

# SIGNAL CONTROL OF DUAL T-INTERSECTIONS AND PARTIAL CLOVERLEAF INTERCHANGES WITH ONE CONTROLLER

Zhen Zhang, and Zong Tian

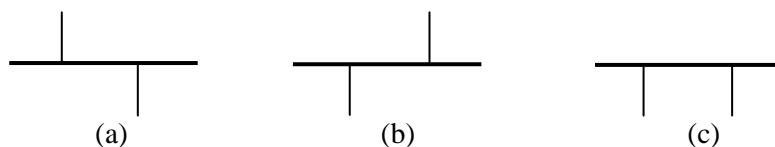
## ABSTRACT

This paper provides a study on the possibility of controlling two adjacent T-intersections and partial cloverleaf interchanges with one controller. Partial cloverleaf interchanges have similar geometry with dual T-intersections; and therefore the signal timing is basically the same with dual T-intersections. The signal phasing is firstly given in this paper, with different phase sequences and control types. And discussions on the different phase sequences are then provided. It is demonstrated in this paper that, when closely spaced, the dual T-intersections can be controlled by one controller with NEMA phasing for the different movements of both intersections. And 3-phase and 4-phase operation that was originally used in the signal timing of diamond interchanges could be applied in the cases of dual T-intersections. For different types of dual T-intersections, different phase schemes should be chosen to yield to the maximum bandwidth. A case study is conducted. The simulation indicates that in the controlling of two adjacent T-intersections, one controller can be used, and the selection of different phasing scheme can yield to different progression performances.

**Keywords:** Partial Cloverleaf Interchange, T-Intersection, Signal Timing, Signal Control.

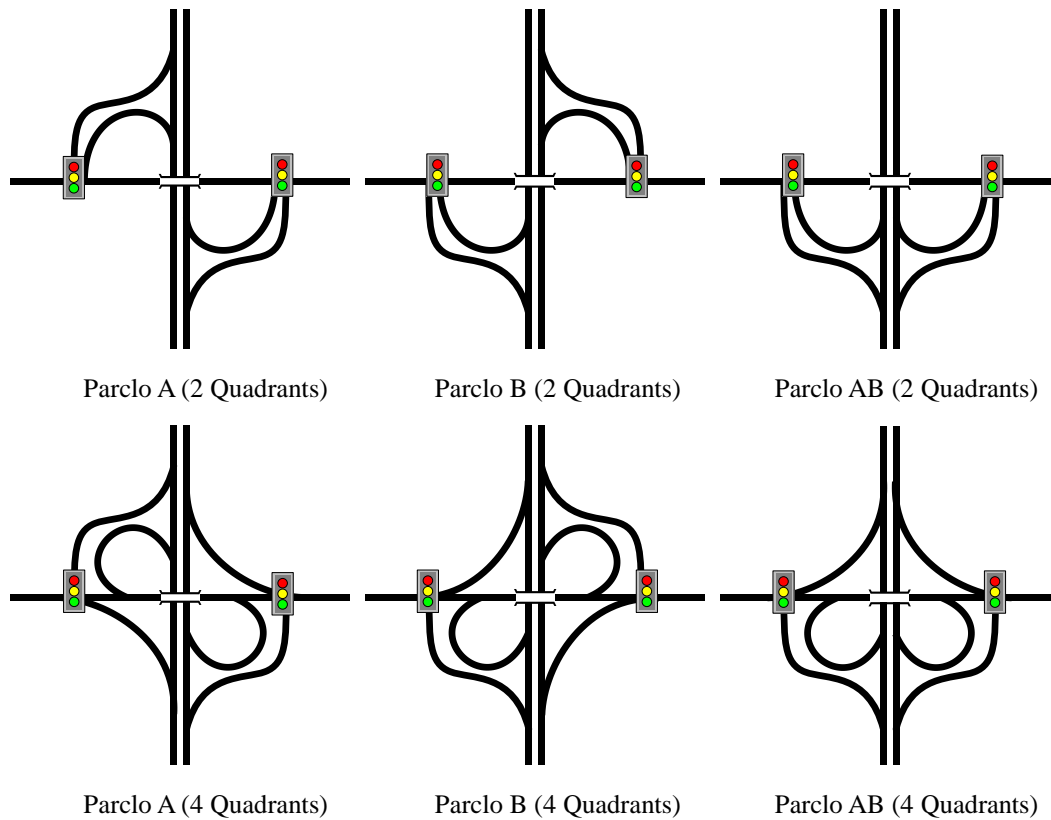
## INTRODUCTION

T-intersection is a type of intersection that has three arms, one of which is generally a minor street connected to a main street. Some T-intersections are controlled by stops signs when the traffic volume on the minor street is low. When the traffic volume is high, or for some safety concerns, a signal controller is sometimes required at a T-intersection. It is very common that there are two adjacent signalized T-intersections, especially in the cases of partial cloverleaf interchanges. The variations of the two T-intersections in geometry can be illustrated in Figure 1.



**Figure 1:** Variations of Two Adjacent T-Intersections in Geometry

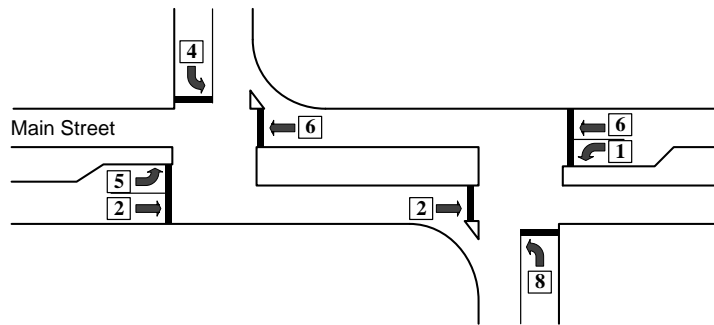
Partial cloverleaf is now well received as one of the most popular freeway-to-arterial interchange designs in North America, and this type of interchange consists 16% of all types of interchanges in the US (*1*). There are six common types of partial cloverleaf interchanges as shown in Figure 2. It could be seen that the signal control of partial cloverleaf interchanges is the same with T-intersections.



**Figure 2:** Six Common Types of Parclos

When there are two adjacent signalized T-intersections, it is generally considered that two controllers are necessary. In most researches, the phasing of partial cloverleaf interchanges or two T-intersections is shown in Figure 3; however, due to similar traffic pattern and geometric characteristics with diamond interchanges, the diamond interchanges control strategies using one controller can be applied on the partial cloverleaf interchanges or the dual T-intersections.

The objective of this paper is to provide a solution on controlling two adjacent T-intersections with one controller; and to analyze how 3-Phase and 4-Phase operation could be used on the signal control.



**Figure 3:** Phasing of Two T-Intersections with Two Controllers

## BACKGROUND

It is generally accepted that one controller is adequate to control closely spaced intersections of diamond interchanges. It is generally adequate to use just one controller to control the closely spaced intersections. For long spacing between intersections, two controllers are necessary because of higher cost and technical problems (2). For diamond interchanges, it's generally recognized that for intersection spacing less than 800 feet, a single controller should be used, and for intersections spacing more than 800 feet, two controllers with interconnect should be considered. Using one controller can maintain better progression at even tight spacing between intersections (i.e. spacing < 200 ft) especially when transitioning between signal timing plans (3).

When using one controller for diamond interchanges, there are two main categories for the phasing scheme of diamond interchanges: 3-Phase and 4-Phase operation (4).

## PHASE SCHEMES USING ONE CONTROLLER

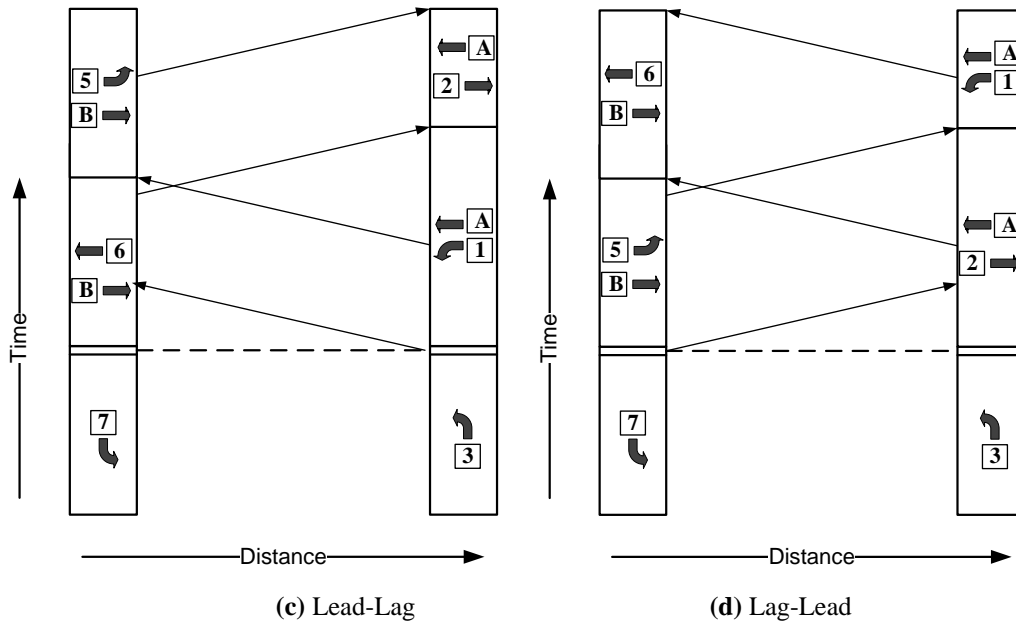
### *Type (a) T-Intersections*

For two adjacent T-intersections of type (a) as shown in Figure 1, and parcel A (2 quadrants) as shown in Figure 2, the phase scheme using one controller is shown in Figure 4.

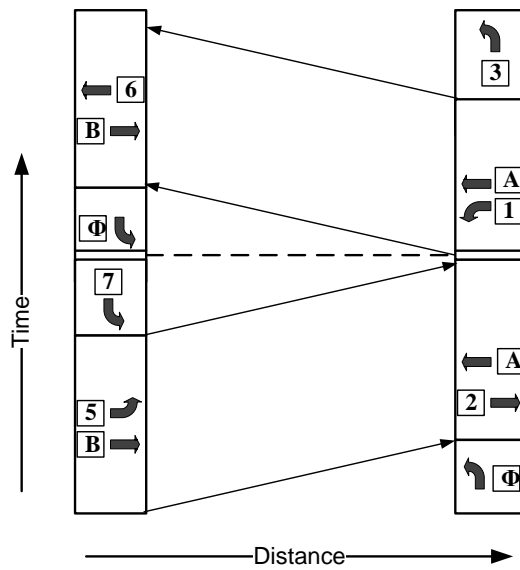
For each intersection, there is always traffic entering the space in between, either from the overlap phase or the left turn from the ramp. As can be seen from the Time-Space Diagram in Figure 5, in the 3-phase scheme, regardless of leading (a), lagging(b), lead-lag (c) or lag-lead (d) for the main street left-turn, the progression totally depend on the splits of phase 6 and phase 2. It is the same for the 4-phase scheme (Figure 4). There will always be vehicles having to make stop at phase 2 and phase 6.

As can be seen in Figure 5, with leading left turns (a), the maximum bandwidths on the main street can be obtained, which are the splits of phase 2 for westbound, and phase 6 for eastbound. Lead-lag (c) or lag-lead (d) can only yield to maximum bandwidth in just one direction; while with lagging (b), there are chances that maximum bandwidth could not be





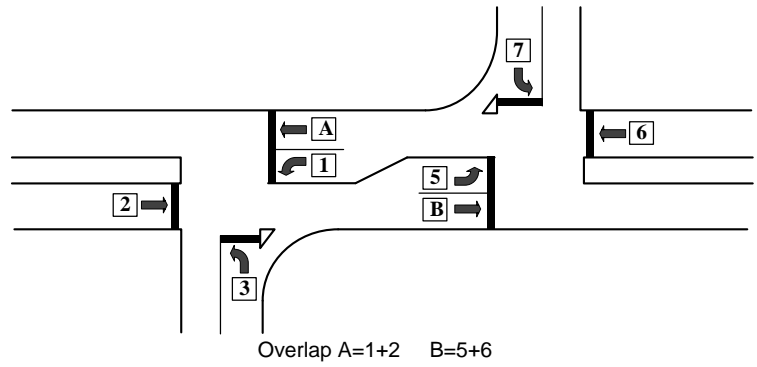
**Figure 5:** 3-Phase Scheme of Type (a) T-Intersections



**Figure 6:** 4-Phase Scheme of Type (a) T-Intersections

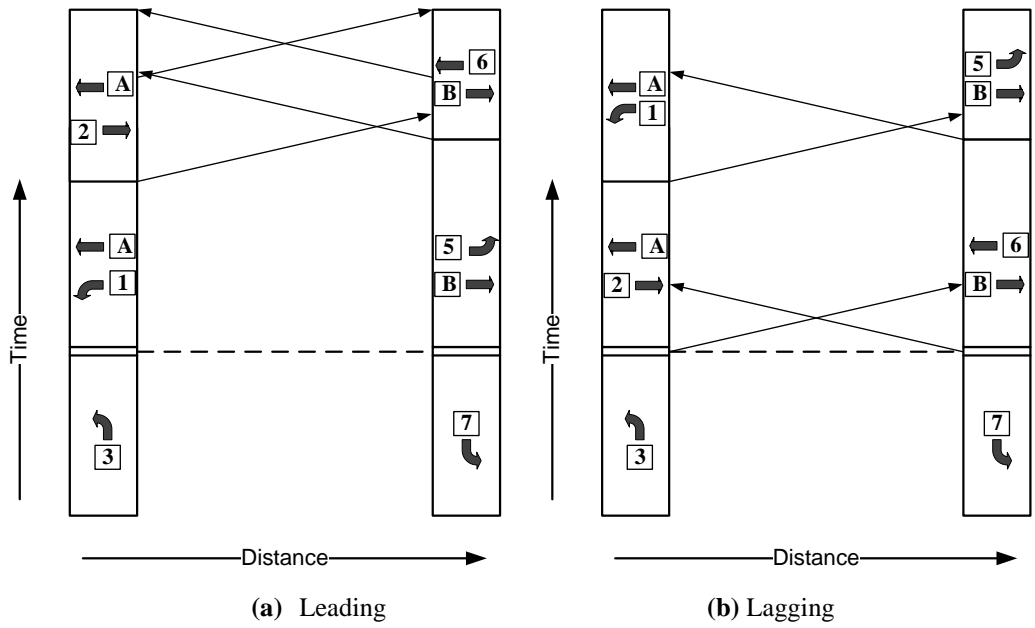
***Type (b) T-Intersections***

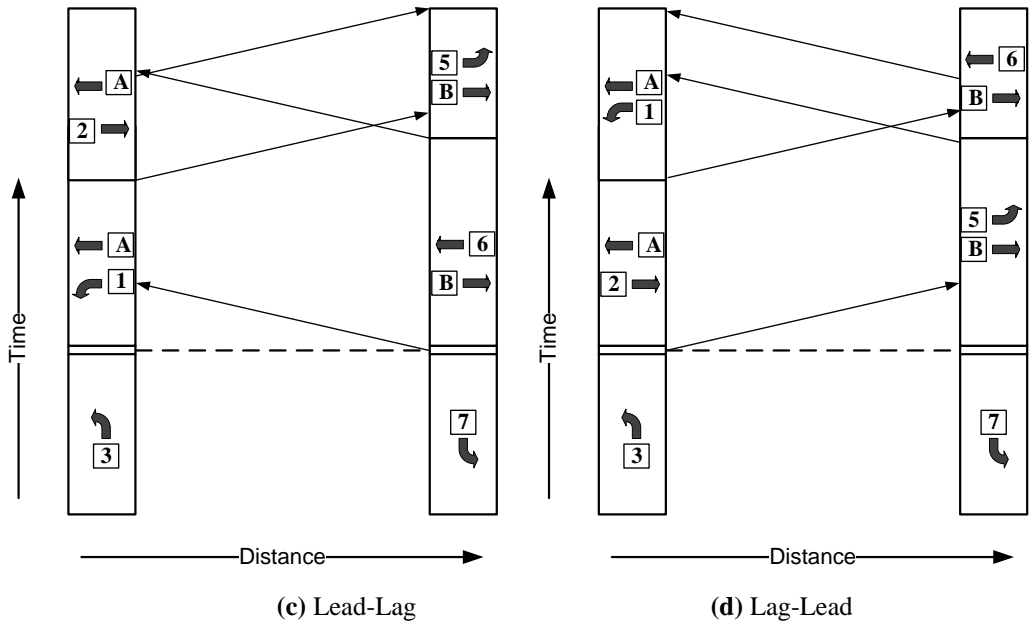
For two adjacent T-interactions of type (b) as shown in Figure 1, and parcel B (2 quadrants) as shown in Figure 2, the phase scheme using one controller is shown in Figure 7.



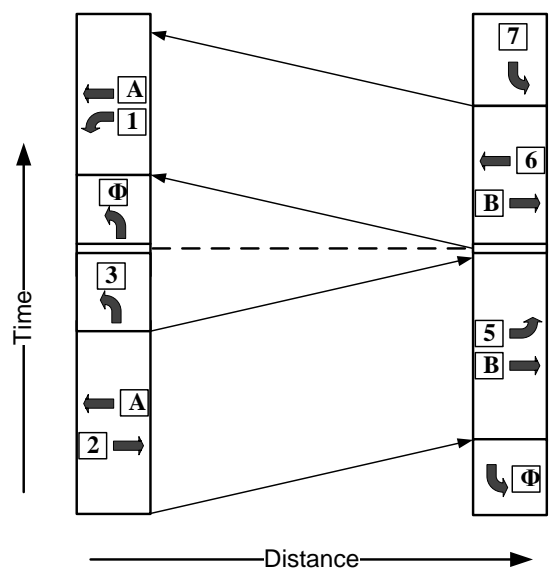
**Figure 7:** NEMA Phasing of Type (b) T-Intersections

It can be seen from the Time-Space Diagram in Figure 8 and Figure 9 that the possible maximum bandwidth for the main street is the split of phase 2 for eastbound and split of phase 6 for westbound.





**Figure 8:** 3-Phase Scheme of Type (b) T-Intersections



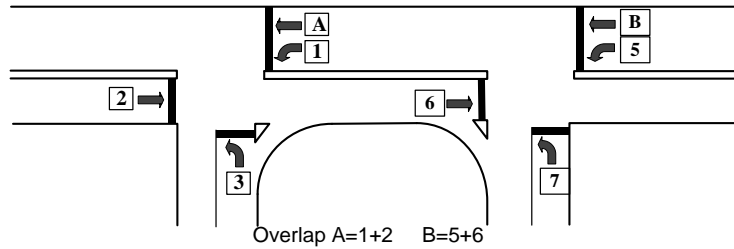
**Figure 9:** 4-Phase Scheme of Type (b) T-Intersections

As can be seen in Figure 8, with lagging left turns (b), the maximum bandwidths on the main street can be obtained, which are the splits of phase 2 for westbound, and phase 6 for eastbound. Lead-lag (c) or lag-lead (d) can only yield to maximum bandwidth in just one direction; while with leading (d), maximum bandwidth could not be obtained in either direction. It could also be illustrated in Figure 9 that 4-phase scheme could also yield to the same maximum bandwidth.

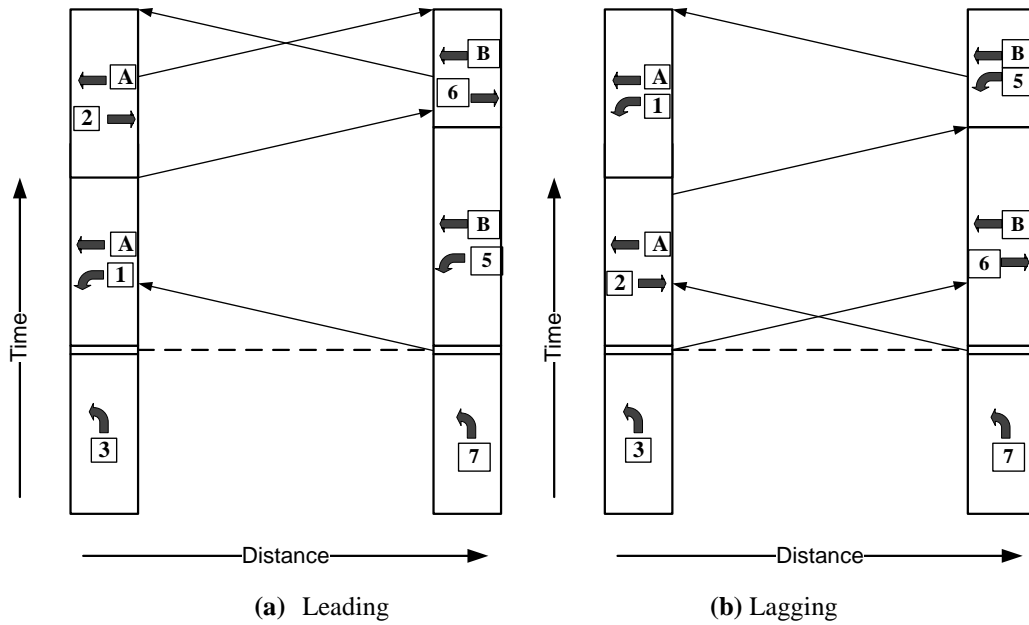
Therefore, in the type (b) T-intersections, to obtain the maximum bandwidth for the main street, it is desired to use 4-phase scheme or lagging left turn when using 3-phase scheme.

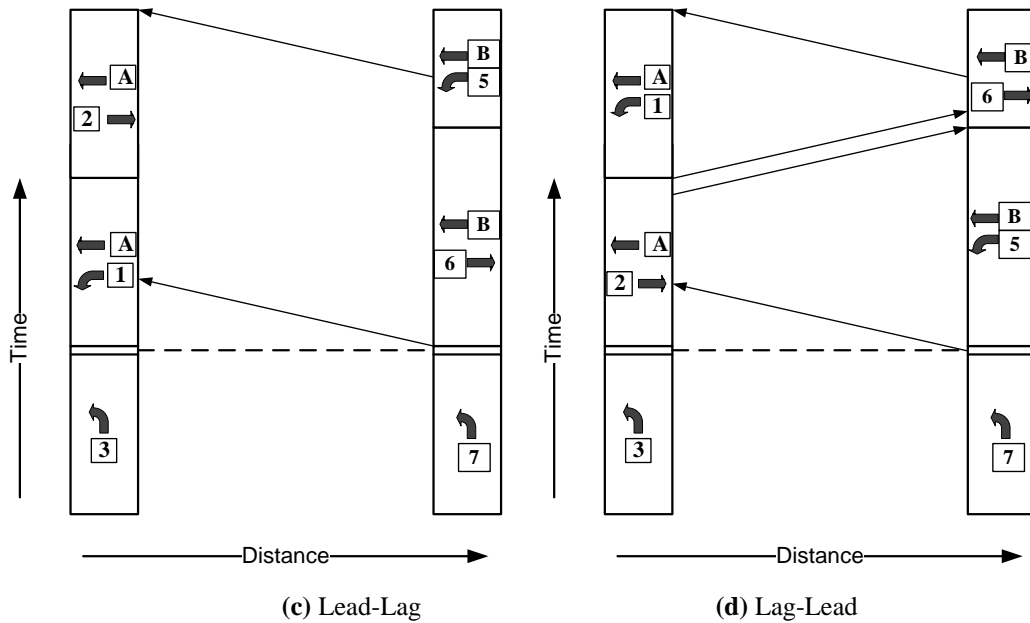
**Type (c) T-Intersections**

For two adjacent T-intersections of type (c) as shown in Figure 1, and Parclo AB (2 quadrants) as shown in Figure 2, the phase scheme using one controller is shown in Figure 10.

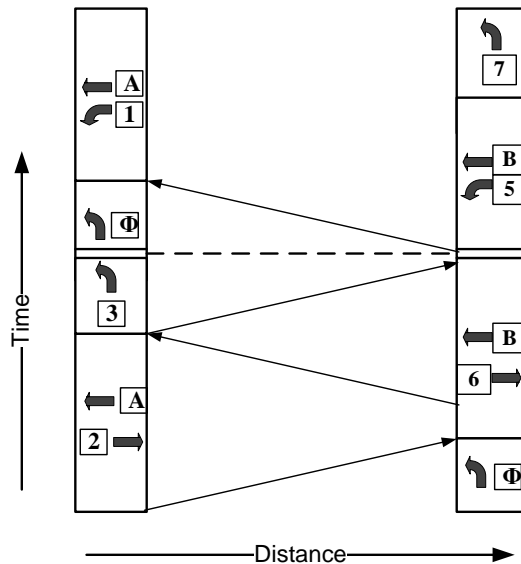


**Figure 10: NEMA Phasing of Type (c) T-Intersections**





**Figure 11:** 3-Phase Scheme of Type (c) T-Intersections



**Figure 12:** 4-Phase Scheme of Type (c) T-Intersections

For parcel AB (2 Quadrants) shown in Figure 10, there is always traffic going between the intersection from westbound through movement or left turn from the minor street. As can be illustrated in Figure 11, all four types of 3 phase scheme yield to the same westbound bandwidth. While the maximum bandwidth of eastbound through movement could be the phase 2 or phase 6, depending on which one is shorter. When lagging left turns on the main street, the maximum bandwidth could be obtained, which is the split of phase 2. When lagging left turn at the first intersection and leading left turn at the second intersection, the maximum bandwidth could be the split of phase 6. It could be seen in Figure 12 that although the maximum bandwidth for eastbound through movements could be easily obtained when using 4-phase scheme, the progress is not as good as using 3 phase scheme.

Therefore, in the type (c) T-intersections, to obtain the maximum bandwidth for the main street, it is desired to use 3-phase scheme and lag the left turn of the first intersection.

The partial cloverleaf interchanges with 4 quadrants do not have left-turns from the off-ramps, and thus one-controller is also adequate to control two intersections.

### CASE STUDY

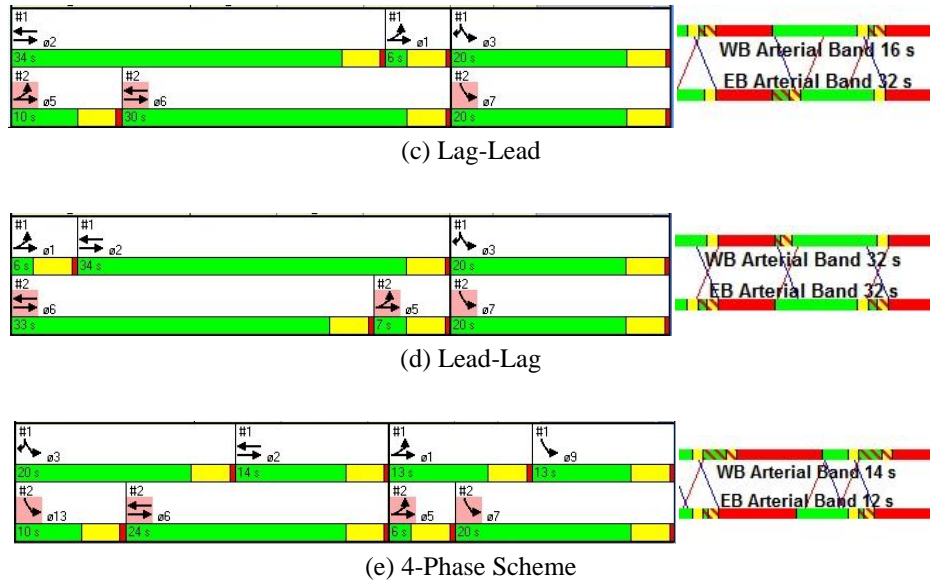
The study site includes two T-intersections with both minor streets on the same side of the main street, as shown in Figure 13. It could be seen that the studied site has two T-intersections which are symmetry of type (c) as shown in Figure 1. Based on the discussion above, to yield to the maximum bandwidth on the main street, the lagging left turn at intersection #2 should be used.



**Figure 13:** Geometry of Studied Site

Synchro is used to simulate the 3-phase and 4-phase operations. Cycle length of 60s is used in the simulation. The signal timing yielding to maximum bandwidth for both directions and the maximum bandwidth are illustrated separately in Figure 14.





**Figure 14:** Simulation Results in Synchro

It can be seen from the simulation results that lagging left-turn at intersection #2 could yield to the maximum bandwidth for both directions, which are all 32 seconds.

In providing the signal timing plan with minimum delay and stops, using lagging left-turn can yield to minimum delay and stops, as shown in Table 1.

**Table 1.** Simulation Results on Delay and Stops

	Delay/Vehicle (s)	Stop/Vehicle
lagging	14.9	0.72
laglead	19.4	0.83
leading	16.3	0.73
Leadlag	16.5	0.84
4phase	17.6	0.79

## CONCLUSIONS

Based on the discussions and the case study, it is obvious that one controller can be used to control dual T-intersections which are closely spaced.

For type (a) T-intersections, using 4-phase scheme or leading left turn of 3-phase scheme can yield to maximum bandwidth on the main street. For type (b) T-intersections, using 4-phase scheme or lagging left turn of 3-phase scheme can yield to maximum bandwidth. And for type (c) T-intersections, lagging left turn for the first intersection should be used.

Further study will be made on the analysis of the relationship between the choosing of phasing schemes and the distances between the T-intersections, and the impacts of different control types on delay, and queue length.

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### **REFERENCES**

- (1) Bonneson, J., and Zimmerman, K. (2003). *Review and Evaluation of Interchange Ramp Design Considerations for Facilities without Frontage Roads*. Texas Transportation Institute.
- (2) Sunkari S.R., and Urbanik II, T. (2000). *Signal Design Manual for Diamond Interchanges*. Project Report No. 1439-6. Texas Transportation Institute.
- (3) Trafficware. *Signal Timing Background*.
- (4) Messer, C.J., and Chang, E.P. (1985). *Traffic Operations of Basic Actuated Traffic Control Systems at Diamond Interchanges*. Research Report 344-2F. Texas State Department of Highways and Public Transportation, Austin.