ACCOMODATING PEDESTRIANS IN SPLIT PHASING

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Introduction

Split phasing is a type of signal phasing scheme which separates vehicle conflicts by assigning the right-of-way sequentially to the two opposing approaches. Split phasing is often used when the intersection geometric layout would not allow the two left-turn movements on the opposing approaches to move simultaneously, or on an approach with a shared left/through lane. Such an intersection geometric layout may be a result of a need to serve specific traffic flow patterns. An example of this is when two left-turn lanes are needed but the budget or right-of-way constraints would not allow having two exclusive left-turn lanes. The left-turn demand is better served by using an exclusive left-turn lane plus a shared left/through lane. From a safety and capacity point of view, the two opposing left-turn movements have to be separated by using a split-phasing scheme.

Previous research has been focused on analyzing vehicle conflicts with respect to various left-turn phasing schemes [1,2]. These studies investigated the effect of various left-turn controls on potential conflicts between the left-turn vehicles and the opposing through vehicles. However, studies on pedestrian timing as well as the efficiency of traffic operations under split phasing operations are somewhat limited.

There are a number of issues related to split phasing and pedestrian timing treatment. In order for a driver unfamiliar with an intersection to understand that he or she has a protected movement, a left turn arrow must be displayed. However, the display with left turn arrows would require serving the pedestrians on each crosswalk in two separate sequential phases, which could significantly affect the efficiency of signal operations. The purpose of this paper is to address these various issues related to split phasing and pedestrian timing considerations. A new split phasing scheme called *Protected/Permitted Left Turns* is proposed for achieving the maximum efficiency but yet maintaining safe traffic operations.

Pedestrian Timing Treatment

Pedestrian safety has been a major focus in transportation engineering practices. Various pedestrian timing treatments have resulted in various forms of split phasing operations. In current practices, there are three alternatives on how the pedestrian timing has been treated (not counting exclusive pedestrian phases which are not part of this paper): no pedestrian indication, pedestrians concurrent with vehicle phases, and special pedestrian overlap phases.

No Indication
No indication of pedestrian phase is when a pedestrian signal is not provided at the crosswalk. Pedestrians would have to observe the vehicular signals and cross with the parallel traffic flows. The phase duration is totally controlled by vehicular demand. Although this is the least costly alternative, it has not been considered as a preferred alternative in urban areas. Some kind of pedestrian indication is generally provided at most urban area intersections.

Concurrent Vehicle and Pedestrian Phases
Concurrent vehicle and pedestrian phase is a common practice at most signal locations. Pedestrians cross the street concurrently with the adjacent through vehicle movements, and are provided with WALK and Flashing DON'T WALK (FDW) indications while crossing the intersection. The WALK and FDW intervals are a portion of the timing of its adjacent vehicle phases. Sufficient time would be provided for the WALK and FDW intervals to ensure safe crossing of the street. When there is no pedestrian call, the actual phase duration would be governed by the vehicle demand. When there is a pedestrian call, the actual phase duration is governed by the maximum of the time required to serve the vehicle demand and the required pedestrian crossing time. Although concurrent phasing would not separate the conflicts between right turning vehicles and pedestrians, it provides positive information to the pedestrians when crossing should be made. Due to the minimum required pedestrian crossing time being included in the vehicle phases, frequent pedestrian crossing could significantly reduce the intersection capacity.

Special Pedestrian Overlap Phases
The use of overlap phases is mainly for the purpose of improving operational efficiencies. This technique would use both concurrent vehicular phases, thus minimizing the total time consumed by pedestrian crossings. Details of this technique and the implementation strategies will be discussed in the next section.

Split Phasing Alternatives and Implementation Strategies

The basic principle of split phasing is to control the traffic on the opposing approaches to move in separate sequences. Figure 1 illustrates a typical phasing scheme for a signalized intersection where the side street is operating with split phasing. Pedestrian timing is not considered in this example. Figure 2 is the controller phase and ring configurations for implementing such a phasing scheme. As can be seen, the two controller phases in the Ring 1 (ϕ3 and ϕ4) are used to control each approach. Controller phases in Ring 2 (ϕ7 and ϕ8) are not used in this case. Another alternative to implement the split-phasing scheme is to use two controller phases in different rings (e.g., use ϕ4 and ϕ8), but would have a barrier between the two phases, as shown in Figure 3.

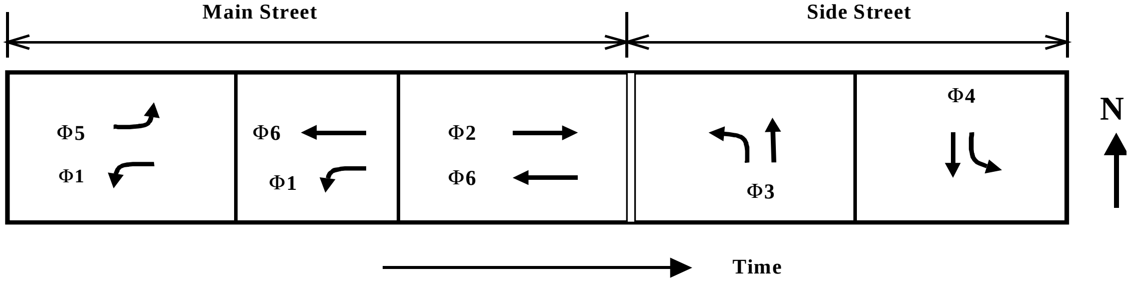


Figure 1 Typical Phasing Scheme with Split Phase on Side Street

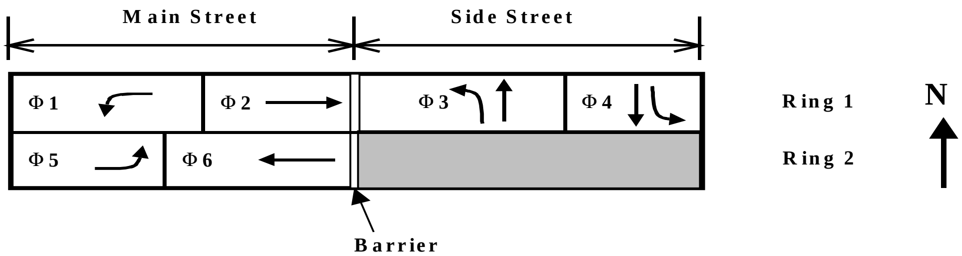


Figure 2 Controller Phase and Ring Configurations Using Phases in Ring 1

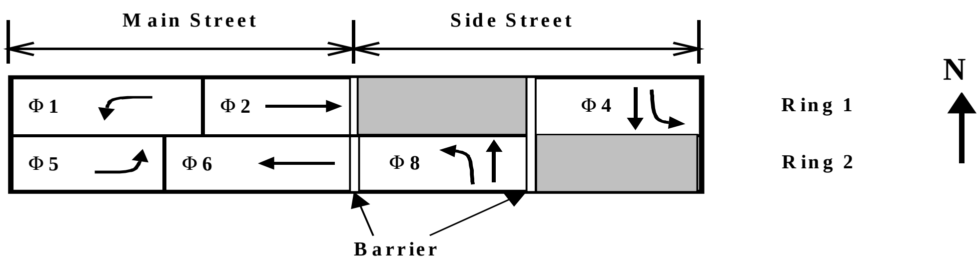


Figure 3 Controller Phase and Ring Configurations Using Phases in Ring 1 and Ring 2

With the basic concept of split phasing illustrated above, various forms of split phasing may be evolved from the various pedestrian timing treatments. As mentioned earlier, the use of split phasing is mainly due to safety and operational concerns related to the left turn movements. Therefore, the following discussions will be focused on the left-turn treatment with respect to various pedestrian timing considerations. The right-turn movements which have to yield to pedestrians under most cases are not part of this paper. The various forms of split phasing resulting from the left-turn phasing and pedestrian timing are presented below using various phasing diagrams. Implementation strategies are also discussed based on modern controller features.

Split Phase with Protected Left-Turns

Protected left turn display, the preferred display from a driver's understanding point of view, requires a green arrow being displayed while the approach receives green. A 4-

section signal head is typically required for such a signal display. As illustrated in Figure 4, the two crosswalks have to be served in two separate sequential phases. For example, the pedestrians using the east crosswalk would be served while the northbound (controller ϕ3) receives green, and the pedestrians using the west crosswalk would be served when the southbound (controller ϕ4) receives green. A dashed left turn or right turn arrow in all the figures presented below indicate a permitted movement where the vehicles have to yield to the pedestrians. The ring and phase configurations for such a phasing scheme are illustrated in Figure 5. The pedestrian timing (WALK and FDW intervals) are accommodated in the concurrent vehicular phases.

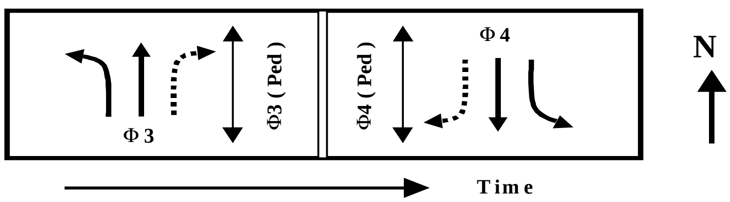


Figure 4 Split Phase with Protected Left-Turns

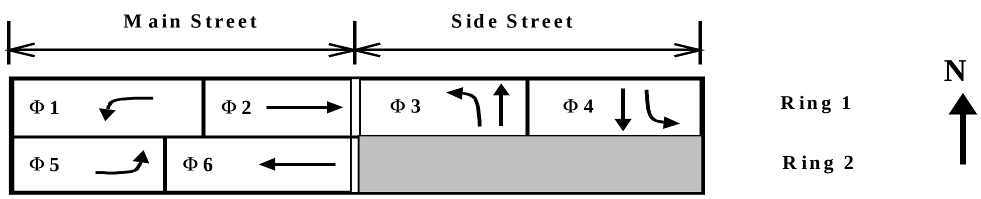


Figure 5 Controller Phase and Ring Configurations for Protected Left-Turns

The major advantage of such a phasing scheme is to eliminate the conflicts between left turn vehicles and pedestrians. However, it presents the least efficient traffic operations due to the significant amount of time consumed by the pedestrians when pedestrian crossing exist on both crosswalks during the same cycle. The impact is more dramatic when the required pedestrian crossing time is significantly higher than the time required to serve the vehicle demand, which is typically the case for the side street where split phasing is often used. Another issue related to split phasing with protected left turn display is the potential impact on a coordinated signal system which would either require longer cycle length be used to accommodate the pedestrians, or would result in frequent signal out-of-coordination [3]. To minimize the pedestrian impact, an alternative is to provide a pedestrian signal at only one crosswalk; however, it may not be a preferred design from pedestrian safety and convenience point-of-view.

Split Phase with Permitted Left-Turns

In order to reduce the impact of pedestrian timing with protected left turn display, some jurisdictions use a permitted left turn display for split phasing. Split phasing with permitted left-turns would provide a green ball to the drivers, indicating that the left turning vehicles can proceed but would have to yield to pedestrians. Figures 6 and 7 illustrate the phasing scheme and the recommended controller phase and ring configurations for the permitted left-turn displays. A 3-section signal head is sufficient for this application.

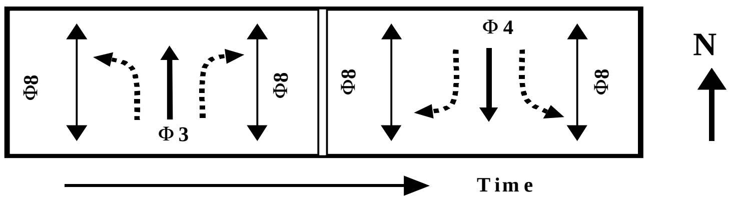


Figure 6 Split Phasing with Permitted Left-turns

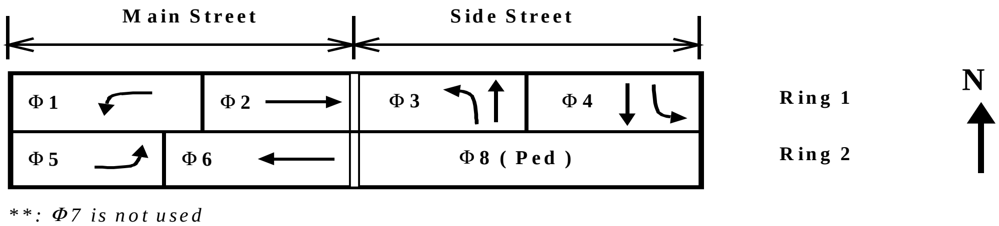


Figure 7 Controller Phase and Ring Configurations for Permitted Left-turns

With a permitted left turn display, the pedestrian phase (ϕ8) is overlapped with the two vehicle phases (ϕ3 and ϕ4); therefore, pedestrian crossing on both crosswalks is allowed during both side street phases.

The major advantage of such a phasing scheme is to minimize the impact of pedestrian timing and to improve operational efficiency since pedestrian crossing is accommodated in a single phase. However, the green ball display of such a phasing scheme has raised concerns among traffic engineers. The first concern is that a left turning vehicle might get *trapped*. Such a situation occurs when a left turning vehicle has already entered the intersection and is yielding to a pedestrian on the left, but then its own vehicle phase terminates. The second concern is that the green ball display under split phase would train people to think that sometimes left turns are protected on the circular green, which could cause a driver to make a left turn without yielding to opposing traffic at a permissive left turn location [2]. The third concern is the likely increase of start-up lost time since a green ball is not clear to a new driver whether he/she is supposed to accelerate and proceed.

Despite the various concerns, the permitted left turn display under split phasing has gained acceptance by some traffic engineers and jurisdictions due to its efficiency in serving vehicular traffic.

Split Phase with Protected/Permitted Left-Turns

Due to the efficiency and safety concerns related to the protected or permitted left turn displays under split phasing, we proposed an alternative solution, namely *protected/permitted* split phasing scheme. The basic idea is to provide a protected left-turn arrow while there is no conflicting pedestrian crossing, but to provide a permitted green ball when there is conflicting pedestrian crossing. For example, when a pedestrian is being served or a pedestrian call was placed before the side street phase begins, the conflicting left-turn phase or the left-turn arrow should be omitted. On the other hand, while a left-turn phase is being displayed (i.e., no pedestrian call is placed before the side street phase starts), no pedestrian call should be served (i.e., pedestrian calls placed after the end of main street phase will have to be served the next cycle).

Implementation of such a phasing scheme would require the use of 10 phases and 4 rings on existing controllers. Therefore, the controller must be able to handle multiple phases and flexible ring structures. Furthermore, a proper signal display also requires either a NEMA TS1 back panel be used (which is demonstrated in the paper) or the equivalent logic be implemented in the controller software. The following steps outline the implementation process using the features of Eagle EPAC300 [4] controllers and the cabinet back panel:

- Proposed controller phase and ring configurations are shown in Figures 8 and 9.
- For proper signal display, ϕ9 and ϕ10 should output to the vehicle load switches of ϕ8 and ϕ4, respectively, since no vehicle load switch output is available for ϕ9 and ϕ10 in the controller.
- The phase omit, ped omit, phase check, and phase on features are implemented by wiring the cabinet back panel as shown in Figure 10.

As can be seen from Figures 8 and 9, two individual pedestrian phases (ϕ4 and ϕ8) are designated for each crosswalk. Vehicle phases controlling the two approaches are separated by a barrier. The two left-turn phases (ϕ3 and ϕ7) are used only for the purpose of signal display. Separate detectors are not necessary for these left-turn phases, i.e., the left-turn phase and the through phase on the same approach can be actuated by the same detector. ϕ9 and ϕ10 are used for the through movements because ϕ4 and ϕ8 must be able to receive ped omit inputs and ϕ3 and ϕ7 must be able to receive vehicle omit on a NEMA TS1 back panel inputs. Vehicle and ped omits are available only for ϕ1 - ϕ8.

The proposed protected/permitted phasing scheme would provide an alternative solution between the permitted and protected left-turn phasing scheme. Such a phasing scheme would provide the efficiency and safety during the protected phase (e.g., reducing start-up lost time), and would minimize the impact of pedestrian crossing by accommodating the pedestrians in two parallel pedestrian phases.

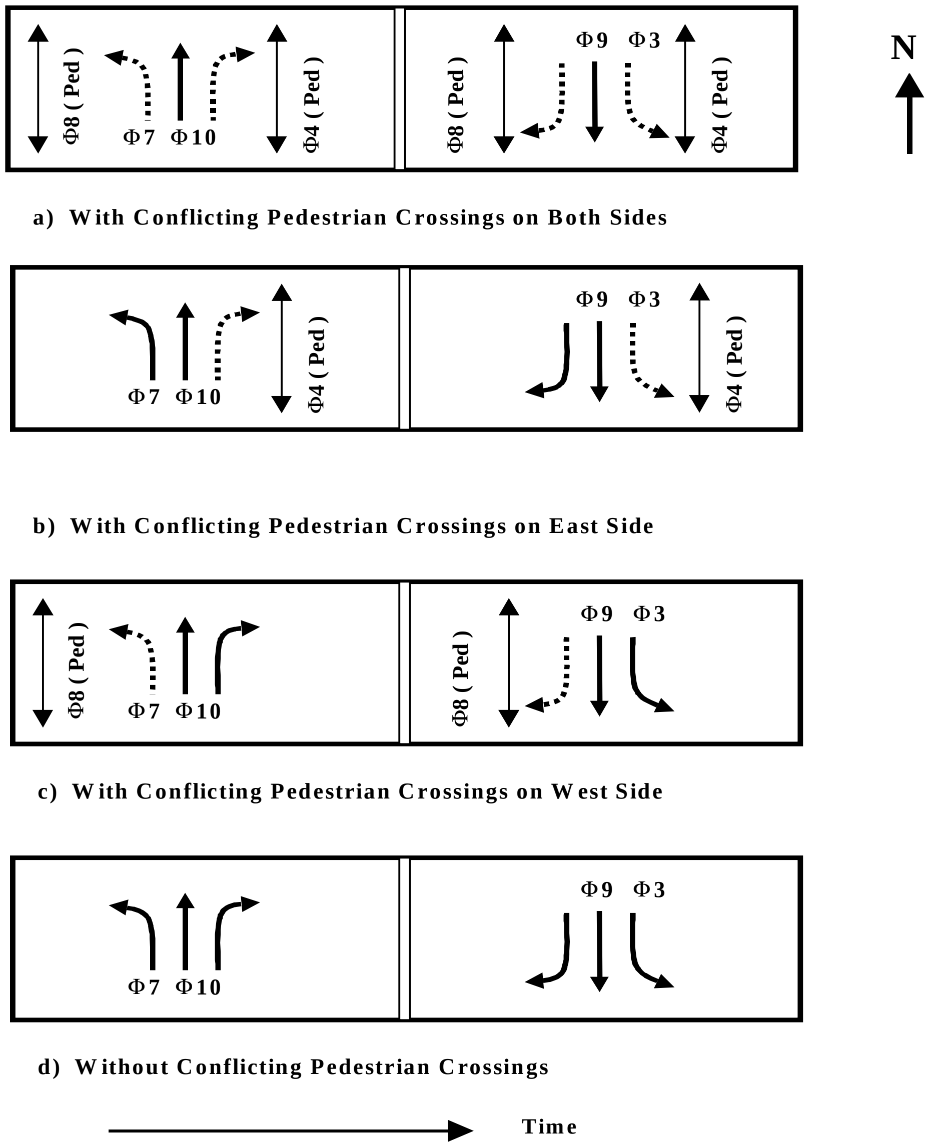
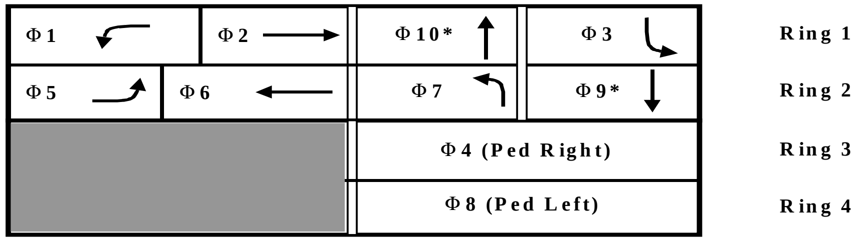


Figure 8 Phasing Scheme for Split Phase with Protected/Permitted Left-turns



* *Note: ϕ9 and ϕ10 output load switches to ϕ8 and ϕ4, respectively*

Phase	Ring	Next	Concurrent	Phase	Ring	Next	Concurrent
1	1	2	1,5,6	7	2	9	3,4,7,8
2	1	10	2,5,6	8	4	8	3,4,7,8,9,10
3	1	1	3,4,8,9	9	2	5	3,4,8,9
4	3	4	3,4,7,8,9,10	10	1	3	4,7,8,10
5	2	6	1,2,5				
6	2	7	1,2,6				

Figure 9 Proposed Controller Phase and Ring Configurations for Split Phasing with Protected/Permitted Left-turns

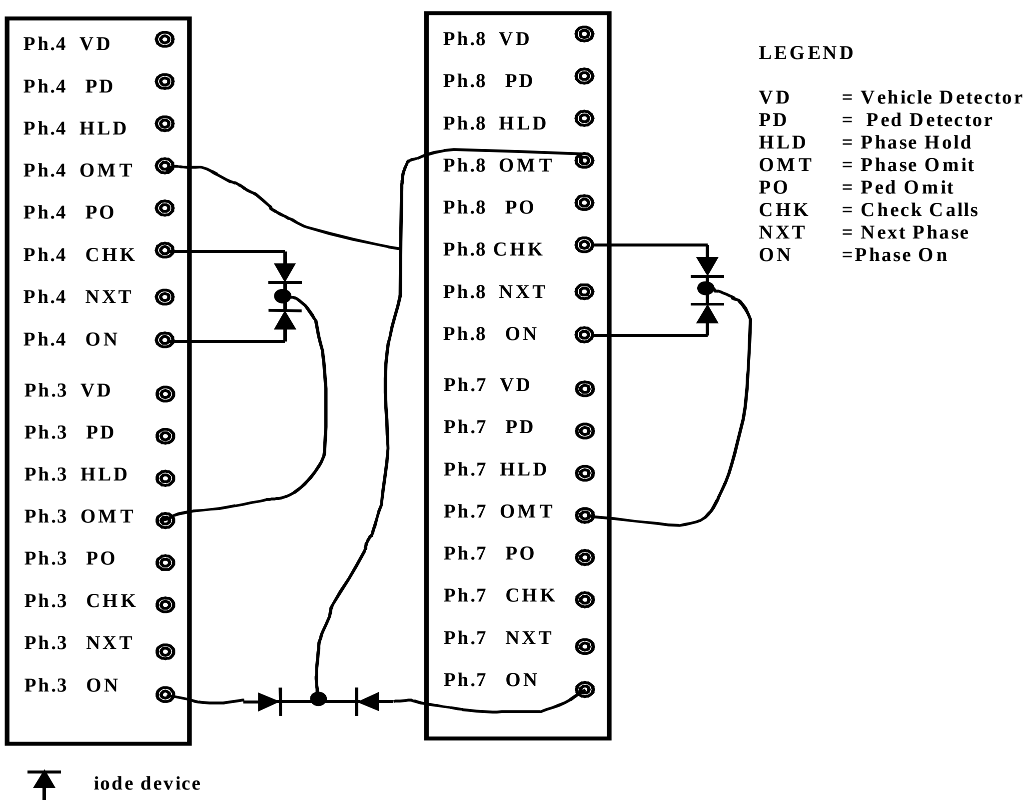


Figure 10 Illustration of Cabinet Wiring

Summary and Conclusions

The paper addresses the various issues related to pedestrian timing treatment with split phasing operations. Advantages and disadvantages of each form of split phasing were examined from safety and operational efficiency point of view. The paper proposes a protected/permitted left turn display for split phasing which can maximize the efficiency while maintaining safe traffic operations. The analysis of phasing alternatives reached the following conclusions:

- Split phasing with protected left-turns eliminates the conflicts between pedestrian and left turn vehicles; however, the provision of two pedestrian splits could significantly reduce the intersection capacity, and normally requires use of longer than optimal system cycle length in coordinated signal systems. When sufficient phase splits are not provided, pedestrian crossing could result in the signal out-of-coordination.
- Split phasing with permitted left-turns provides more efficient traffic operations due to accommodation of pedestrian crossing within a single pedestrian phase. However, the display of a green ball may not convey clear information to the drivers and could condition people to make a left turn without yielding to opposing traffic at a permissive left turn location.
- The paper recommends a protected/permitted left turn phase under split phasing operations. Such a phasing scheme would provide an alternative solution between protected and the permitted left-turn phasing schemes. Implementation of such a phasing scheme on existing controllers requires the use of 10 phases and 4 rings in order to use some existing controllers. Further more, a proper signal display also requires either a NEMA TS1 back panel be used or the equivalent logic be implemented in the controller software.
- Field testing of the proposed protected/permitted phasing scheme is necessary to verify its efficiency and safety.

References

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3. Tian, Z; Kacir, K; Vandehay, M; and Long, H. *Signal Timing Strategies in Dealing with Pedestrian Crossings*. Proceedings of the 69th ITE Annual Meeting, Las Vegas, August 1999.
4. Eagle Traffic Control Systems. *EPAC300 Actuated Controller Unit*, 1997.