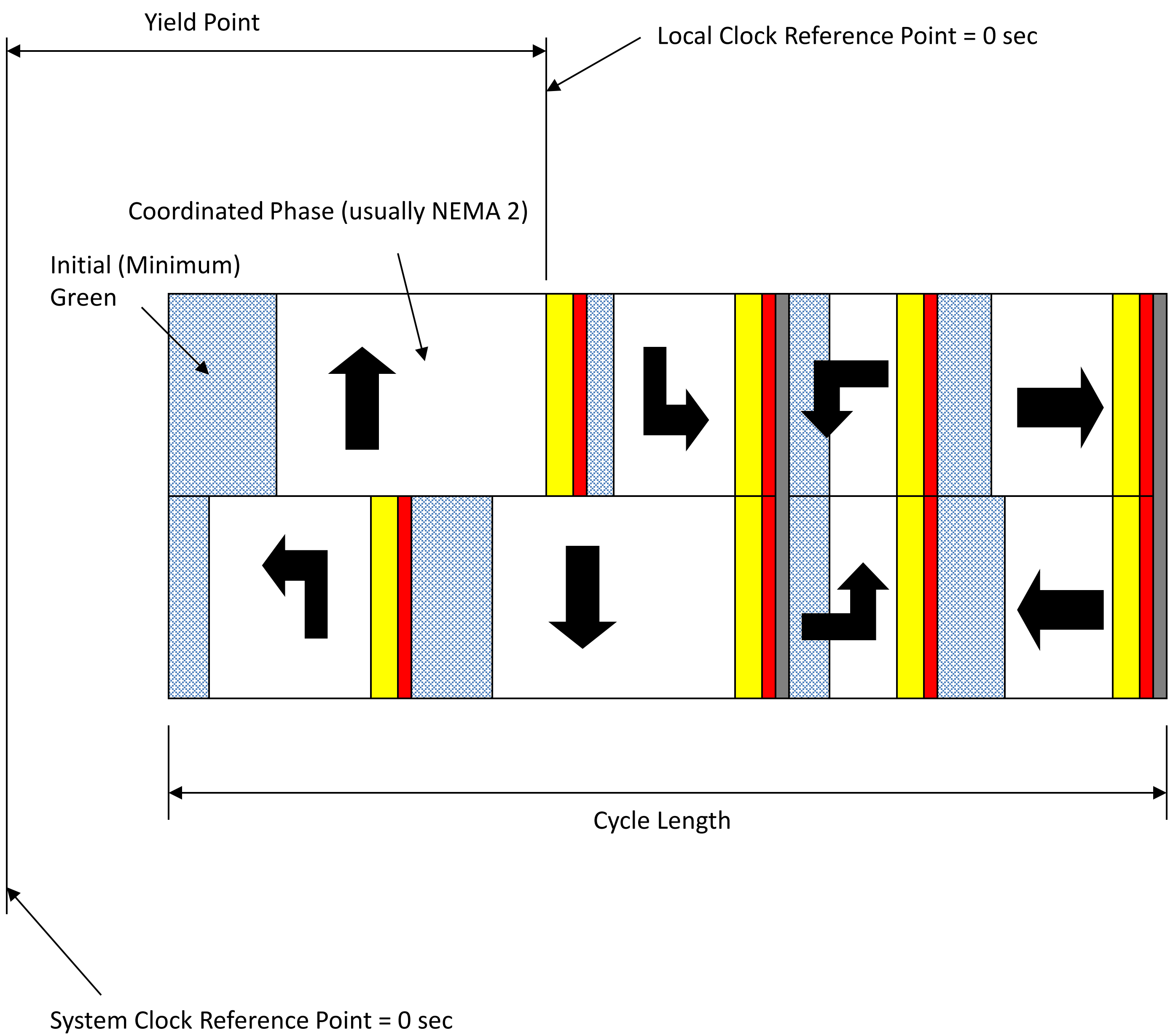
REVISED PHASING DIAGRAM
for Intersection 2



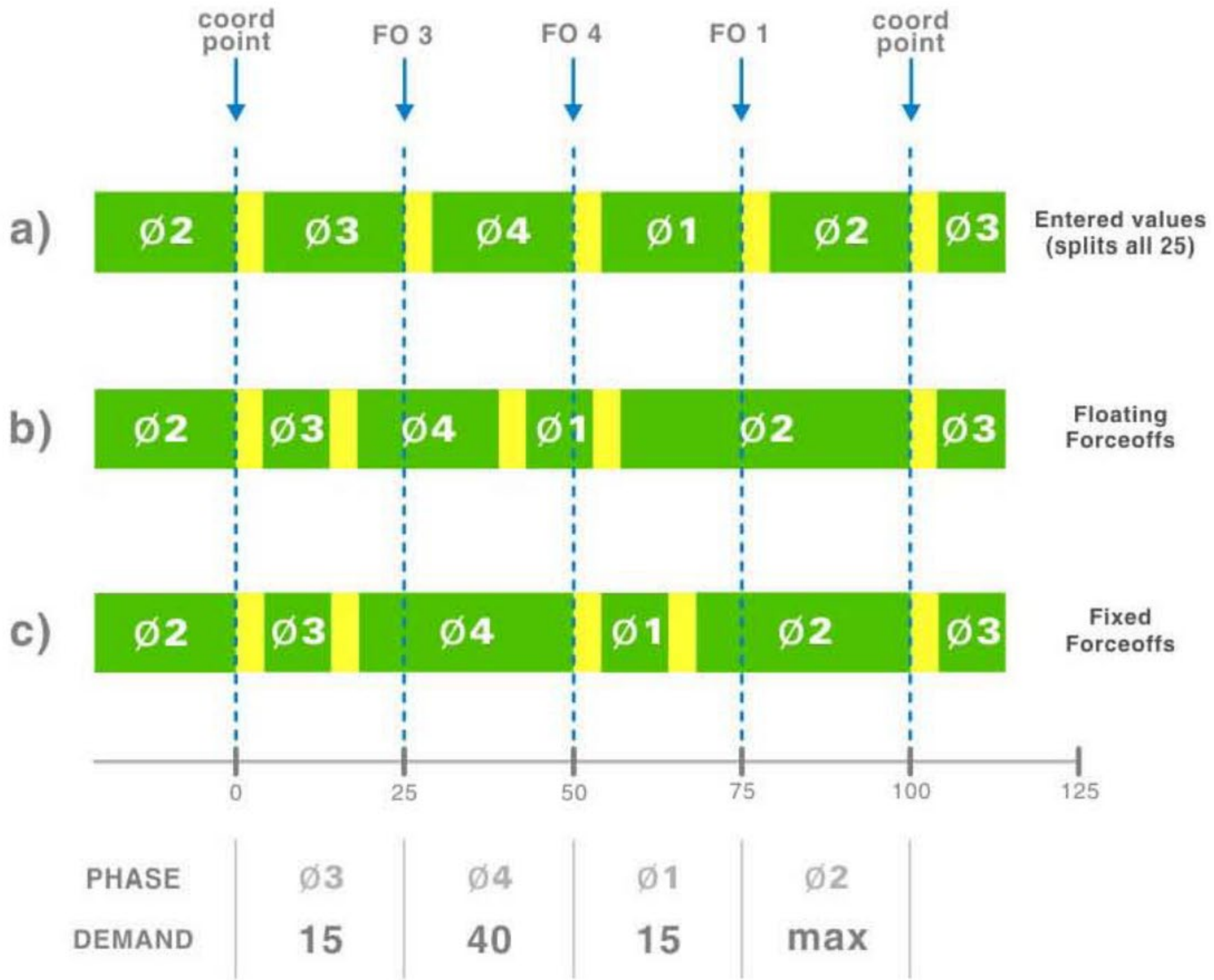

Regain Green Band in North Direction (NEMA 2)
Regain Green Band in South Direction (NEMA6)
C
C
C
1
2
3
L_1
L_2
Time
Adjust Phasing

Coordinated Actuated Signal Control

- Key Concepts
  - **Coordinated Phase**: usually through movement of major arterial
  - Un-coordinated phase
  - Cycle Length: all intersections share the same cycle
  - Splits: pre-determined split, green time assigned to each phase
  - **Yield Point**: start of the yellow time of the coordinated phase (which is also the offset if you use the same time for local reference time)
  - **Force-Off Point**: non-coordinated phases must end even if there is continued demand (max-out for uncoordinated)


Yield Point
Local Clock Reference Point = 0 sec
Coordinated Phase (usually NEMA 2)
Initial (Minimum) Green
Cycle Length
System Clock Reference Point = 0 sec

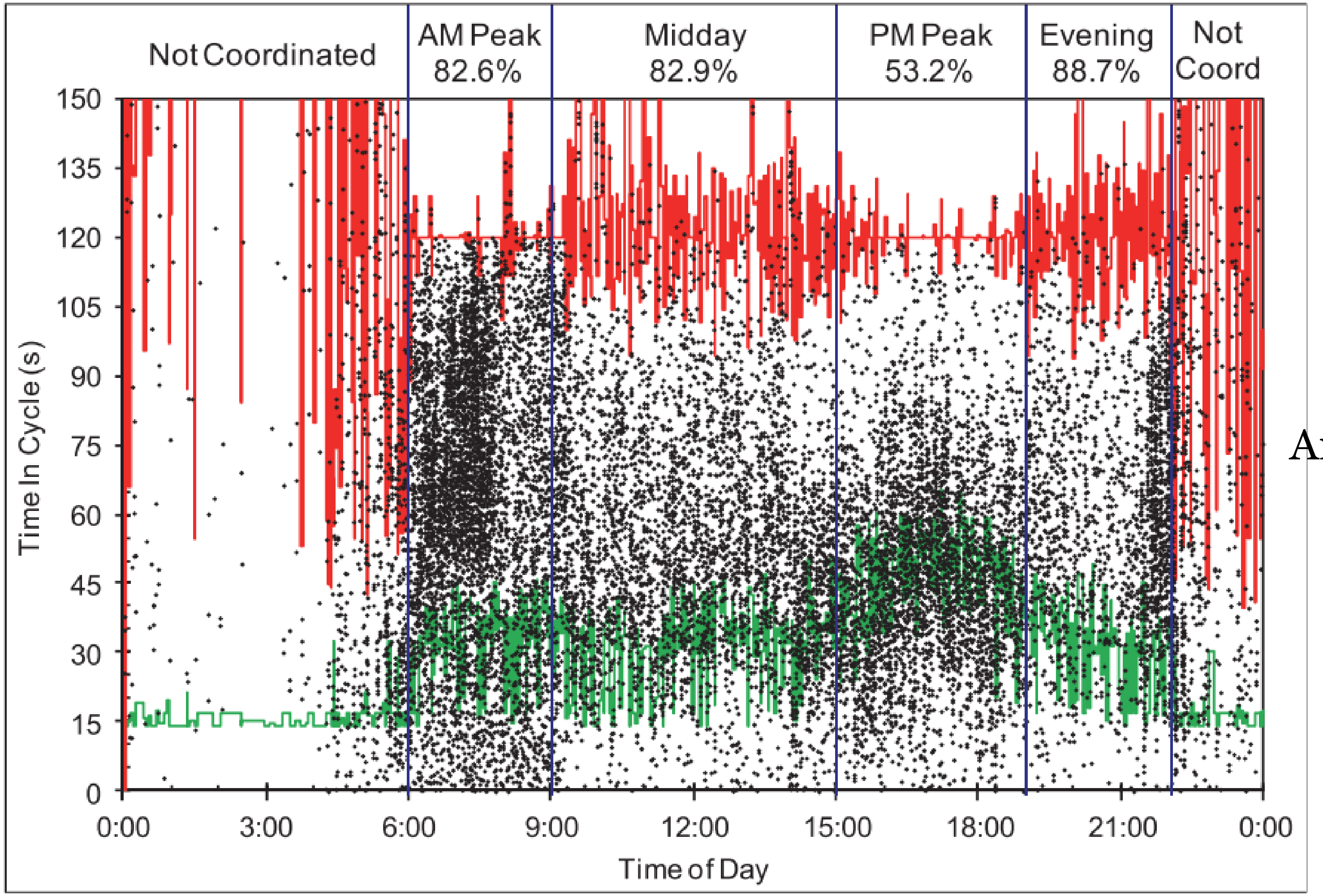
Floating and Fixed Force-Offs



Floating and Fixed Force-Offs

- Floating forced-off
  - A force-off mode where force-off points cannot move.
  - Non-coordinated phase can use unused time of previous phases
- Fixed forced-off
  - A force-off mode where force-off points can move depending on the demand of previous phases
  - Non-coordinated phase times are limited to their defined split amount of time and all unused time is dedicated to the coordinated phase

Offset Evaluation: Purdue Coordination Diagram (PCD)



Arrival on green

Readings

- Signal Timing Manual (2nd Edition): Chapter 7, 12