THE INSTALLATION OF PRE-SIGNALS AT RAILROAD GRADE CROSSINGS

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INTRODUCTION

Each signalized intersection adjacent to a highway-rail grade crossing presents the danger of extending queues onto the tracks. Common sense dictates that motorists, queued back from an intersection, should not idle on active railroad tracks. It is, however, becoming more and more apparent that designers cannot rely on the common sense of most drivers. Railroad preemption, which connects the traffic signals to the railroad active warning devices, can often be designed to clear the tracks of queued vehicles. There are some instances, however, where railroad preemption alone cannot clear the tracks and other measures must be implemented.

This paper documents one design alternative, the installation of advance “pre-signals”, to aid railroad preemption in the clearance of the grade crossings. This design was considered at two locations as part of the Old Colony Railroad Rehabilitation Project in Massachusetts. The 1988 Manual of Uniform Traffic Control Devices (MUTCD) sets 200 feet between the railroad crossing and the adjacent intersection as the upper limit at which preemption should be considered.(1) This paper will illustrate that suggestion of any threshold is misleading. Calculations to set railroad preemption timing, and the use of “pre-signals” to control queues and provide additional protection at grade crossings will also be presented.

OLD COLONY RAILROAD REHABILITATION PROJECT

The Old Colony Railroad Rehabilitation Project (OCRR) was undertaken by the Massachusetts Bay Transportation Authority (MBTA) to restore the Old Colony Line commuter rail to service southeastern Massachusetts. The project includes two lines that have been constructed (Middleborough and Plymouth) and a third under design. All three lines have been inactive since 1959. As part of the MBTA’s commitment to improving vehicular traffic flow in communities affected by the resumption of service, Sverdrup Civil, Inc., was asked to design roadway improvements at grade crossings and at intersections expected to carry increased traffic to the stations. Improvements at grade crossings included implementation of railroad preemption at adjacent signalized intersections. Throughout the project, from construction through completion, the MBTA was committed to making every grade crossing as safe as possible.

RAILROAD PREEMPTION

Railroad preemption is the coordination between traffic signal controllers and active warning devices at railroad grade crossings. Railroad preemption at signalized intersections adjacent to railroad grade crossings is typically implemented for one of two reasons: 1) to prevent the queue of vehicles at the intersection from extending onto and/or past the grade crossing and 2) to control vehicles approaching the grade crossing. This paper focuses on the first case.

The critical leg of an intersection is the approach that includes the grade crossing. Preemption activates a clearance phase at the intersection for the critical approach to clear vehicles off the tracks before the railroad equipment is activated. There are, however, locations where railroad preemption alone becomes insufficient. This can occur when the queue from the intersection extends significantly past the grade crossing. Most often the railroad preemption phase timing would be set to move that one vehicle off of the tracks. If, however, the queue extends significantly past the crossing, there is no guarantee that the next vehicles in line would not move forward as well during the preemption phase and possibly stop on the tracks. In order to clear a long queue beyond the tracks, the activation equipment for the clearances phase would need to be set at a distance that, under most construction budgets, would not be feasible. In addition, such a lengthy railroad preemption phase could significantly affect the operation of the signalized intersection.

In this case, the installation of “pre-signals” at the grade crossing can control the queue of vehicles in two ways. First, the “pre-signals," operating in coordination with the signalized intersection, can dampen the queue by retaining a portion on the approach side of the crossing during each phase. Thus, where the vehicles would otherwise be queuing onto and past the tracks, the number of vehicles allowed to proceed across the tracks and to the intersection would be controlled. Calculations of preemption timing should be made to ensure that the amount of vehicles allowed through will not queue to the crossing and create a hazardous condition. The “pre-signals” should go to red a few seconds before the intersection signals, a timing plan also known as a trailing green overlap.

Second, during railroad preemption, the “pre-signals” can help prevent vehicles from proceeding onto the tracks or attempting to sneak around the railroad gates (if present). Unfortunately, motorists tend to respect and obey traffic signals more often than railroad signals. The discussion of J. Mahar Highway provides calculations to determine the timing for a railroad preemption clearance phase as specified by Marshall and Berg, “Design Guidelines for Railroad Preemption at Signalized Intersections.”(2)

As an alternative to installing pre-signals, engineers often recommend queue detection to clear vehicles extending from an adjacent intersection onto railroad tracks. The queue detector would be placed at a reasonable location between the intersection and the grade crossing and would place a call for the clearance phase. This would keep the queue of vehicles from extending past the queue detector and onto the tracks. In some cases, a queue detector is a sufficient solution to the queuing problem. The two cases examined in this paper will illustrate the benefits and disadvantages of using queue detectors or pre-signals.

RAILROAD PREEMPTION CRITERIA

There are a variety of manuals written on railroad preemption and where to implement it. The 1988 edition of The Manual of Uniform Traffic Control Devices (M.U.T.C.D.) indicates that "Except under unusual circumstances, preemption should be limited to the highway intersection traffic signals within 200 feet of the grade crossing." The proposed amendments to Chapter 8 now indicate;

> "When a roadway-rail intersection with an active traffic control system is located within 60 m (200 ft) of an intersection or mid-block location controlled by a traffic control signal, the traffic control signal should be provided with preemption in accordance with section 4c-13. Coordination with the roadway-rail intersection warning system should be considered for traffic control signals located more than 60 m from the crossing. Factors should include motor vehicle traffic volumes, approach speeds and queue lengths." (3)

This change to the manual is an important one in that it calls attention to the fact that the 200 foot threshold is somewhat limiting. Intersections near grade crossings should be evaluated regardless of the distance between the intersection and the crossing (within reason). The "Recommended Practice of ITE on the Preemption of Traffic Signals at or near Railroad Grade Crossings with Active Warning Devices" 1997, also indicates that 200 feet is too limiting.(4) The Recommended Practice states "The distance between the tracks and the signalized intersection must be carefully evaluated, and traffic and geometric conditions must be diligently reviewed and analyzed." In addition, the Recommended Practice suggests "if vehicles regularly queue across the tracks, a pre-signal should be considered."(4)

JOHN MAHAR HIGHWAY - BRAINTREE, MASSACHUSETTS

The Plymouth Line grade crossing at John Mahar Highway (Mahar) is located approximately 450 feet to the north of the intersection of Mahar Highway and Plain Street in Braintree, Massachusetts. The intersection of Mahar Highway and Plain Street is a T-intersection with Mahar Highway as the stem. The Plain Street eastbound approach consists of two lanes, used typically as one left-turn lane and one through lane. The Plain Street westbound approach consists of one right-turn lane and one through lane. The Mahar Highway southbound approach consists of one left-turn lane and one right-turn lane. The intersection is fully actuated.

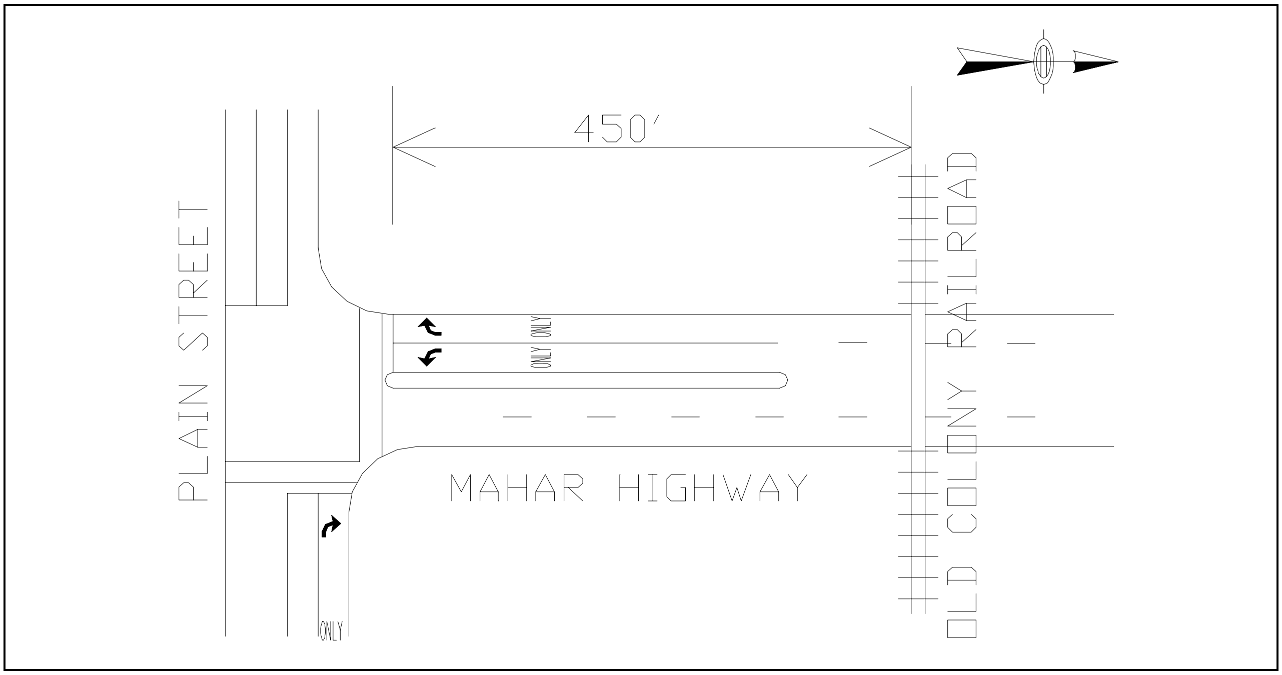

Figure 1 The intersection of Mahar Highway and Plain Street

Observations in the field indicate that during the weekday A.M. peak period, queues on Mahar Highway do not extend back to the grade crossing. During the weekday P.M. peak period, however, queues do extend past the crossing. This queue is the result of historically high volumes on Plain Street and continued build-out on the Mahar Highway corridor. This growth resulted in a significant volume of left-turns (671) heading southbound on Mahar Highway during the P.M. peak period.

Analysis on the intersection was performed using Synchro 3.2, a traffic network LOS analysis software package. According to a Synchro analysis, the 95th percentile queue is approximately 650 feet under the optimized timing plan and existing traffic volumes. Future year projections indicate that the crossing will continue to be blocked by vehicle queues, unless some improvements are made. Although analysis indicates that the addition of a second left-turn lane on Mahar Highway and a new timing plan could alleviate the queue extending past the grade crossing most of the time, railroad preemption would still be required to clear the tracks. Because this grade crossing is currently active, an immediate solution was necessary to solve the queuing problem.

Use of railroad preemption alone to clear the queue would have to be set not only to clear out the vehicle sitting on the tracks, but also the vehicles behind. There is no guarantee that vehicles in queue will not continue to sneak over the tracks during the railroad preemption phase because the queue is so much longer than the clear distance. Re-timing the traffic signal phasing to keep the queue less than 450 feet would significantly affect Plain Street, sending both approaches to a LOS F. This re-timing would also affect the queues on Plain Street, sending the eastbound queue back to another grade crossing to the west.

Installation of a queue detector was considered at this intersection, but dismissed for the following reason. The queue detector would have to be placed to provide ample time to clear the queue before grade crossing activation. Given the nature of the queue, the detector would constantly be placing a call. At this intersection, Plain Street is the major street and Mahar Highway is the minor street. Continually servicing the minor street due to constant queue detection would leave the intersection at a LOS F.

The solution here is to install "pre-signals" at the crossing along with a slight adjustment to the timing of the signals to reduce queues on Plain Street. The intent of the "pre-signals" is to control the queue at the intersection. Even with the "pre-signals" it is still necessary to calculate the railroad preemption as an added precaution. In this case, the railroad preemption timing would only have to be set to clear one vehicle sitting on the tracks, since the remainder of the queue would be controlled by the pre-signals.

According to Marshall and Berg, there are two equations necessary to perform the timing calculation. The first calculates the time it takes to get that vehicle on the tracks to begin to move (start-up time), and the second calculates the amount of time it takes to move that vehicle across the tracks.(4) According to Marshall and Berg, the equation for the start-up time is as follows:

$$T1 = (L*kj)/(2.94*S)$$

Where:

L= length of queue to be cleared , as measured from this intersection stop line to the point where a vehicle needing to be cleared may be stopped (ft)

kj = jam density (vpm)

S = saturation flow rate (vph, 1600 for through movements, 1400 for designated turn lanes)

Given that L=450', kj=5280/25, and S=1400 for left-turns, T1=23.09 seconds.

Again, according to Marshall and Berg, the second equation, the time it takes to move the vehicle off of the tracks, is as follows:

$$T2=[2(L+2D+W)/a]0.5$$

Where:
L= length of design vehicle (ft)
D= clearance distance on either side of the tracks (default 15 feet)
W= width of the crossing, or distance between outermost rails (ft)
a= acceleration rate for the design vehicle,
4.4 ft/sec2= P vehicle
2.5 ft/sec2=SU vehicle
1.6 ft/sec2=MU vehicle (4)

Given that L=25 ft, W=5 ft, D=15 ft, the following times would be set per design vehicle:

P vehicle	T2=5.22 seconds
SU vehicle	T2=6.93 seconds
MU vehicle	T2=8.67 seconds

Therefore, if designing for truck traffic, the total railroad preemption time should be set for (23.09+8.67) 32 seconds. This timing is set only to move that last vehicle in line across the tracks, not the entire queue length stacked on Mahar Highway.

ROUTE 123 - ABINGTON, MASSACHUSETTS

The Plymouth Line grade crossing at Route 123 is located approximately 700 feet to the west of the intersection of Route 123 and Route 58 in Abington, Massachusetts. The intersection of Route 123 and Route 58 is a four-way intersection, with Route 123 (major street) running east-west and Route 58 (minor street) running north-south. Each approach consists of two lanes, a left-turn lane and a through-right lane. The intersection is fully actuated and operates using a semi-quad-left phasing (on Route 123) plan.

Observations in the field indicate that during the weekday A.M. peak period, queues on Route 123 do not extend back to the grade crossing. During the weekday P.M. peak period (579 vehicles per hour) queues extend past the crossing. This queue results from a combination of factors. During the P.M. peak period there is significant volume of traffic heading eastbound on Route 123. The grade crossing itself is located only 500 feet from the platform at the nearby station stop. Therefore, when the train pulls into the station, it activates the grade crossing warning devices and the gates come down. These gates stay down for the duration of the train stop and until the train proceeds through the grade crossing. This extended activation time (approximately 1 minute and 45 seconds) results in a platoon of vehicles on the west side of the grade crossing. Once the grade crossing is clear, this platoon of vehicles approaches the intersection and, under the existing timing plan, queues 200 feet past the grade crossing, or 900 feet from the Route 123/Route 58 intersection.

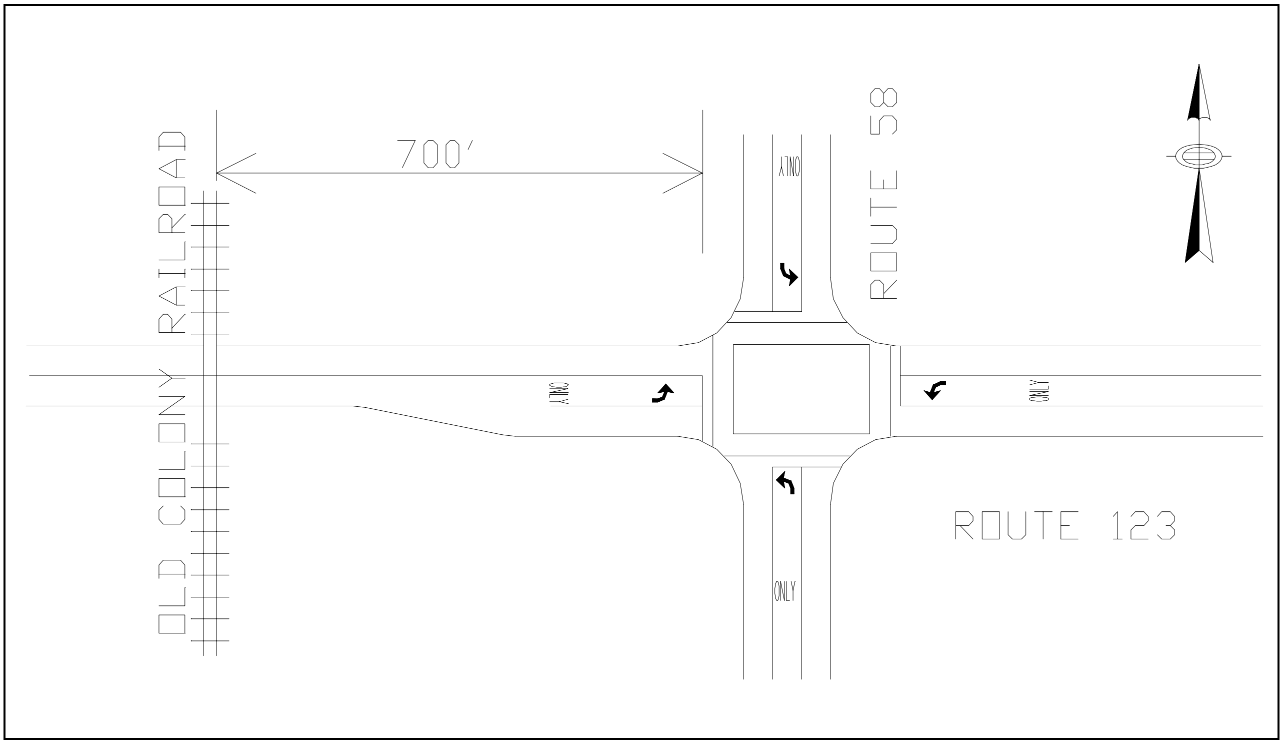

Figure 2 The intersection of Route 123 and Route 58

According to a Synchro analysis, the 95th percentile queue is approximately 620 feet, ("exceeds capacity and could be longer") under the existing timing plan and traffic volumes. Traffic projections to the year 2010 indicate that the crossing would continue to be blocked by vehicle queues, unless some improvements are made. Geometric improvements at the intersection such as additional lanes are not feasible due to restricted right-of-way. Because the grade crossing is also currently active, a temporary and immediate solution was necessary to solve the queuing problem.

A new timing plan for existing volumes was developed to add more green time to the eastbound approach. Calculations indicate that with the new timing plan, the 95th percentile queue would be reduced to 470 feet, less than the 700 foot distance between the intersection and the crossing. Since the grade crossing operation hampers the accuracy of Synchro, observations in the field, after the new timing plan was implemented, indicated that the queue length is indeed less than the 700 foot storage available, but appears to be more than Synchro's 470 foot calculation. While the eastbound approach would now be "fixed" temporarily, the timing plan is barely sufficient to handle the existing volumes and will not handle any future growth. In addition, by adding more green time to the eastbound Route 123 approach to Route 58, the minor street left-turns experience LOS F. No more green time can be added to the eastbound approach without significantly affecting the other approaches to the intersection.

Unlike Mahar Highway, the grade crossing is located on the major street of the intersection, and significantly further back from the intersection. Also unlike Mahar Highway, the current timing plan changes effectively control the queue without degrading the major street movements. At this location, pre-signals were not recommended for two reasons. First, pre-signals would not effectively control the queue as they would at Mahar Highway due to the extended distance. Second, pre-signals would be a more expensive solution than the installation of a queue detector. A queue detector at this location is more feasible in that it will service the major street at the intersection. Given the effectiveness of the timing plan, the queue detector is essentially a cautionary measure more than a solution. Also, given the extended distance between the intersection and the grade crossing, a queue detector can be placed at an acceptable location to activate the clearance phase and effectively control the queue.

SUMMARY

As illustrated in this paper, the 200 foot threshold was not appropriate at two locations which did indeed require some form of railroad preemption, whether it be a queue detector or the installation of pre-signals. In both cases, the traffic volumes were high enough to extend queues significantly past the grade crossings. When dealing with grade crossings and adjacent intersections, it is important to consider some form of railroad preemption regardless of the distance between (within reason). One solution which deserves further recognition is the installation of "pre-signals" at the grade crossings. The "pre-signals" can supplement the operation of the signals at the intersection to prevent lengthy queues as well as provide significant additional protection at the grade crossing.

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ENDNOTES

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2. Marshal, P.S., W.D. Berg. *Design Guidelines for Railroad Preemption at Signalized Intersections.* Washington, D.C.: Institute of Transportation Engineers, ITE Journal, February 1997.
3. U.S. Department of Transportation. *Proposed Amendments to the Manual on Uniform Traffic Control Devices (MUTCD).* Washington, D.C.: Federal Highway Administration, Federal Register Vol. 62, No. 3, Monday, January 6, 1997.
4. Traffic Engineering Council Committee TENC-4M-35. *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices: A Recommended Practice of the Institute of Transportation Engineers.* Washington, D.C.: Institute of Transportation Engineers, Publication No. RP-025A, 1997.