2013

Evaluating At-Grade Rail Crossing Safety along the Knowledge Corridor in Massachusetts

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A Thesis Presented

By:

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Submitted to the Graduate School of the

University of Massachusetts Amherst in partial fulfillment

of the requirements for the degree of

Master of Science in Civil Engineering

February 2013

Department of Civil and Environmental Engineering

Transportation Engineering

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ABSTRACT

EVALUATING AT-GRADE RAIL CROSSING STANDARDS ALONG THE KNOWLEDGE CORRIDOR IN MASSACHUSETTS

FEBRUARY 2013

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Highway-rail grade crossings are safer than ever, but collisions between motor vehicles and trains persist. Some collisions could be prevented by actively maintaining such grade crossings, yet many at-grade rail crossings are only evaluated following collisions. Those crossings that experience no collisions may go decades without being inspected. In recent years, the Congress has allocated funds for a national High-Speed Intercity Passenger Rail program, and it is in the public's interest for state road/highway agencies to inspect all highway-rail crossings in high-speed rail corridors to ensure that the warning systems in place are commensurate with the crossings' needs.

The objectives of this research are to a) determine the adequacy of traffic control devices at highway-rail grade crossings along the restored Vermonter tracks in Massachusetts; and b) to recommend crossings for closure and/or grade separation if it is determined that the traffic control devices are inadequate at an intersection. The major findings of this paper are that a majority of the at-grade rail crossings need some improvements to be in compliance with MUTCD standards. Additionally, four at-grade crossings are identified for closure, grade-separation, and/or additional traffic control devices beyond MUTCD standards.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the field of transportation, highway-rail grade crossings are unique because they are intermodal intersections. Unlike intra-modal intersections, where vehicles/trains from adjacent approaches take turns traversing the crossing, trains have the right of way through highway-rail grade crossings. Trains have been given the right-of-way because of their character and momentum. Vehicular traffic must yield to trains at every grade crossing every time, and may not proceed until all trains have cleared the intersection.

There are two types of crossings in the United States, public and private. Public crossings may be used by anybody and are located "on highways under the jurisdiction of and maintained by a public authority." [1] Highways include all roads, not just those with limited access. Private crossings are located where railroad tracks intersect roadways on privately owned land. These latter crossings are used exclusively by the landowner and those with the owner's permission. Private crossings may also be sub-divided into one of four categories: Agricultural, Industrial, Residential, and Temporary. Agricultural crossings allow farmers to access farm land that lies on the opposite side of the track. In 2005, there were 147, 805 public highway-rail grade crossings and 97,306 private crossings. Additionally, there were 3,162 pedestrian crossings

Traffic control devices (TCDs) are present at highway-rail grade crossings to remind highway users that they must stop for trains. The types of TCDs found at these crossings can be divided into two categories: passive and active. Passive TCDs display a constant message with regard to time (e.g. advanced warning signs, pavement markings and Crossbucks). A Crossbuck is shown in Figure 1.

Figure 1 – Crossbuck Sign

Active TCDs generate a variable message based upon whether or not a train is approaching or occupying the crossing. When a train approaches a highway-rail grade crossing that employs active TCDs, lights will flash, bells will ring and a gate may descend to a horizontal position, blocking traffic movements. Once all trains have cleared the intersection, the active TCDs will return to their dormant states, until the next train activates the intersections control circuitry. At high volume crossings where queuing could occur, traffic signals may be employed as well.

Responsibility for highway-rail grade crossings has been contentious and at times, litigious. As early as 1877, the U.S. Supreme Court ruled that railroads are obligated to warn highway travelers of an approaching train, yet travelers are responsible for stopping, looking and listening for approaching trains. [1]. It is clear from this first court opinion that there is a shared responsibility between the highway users and railroads. The idea of shared responsibility for highway-rail grade crossings is still present today. When it comes to controlling traffic, only the highway agency with jurisdiction at the crossing may legally do so. Consequently, a single agency is responsible for the installation and maintenance of TCDs at highway-grade rail crossings. This authority varies by state, in Massachusetts, the authority rests with Massachusetts Department of Transportation (MassDOT). A single exception applies; railroads are responsible for the installation and maintenance of Crossbucks at passive crossings in addition to the installation and maintenance of railroad crossing signals.

Safety is a concern at highway-rail grade crossings because at the vast majority of these intersections, vehicular drivers are able to circumvent the warning systems, which can lead to catastrophic collisions. A study conducted by the Office of the Inspector General in 2004 found that in the preceding ten years, most vehicle-train collisions were attributable to "risky driver behavior or poor judgment." [11] The study concluded that 94% of vehicle-train collisions were attributable to vehicular drivers acting in an unlawful manner, and that most of the remainder of the collisions resulted from stuck, stalled, or abandoned vehicles on the crossing. [11] By acting in an unlawful manner, vehicular drivers endanger themselves, the train's passengers, and they place a strain on the public good when law enforcement is deployed to investigate the collision.

Providing safe transportation for public and private entities is paramount to the federal and state Departments of Transportation. The United States Department of Transportation (USDOT) has been prolific in issuing guidance to state DOTs in the form of standards, guidelines, technical reports, and direct funding to improve highway-rail grade crossing safety. Standards relating to highway rail grade crossings are contained in the *Manual on Uniform Traffic Control Devices*, published by the Federal Highway Administration (FHWA), an arm of the USDOT. The Federal Railroad Administration (FRA) another arm of the USDOT, has issued additional rules and guidelines for states and railroads to follow. While FRA rules do not carry the force of law, they obtain compliance by providing funding only to parties that meet their requirements in addition to *MUTCD* standards. Individual states, at their discretion, may implement more stringent practices then are required. Presently, Massachusetts follows the federally mandated standards and does not have a supplemental program.

Each crossing has a unique identifier which consists of six digits and one letter identifier, known as the crossing number, which is assigned by the USDOT. A sample US DOT crossing number is shown in Figure 2.

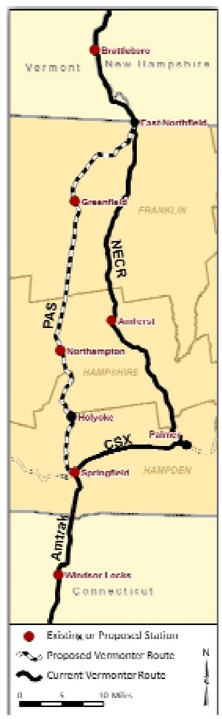
Figure 2 – Sample USDOT Crossing Identifier

The six digit identifier is assigned using an algorithm and the letter at the end is a checksum. Each crossing number is unique so the precise location of each crossing, nationwide, can be determined solely by using its crossing number.

1.2 Problem Statement

As part of the American Reinvestment and Recovery Act of 2009, $8 billion was allocated to passenger rail improvements under the federal High Speed Intercity Passenger Rail (HSIPR) Program. Of the $8 billion, Massachusetts was awarded $73 million to restore Amtrak's Vermonter service to its original tracks on the west bank of the Connecticut River, passing through Holyoke, Northampton and Greenfield[1]. Figure 3 shows the existing route of Amtrak's Vermonter Service in relation the new route once the original track is restored. The Connecticut River is not shown but passes in between the two tracks between Northfield and Springfield. Freight trains still use the original track; however, the runs are infrequent and the trains operate at speeds varying between 10 mph and 35 mph.

Figure 3 – Existing and Restored Knowledge Corridor Railroad Routes Used for Amtrak's Vermonter Service



The Commonwealth of Massachusetts is rehabilitating the tracks to allow for Amtrak to operate its trains as fast a 79 mph. Not only will speeds increase, but also the frequency as well; the Commonwealth has plans to run up to four passenger trains a day, double the number of

[1] Both existing and restored sections of track pass through the Massachusetts section of the Knowledge Corridor, also known as the Hartford-Springfield Metropolitan Area.

trains that run presently through the Knowledge Corridor. These additional trains will operate during the morning and evening rush hours, when traffic volumes are greatest, which increases the risk of collisions.

Many of the highway-rail grade crossings in the Commonwealth have not been inspected in over thirty years, since the United States Congress passed a law establishing a federal database for all highway-rail crossings (at-grade and grade separated). The crossings along the western bank of the Connecticut River are infrequently used by the parent railroad, PanAm Railways, and many have not been inspected since the 1970's. Now that the tracks are being restored, and will have passenger trains running at speeds up to 79 mph four times a day, the highway-rail grade crossings need to be evaluated to determine the adequacy of their TCDs. Intent of this research is to provide guidance to MassDOT as it develops a plan to improve highway-rail grade crossings along the Knowledge Corridor.

1.3 Objectives

The objectives of this thesis are to a) determine the adequacy of TCDs at highway-rail grade crossings along the restored Vermonter tracks in Massachusetts; and b) to recommend crossings for closure and/or grade separation if it is determined that the TCDs are inadequate at an intersection. It is intended that the recommendations be made to the Massachusetts Department of Transportation, Rail & Transit Division.

1.4 Organization of Report

In order to achieve the objectives outlined in the previous section, a set of tasks was developed. The tasks, which are discussed further in the following chapter, included a literature review, standards review, a case study, and recommendations.

Task 1 – Literature Review

Identify pertinent research studies that focused on improving safety at highway-rail crossings, such as when to close crossings, grade-separate crossings, or install additional TCDs at highway-rail grade crossings. This task will be completed in Chapter 2.

Task 2 – Standards Review

Determine what TCDs should be installed at each public highway-rail grade crossing in the corridor to conform to *MUTCD* standards. This task will be completed in Chapter 3.

Task 3 – Case Study – Knowledge Corridor (MA)

Visit each highway-rail grade crossing along the Knowledge Corridor; both public and private, to evaluate what TCDs are present at the intersection. This task was performed between June and August using a camera and an electronic tablet. The camera was used to collect pictures of each intersection while the electronic tablet contained a database to input data about each highway-rail grade crossing. The documentation for this section will appear in Chapter 4.

Task 4 – Recommendations

Make recommendations on how to improve the safety of at-grade crossings along the Knowledge Corridor, bringing all crossings into compliance with *MUTCD* and identifying crossings for closure and/or grade-separation. These recommendations will be provided in Chapter 4.

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CHAPTER 2

LITERATURE REVIEW

This section provides an overview of studies that investigate techniques that may be employed to improve highway-rail grade crossing safety and include the following: closure to one of the modes; grade separation of the modes; keeping and improving the at-grade crossing, and doing nothing.

Even though states are solely the responsible party in mitigating risk at highway-rail grade crossings, railroads have a vested interest in promoting grade crossing safety, because train speed and frequency of operation are directly proportional to collision rates at highway-rail grade crossings.

Guidelines facilitate the decision-making process when evaluating alternatives to improve safety at highway-rail grade crossings. The alternatives include closing the highway-rail grade crossing to highway traffic, grade-separating the modes or keeping the at-grade crossing. Guidelines provide factors to consider when determining when conducting an engineering study, to the installation of additional TCDs beyond what is called for in the *MUTCD*, and even in evaluating whether an at-grade crossing should be closed or grade-separated.

2.1 Closing (Consolidating) an At-Grade Crossing

One of best ways to improve the safety at an at-grade crossing is to close the intersection to one of modes, allowing the other to move unimpeded.

Molitoris and Slater (1994) developed a methodology that could be applied to highway-rail crossing closure, based on a USDOT study of grade crossing closures across the country.

They found that the vast majority of grade crossing closure programs included improvements to adjacent remaining grade crossings, so the term “grade crossing consolidation” should be used in lieu of “crossing closure” and/or “crossing elimination.” The following elements should be considered when embarking on a grade crossing consolidation program: grade crossing consolidation projects should be reviewed by a traffic engineering professional to ensure that increased traffic on alternate routes does not diminish public safety; address local community’s emotional attachment to highway-rail grade crossings and other concerns; community support is critical; hazardous crossings that are not also redundant are unlikely to close; and community level incentives, possibly including compensation is expected. Taking these elements into consideration, a five step model approach is presented: screen projects, coordinate state & railroad efforts, know the community, build community support and include incentives. Omitting a step from the model approach is likely to result in failure to consolidate a crossing and even by following all of the steps, grade crossing consolidation programs are not guaranteed.

A USDOT Technical Working Group (TWG, 2002) discusses crossing closure as one alternative to maintaining a grade crossing that “requires balancing public necessity, convenience and safety.” [6] The TWG report confirms the Molitoris and Slater study from 1994, and frames the crossing closure issue as an economic one. Crossings should be evaluated for closure if the benefits of closing the crossing, including the unrealized costs of future maintenance costs, accidents, and improvements, exceed the cost of providing alternate access and increased user travel costs. The TWG report also provides guidance with quantifiable metrics that, if one or more satisfied, warrant considering a crossing for closure. One of the metrics is determining whether the benefits exceed the costs, as described previously. The other metrics involve performing an engineering study.

Ogden (2007) discusses adverse impacts of grade crossings including travel time delays and the possibility of non-train collisions, and concludes that grade crossing elimination will negate these issues. In confirming the TWG and Molitoris & Slater works, Ogden adds that a criterion for crossing closure on mainline tracks is if there are five or more crossings within a one-mile segment. Ogden discusses who the responsible parties are with regard to removing the crossing surface (the railroad), the TCDs (the highway authority), and erection of barricades (the highway authority) once a grade crossing is closed.

In 2009, the FRA issued guidelines for highway-rail grade crossings along high speed rail corridors, in which it was noted that mobility and safety are the primary concerns that should be considered when reviewing grade crossings for closure. They state that "crossing closures are typically very cost-effective when compared to the alternative" and that efforts to minimize the number of highway-rail grade crossings will be favored when funding requests are evaluated. The FRA confirms the "systems" approach to grade crossing closure established by Molitoris & Slater and states that involving the many disparate parties including the railroad and local community is critical to successful closure programs.

2.2 Grade Separation

Grade-separating an at-grade crossing can be done as an alternative to or as part of a crossing consolidation program. Typically, grade-separations are coupled with crossing consolidations; however, there could be instances where isolated crossings warrant grade-separation when there are no other crossings in the area that could be closed.

TWG (2002) discusses the decision to grade separate a highway-rail crossing as primarily an economic matter. Grade separation has a high initial cost, in the millions of dollars, which serves as a deterrent for many projects. TWG recommends that the decision to grade-separate should look beyond the initial cost of construction and include life cycle benefits that include delay cost savings, fuel cost savings, improved emergency access, and the potential to close adjacent crossings, among others. Grade separation should be considered if the benefits over the life of the project exceed the initial construction costs and the life cycle costs. Metrics are provided to guide decision-makers in determining whether a crossing should be grade-separated.

2.3 Keeping an At-Grade Crossing

Because of the economic and political hurdles that must be overcome to grade-separate or close crossings, eliminating at-grade crossings is a slow process. Many crossings will not meet the criteria for consolidation or grade-separation, so they should be evaluated for additional TCDs. The public will not realize all of the safety gains associated with closing or grade-separation; however, they gain in not having to pay the costs associated with either of the aforementioned approaches either.

In the late 1990's, North Carolina DOT pioneered the concept of a "sealed corridor" in which all public highway-rail grade crossings in a corridor are systematically evaluated for additional TCDs, closure, or grade separation. The process applies to both public and private crossings.

An engineering study provides a rational defense for what TCDs should be at a highway-rail grade crossing, with specific recommendations where the needs are deemed to be in excess of present installations. TWG (2002) outlines a four-step traffic control device selection procedure that would form the basis of an engineering study: gather highway-rail grade crossing information; evaluate highway traffic flow characteristics; possible revision to highway-rail grade crossing; and interim measures and/or documentation.

In their “Guidelines for Highway-Rail Grade Crossings,” the FRA gives special treatment to four types of private crossings: public access, industrial, residential and agricultural. They state uniformly that the goal for private crossings, as for public crossings is to eliminate as many as feasible and the remainder should be evaluated for additional TCDs in a similar manner as to public crossings. FRA Guidelines do not have the force of law but to receive funding from the FRA, the guidelines should be followed. These guidelines are summarized in Table 1.

Table 1: FRA Guidelines for At-Grade Crossings on High-Speed Rail Corridors

Rail Speed (mph)	Public Crossings	Private Crossings
80 to 110	"Sealed Corridor" Presence Detection (>100 mph) Barrier Systems (Optional) Train Control Integration (Optional) Remote Health Monitoring (Optional)	Four-quadrant gates preferably normally closed or closed when not in use. Special exceptions <90 mph may remain passive.
111 to 125	"Sealed Corridor" Presence Detection Barrier Systems Train Control Integration Remote Health Monitoring (Optional)	"Sealed Corridor" Normally Closed Crossings Presence Detection Barrier Systems Train Control Integration Remote Health Monitoring (Optional)
Above 125	Close or grade-separate all highway-rail crossings	Close or grade-separate all highway-rail crossings.

The concepts presented in Table 1 have been developed to promote an extremely high-level of safety with redundant controls and fail-safe systems at highway-rail grade crossings which high-speed passenger trains will use.

Presence detection allows for feedback within the crossing to delay an exit gate's descent if a vehicle has yet to clear the crossing. For crossings where train speeds will exceed 100 mph, the FRA states that presence detection should be coupled with a train control system. Train control systems provide a locomotive engineer with critical information regarding route conditions ahead and will be required by all trains operating at speeds above 110 mph.

Barrier systems are defined as devices that can withstand the impact of the design vehicle for the highway classification at the posted speed limit and will be required at all crossings where train speeds will exceed 110 mph. As of this writing, there are no known products that can meet the FRA's standard for barrier systems.

Lastly, remote health monitoring is a life-cycle maintenance tool that provides additional redundancy in the system by watching crossings and providing alerts to a central control center if malfunctions or failures are detected at an at-grade crossing. The FRA will not allow any trains to operate on a corridor with at-grade crossings at speeds exceeding 125 mph.

The FRA has proposed a separate set of guidelines for private crossings that merge with the guidelines for public crossings as train speeds increase. Below 90 mph, The FRA desires that all crossings have a gate or barrier installed that is normally closed and opened only when necessary to cross the tracks. However, some crossings have such low usages, that passive crossings may remain on a case-by-case basis. Above 90 mph, all crossings will have to have gates. Above 110 mph, the FRA requires that the crossing gate will be locked and integrated into a larger control system so that a railroad dispatcher could operate the gate remotely. Additionally, at speeds above 110 mph, the FRA states that all requirements for public crossings will apply to private crossings as well, generally speaking. On corridors where trains are traveling in excess of 125 mph, all private crossings will be closed or grade-separated.

CHAPTER 3

REVIEW OF STANDARDS AND GUIDELINES

Standards exist to provide uniformity and consistency, so that users of a given system do not have to guess at the function or purpose of various devices or practices. In 1978, the federal government consolidated highway-rail grade crossing standards that had previously been scattered throughout the *MUTCD* into its own division, “Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings.” States are obligated to adopt the federal *MUTCD* or a state *MUTCD* which is similar to the federal version (cite a reference for this).

Many of the *MUTCD* standards only come into effect once a condition has been fulfilled, only a handful of the standards listed in the *MUTCD* are applicable to every crossing, unconditionally and even then they only apply to public crossings (8A.01.01). **There are no federal requirements for private highway-rail grade crossings.** Table 2 lists the standards that must be followed with regard to public highway-rail grade crossings.

Table 2 – Summary of Pertinent *MUTCD* Standards

Section	Standard	Summary	Type
8A.01 Introduction	8A.01.07	*MUTCD* shall be used at public at-grade crossings	Classification
	8A.01.12	Not applicable	Practice
Section 8A.02 Use of Standard Devices, Systems, and Practices at Highway-Rail Grade Crossings	8A.02.05	Installations or modifications must be approved by highway agency and railroad company.	Specification
Section 8A.04 Uniform Provisions	8A.04.01	Sign appearances during day and night	Specification, Practice
Section 8A.05 Grade Crossing Elimination	8A.05.02	Conditions for removal of traffic control devices	Practice
Section 8A.07 Quiet Zone Treatments at Highway Rail Grade Crossings	8A.07.02*	Quiet zone compliance with *MUTCD*	Specification
Section 8A.08 Temporary Traffic Control Zones	8A.08.02	Operations should keep highway vehicles from stopping on railroad tracks.	Practice
Section 8B.01 Purpose	8B.01.01	Standard design and location of signs and pavement markings	Classification
Section 8B.02 Sizes of Grade Crossing Signs	8B.02.01	Standard sizes of grade crossing signs	Specification

Section	Standard	Summary	Type
Section 8B.03 Grade Crossing Sign and Number of Tracks Plaque at Active and Passive Grade Crossings	8B.03.01	Standard design for Grade Crossing sign	Specification, Practice
	8B.03.03	Grade Crossing sign need and placement	Practice
	8B.03.05	Number of tracks plaque need placement	Specification, Practice
Section 8B.04 Crossbuck Assemblies with YIELD or STOP Signs at Passive Grade Crossings	8B.04.01	YIELD or STOP sign need and placement on road	Specification, Practice
	8B.04.09	YIELD or STOP sign placement in relation to Crossbuck	Practice
	8B.04.15	Appearance of Grade Crossing sign back	Practice
	8B.04.18	Conditions for Yield Ahead or Stop Ahead signs	Specification, Practice
Section 8B.06 Grade Crossing Advance Warning Signs	8B.06.01	General instructions for placement of Advanced Warning signs	Specification, Practice
	8B.06.05	Specific instructions for placement of Advanced Warning signs on parallel highways	Specification, Practice
Section 8B.08 Turn Restrictions	8B.08.07	Conditions for turn restrictions	Specification, Practice

Section	Standard	Summary	Type
During Preemption			
Section 8B.10 Tracks Out of Service	8B.10.02	Conditions for removal of traffic control devices	Specification, Practice
Section 8B.18 Emergency Notification Sign	8B.18.02	Design and Placement of Emergency Notification Signs	Specification, Practice
Section 8B.21 No Train Horn Sign or Plaque	8B.21.01*	Need and Placement of No Train Horn Sign	Specification, Practice
Section 8B.23 Low Ground Clearance Grade Crossing Sign	8B.23.02	Need and placement of Low Ground Clearance Grade Crossing Signs	Specification, Practice
Section 8B.25 Skewed Crossing Sign	8B.25.03	Conditions for using Skewed Crossing Sign	Specification, Practice
Section 8B.27 Pavement Markings	8B.27.01	Design and placement and conditions for pavement markings	Specification, Practice
Section 8B.28 Stop and Yield Lines	8B.28.01	Conditions for stop line	Specification, Practice
Section 8B.29 Dynamic Envelope Marking	8B.29.03	Design of dynamic envelope markings	Specification, Practice
Section 8C.01 Introduction	8C.01.04	Location, clearance and meaning of flashing-light signals and gates.	Classification, Specification, Practice
Section 8C.02 Flashing-Light Signals	8C.02.02	Additional features to be used with	Specification, Practice

Section	Standard	Summary	Type
		flashing-light signals	
	8C.02.04	Function and placement of flashing-light signals	Specification, Practice
	8C.02.09	Energy source standards for flashing-light signals	Specification
	8C.02.11	Allowance for variance in type of lamp used in flashing-light signal	Specification
	8C.02.15	Design of overhead or cantilevered structures	Specification
Section 8C.04 Automatic Gates	8C.04.02	Design and Operation of Automatic Gates	Specification, Practice
	8C.04.07	Inclusion of lights on gate arm	Specification
Section 8C.06 Four-Quadrant Gate Systems	8C.06.02	Design and construction of four-quadrant gate systems	Specification, Practice
Section 8C.07 Wayside Horn Systems	8C.07.02	Conditions for using wayside horn systems	Specification
Section 8C.08 Rail Traffic Detection	8C.08.01	Active traffic control system must actuated using rail traffic detection	Specification
Section 8C.09 Traffic Control Signals at or Near Highway-Rail Grade	8C.09.02	Use of traffic control signals at highway-rail grade crossings	Specification

Section	Standard	Summary	Type
Crossings			
	8C.09.08	Design of signal preemption systems	Specification
	8C.09.12	Use of pre-signals during signal preemption	Specification
	8C.09.15	Need and placement of STOP HERE ON RED SIGNs at pre-signals.	Specification, Practice
Section 8C.12 Grade Crossings Within or In Close Proximity to Circular Intersections	8C.12.02*	Need to prevent traffic queues in grade crossing	Specification

Not every section and chapter has been listed in the preceding table, only those that contain standards for highway-rail grade crossings. The following sections have been omitted:

- Sections 8A.03, 8B.05, 8B.13, 8B.14, 8B.15, 8B.16, 8B.19, 8B.26, 8C.03, 8C.05, 8C.10, 8C.11, and 8C.13, because they contain standards that only apply to light rail transit.
- Sections 8A.06, 8A.09, 8B.11, 8B.12, 8B.17, 8B.20, 8B.22 and 8B.24, because they do not contain any standards.
- Chapter 8D, because it covers rail-pathway crossings.

The remaining 28 sections contain 43 standards that should be consulted throughout the lifetime of a highway-grade crossing from design, through construction, modification, and removal. Of these 43 standards, the following are not presently applicable to the Knowledge Corridor: 8A.07.02, 8B.21.01, 8C.06.02, 8C.07.02 and 8C.12.02. These standards have been included in Table 2 and are marked with an asterisk (*).

The *MUTCD* standards under consideration are of three different types: classifications, specifications, and practice. Classification is a “systematic arrangement or division of materials, products, systems, or service into groups based on similar characteristics such as origin, composition, properties, or use.” [15] There are three standards listed in Table 1 which are categorized as classifications. An example is 8B.01.01; this standard classifies which preceding part of the *MUTCD* the design and location of signs and pavement markings must comply, respectively. A specification is defined by the ASTM as “an explicit set of requirements to be satisfied by a material, product, system, or service.” [15] Of the 43 standards listed in Table 2, 36 have an element of specification. Standard 8B.02.01 qualifies as a specification because it lists a requirement (size) to which grade crossings signs (i.e. a product) must conform. Lastly, 28 of the standards listed in Table 2 are categorized, at least in part, as practice. Practice standards are "a definitive set of instructions for performing one or more specific operations that does not include a test result." [15] To illustrate this type of standard, 8A.05.02, which covers grade crossing elimination, states that "when a grade crossing is eliminated, the traffic control devices shall be removed." This is a definite instruction that must be performed if a condition holds true, the condition being that the grade crossing has been eliminated. Just over half of the standards (22/43) in Table 2 can be categorized using more than one type.

3.1 Standards that Apply to Every Crossing

The following standards must be applied at every public crossing, every time:

- 8A.01.07, which mandates that the standards in the *MUTCD* be followed;
- 8A.02.05, which states that approval for the installation or modifications to traffic control devices must be obtained from the highway agency with jurisdictional and/or statutory authority, and the railroad company;
- 8A.04.01, which states that all signs must show the same color and shape at night as during the day, as well as giving specific conditions which allow for traffic control devices in the center of an undivided highway;
- 8A.05.02, which governs the removal of traffic control devices when an at-grade crossing is eliminated;
- 8B.01.01, which governs compliance of signs and pavement markings with Sections 2 and 3 of the *MUTCD*, respectively;
- 8B.02.01, which governs the size of signs;

- 8B.03.01, which governs the definition and design of a Crossbuck sign;
- 8B.03.02, which mandates the installation of at least one Crossbuck sign on each highway approach;
- 8B.03.05 (paragraph 2), which governs the location of the Crossbuck sign in relation each highway approach; and
- 8B.10.02 (all paragraphs), which governs the treatment of at-grade crossings that are not in service.
- 8B.18.02 (all paragraphs), which covers the design, contents and positioning of an emergency notification sign.

Standard 8B.18.02 is optional in the 2009 version of the *MUTCD;* however, the FRA issued a Final Rule in June 2012 mandating the installation of emergency notification signs at all highway-rail grade crossings. Thus, this will be the second sign that will have to be installed at every crossing, along with a Crossbuck sign with every approach. Railroads have until December 31, 2015 to come into compliance with this new regulation [16].

3.2 Standards that Conditionally Apply

The standards that come into effect when certain conditions have been met can be divided into three groups. The first group concerns traffic control signs markings that must be conditionally installed. The second group concerns the design and placement of optional traffic control signs and markings when certain conditions are present, and the third group addresses active TCDs and their applications, once a determination has been made to use them. For the last group of standards, there is standard that says active TCDs must be used. As a result, active TCDs are typically installed following an engineering study.

3.2.1 Conditionally Required Signage and Markings

Standards that discuss required additional signage and markings include the following (applicable conditions in **bold**):

- 8B.03.05 (paragraph 1), which states that grade crossings with **multiple tracks** must have a sign posted for each approach indicating the number of tracks
- 8B.03.05 (paragraph 3), which calls for reflectorized white strips on the back of all Crossucks that are not placed back-to-back with a Crossbuck sign for the opposing approach;
- 8B.04.01 (all paragraphs), which states that all **passive** grade crossings must have a YIELD or STOP sign in addition to the Crossbuck sign;
- 8B.04.09 (all paragraphs), which states how the YIELD or STOP sign should be installed relative to the Crossbuck sign and the distance from the ground or curb;
- 8B.04.15, which states when additional reflectorized white markings should be used on Crossbuck signs;
- 8B.06.01 (all paragraphs), which provides the conditions under which advance warning signs, and stop/yield ahead signs must be posted;
- 8B.08.07, which discusses the use of turn prohibition signs in conjunction with **signal preemption** at grade crossings;

- 8B.21.01, which states that a "NO TRAIN HORN" sign must be erected where a **quiet zone** has been established;
- 8B.23.01, which states that a "LOW GROUND CLEARANCE" sign must be erected when a **hang-up** could occur by a vehicle with a long wheel-base on the grade crossing;
- 8B.27.01, which provides the conditions under which pavement markings must be used in advance of grade crossings; and
- 8B.28.01, which states that stop and yield lines, must be installed at crossings with **active** traffic control devices.

Standard 8B.04.01 is new to the 2009 edition of the *MUTCD*, and the FHWA has provided for a ten-year period, until December 31, 2019, for states to come into compliance with this new standard. [6] Standards 8B.06.01 and 8B.27.01 discuss the conditions under which advance warning signs and pavement markings may be excluded from a nearby highway-rail grade crossing and are too numerous to appear here. The reader is referred to the full text of the *MUTCD* Part 8 in Appendix A for further details.

3.2.2 Conditionally Optional Traffic Control Devices (Signage, Markings, and Devices)

The following standards cover optional TCDs at highway-rail grade crossings. They include the following:

- 8B.10.02 (paragraph 2), which states that a "TRACKS OUT OF SERVICE" sign may be used in lieu of the Crossbuck Assembly at a highway-rail grade crossing which has been temporarily or permanently abandoned;

- 8B.25.03, which covers the placement and use of a "Skewed Crossing" sign at crossings which are not perpendicular to the roadway;
- 8B.29.03, which covers the design requirements for dynamic envelope markings indicating a trains clearance requirements while in the intersection; and
- 8C.07.02, which covers the use of wayside horn systems at grade crossings where the locomotive horn is not sounded.

3.2.3 Active Traffic Control Devices

The decision to install active TCDs typically follows an engineering study which addresses the question of whether they are necessary. These engineering studies happen on a case-by-case basis so two intersections with relatively similar characteristics could have different TCDs (active vs. passive) based upon what factors were taken into consideration when/if an engineering study was conducted (engineering studies will be covered in greater detail in section 2.2). When active TCDs are installed at highway-grade rail crossings, the following standards come into effect:

- 8C.01.04, which covers location and clearance requirements;
- 8C.02.02, which requires a "Number of Tracks" plaque for crossings where the number of tracks exceeds one;
- 8C.02.04, which governs various elements of the flashing signal display;
- 8C.02.09, which governs the energy requirements of active traffic control device systems;
- 8C.02.11, which covers the devices that qualify as lenses;

- 8C.02.15, which covers cantilevered supports and overhead structures;
- 8C.04.01 & 8C.04.07, which cover automatic gate operation;
- 8C.06.02, which governs the use of four-quadrant gates;
- 8C.08.01, which covers active traffic control device actuation;
- 8C.09.01, which covers requirement for traffic control signal design, installation and operation at highway-rail grade crossings;
- 8C.09.08, which covers traffic signal preemption; and
- 8C.09.12, which covers the track clearance portion of a signal preemption sequence; and
- 8C.09.15, which covers signage that may need to be installed at highway-grade rail crossings that are interconnected with a signalized intersection.

3.3 Other Standards

There are two standards that do not fall under the previously defined categories. They are

- 8A.08.02, which covers the use of temporary traffic zones in the vicinity of highway-rail grade crossings; and
- 8C.12.02, which covers circular intersections in the vicinity of highway-rail grade crossings.

These last two standards are in place to prevent vehicle queues in the highway-rail grade crossing. In the former case, detours are recommended to avoid any potential vehicle stoppage on railroad tracks, and in the latter case, a redesign of the intersection could be necessary.

CHAPTER 4

CASE STUDY: KNOWLEDGE CORRIDOR

There are 35 highway-rail grade crossings between Northfield, MA and Springfield, MA on the PanAm owned railroad tracks. There are 23 public and 12 private. Table 3 provides further details about crossing type and ownership along the Knowledge Corridor.

Table 3 – Highway-Rail Grade Crossing Types and Ownership along Knowledge Corridor

	Active	Passive	Total
Public	21	2	23
Private- Industrial	1	1	2
Private – Public Access	0	1	1
Private – Residential	0	1	1
Private – Farm	0	8	8
Total	22	13	35

Summary information about each crossing along the Knowledge Corridor, including the DOT crossing number, the name of the street crossing the railroad, the local jurisdiction, type of signaling present, and the ownership are presented in Table 4.

Table 4: Listing of At-Grade Crossings along the Knowledge Corridor

#	DOT Number	Crossing	Town	Type	Ownership
1	052733M	River Rd	Northfield	Active	Public
2	052730S	Mt. Hermon Rd	Northfield	Active	Public

#	DOT Number	Crossing	Town	Type	Ownership
3	052728R	Gill Rd	Bernardston	Active	Public
4	052727J	Shaw Rd	Bernardston	Active	Public
5	052736C	Merrifield Rd	Bernardston	Active	Public
6	052723G	Cross Rd	Bernardston	Active	Public
7	052719S	Greenfield Country Club	Greenfield	Passive	Private
8	052708E	Keets Rd	Deerfield	Active	Public
9	052706R	Pleasant Ave	Deerfield	Passive	Public
10	052705J	Farm	Deerfield	Passive	Private
11	052704C	Farm	Deerfield	Passive	Private
12	052703V	North Hillside Rd	Deerfield	Active	Public
13	052702N	Farm	Deerfield	Passive	Private
14	052700A	Industrial	Deerfield	Passive	Private
15	052699H	Pleasant St	Deerfield	Active	Public
16	052697B	Elm St	Deerfield	Active	Public
17	052695F	Christian St	Whately	Active	Public
18	052694Y	Egypt Rd	Whately	Passive	Public
19	052693S	Depot Rd	Whately	Active	Public
20	052692K	Farm	Hatfield	Passive	Private
21	052691D	Farm	Hatfield	Passive	Private
22	052690W	N. Hatfield Rd	Hatfield	Active	Public
23	052689C	Farm	Hatfield	Passive	Private
24	052688V	Plain Rd	Hatfield	Active	Public
25	052687N	Chestnut Rd	Hatfield	Active	Public

#	DOT Number	Crossing	Town	Type	Ownership
26	052681X	Damon Rd	Northampton	Active	Public
27	052674M	Industrial	Northampton	Passive	Private
28	052672Y	Industrial	Holyoke	Active	Private
29	052671S	Farm	Holyoke	Passive	Private
30	052670K	Farm	Holyoke	Passive	Private
31	052688J	Old Ferry Rd	Holyoke	Active	Public
32	052638S	Gatehouse Rd	Holyoke	Active	Public
33	052633H	S. Canal St	Holyoke	Active	Public
34	052615K	Plainfield Rd	Chicopee	Active	Public
35	052613W	Wason Rd	Springfield	Active	Public

The crossings in Table 4 will be evaluated using one of three sets of metrics, based on ownership and the type of signaling present at the intersection. The metrics will be associated with the following three categories: public crossings with active signaling, public crossings with passive signaling, and private crossings.

The reader will recall that the private crossings are not obligated by law to follow *MUTCD* standards. If TCDs are installed at a private crossing, they will be evaluated against the appropriate *MUTCD* standards as discussed for public crossings, recognizing that the owner is not obligated to make any changes. Private crossings will be evaluated based upon their location, type, and a qualitative discussion on the daily traffic volumes through the intersection.

There are some standards that apply to all public crossings and others that only conditionally apply, as discussed in Section 3 of this report. Public crossings with passive signaling will be evaluated using the following *MUTCD* standards: 8B.02.01, 8B.03.01, 8B.03.03, 8B.03.05, 8B.04.15, 8B.06.01, and 8B.27.01. Public crossings with active signaling are not subject to standard 8B.04.15, but they will be evaluated against these additional standards 8C.02.02, 8C.02.04, and 8C.02.07, which all concern the use of flashing lights and gates.

4.1. Findings

4.1.1 Private Crossings

Because land owners of private crossings are exempt from *MUTCD* standards, there is no signage at ten of the twelve private crossings. Of the two remaining crossings, one has passive signaling and the other has active signaling.

Crossing 052719S is a private crossing on the property of Greenfield Country Club; the crossing is in the middle of a golf course. There are two advanced warning signs posted on either side of the railroad tracks on the right side of each approach.

Crossing 052672Y is a private crossing on the property of Mount Tom Generation Station; the crossing is on the driveway and has Crossbucks, lights and gates as well as an advanced warning sign as the driver approaches from the facility side of the approach. The installations fully comply with *MUTCD* standards.

4.1.2 Public Crossings

Few public crossings along the Knowledge Corridor meet all applicable *MUTCD* standards. All crossings had Crossbucks installed in accordance with standards 8B.02.01, 8B.03.01 and 8B.03.03. Many of the crossings were missing advanced warning signs, standard 8B.06.01 and/or pavement markings, standard 8B.27.01, on one or more approaches. Standards compliance/non-compliance at each public crossing is summarized as follows:

- Crossings 052706R, 052697B, 052681X, 052633H, 052615K and 052613W are fully compliant with *MUTCD* standards.
- Crossings 052733M, 052728R, 052727J, 0527362C, 052723G, 057708E, 052699H are missing advanced warning signs on both approaches, and pavement marking on both approaches.
- Crossings 052703V is missing advanced warning signs on one approach, and pavement marking on both approaches.
- Crossing 052694Y is missing an advanced warning sign on one approach.
- Crossing 052688J is missing a W10-3 sign on US-5, since the intersection is within a 100 feet of US-5, as well as pavement markings on the approach to US-5.
- Crossings 052730S, 052695F, 052693S, 052690W, 052688V, 052687N, and 052638S are missing pavement markings on both approaches.

4.2 Recommendations

4.2.1 Private Crossing Recommendations

In the immediate future, Crossbucks and stop or yield signs should be installed at the eleven private crossings that presently have no signage. The twelfth crossing, 052672Y, has adequate signage and TCDs; therefore, the recommendation is to keep this crossing as existing.

4.2.2 Public Crossing Recommendations

All public crossings should be brought into compliance with *MUTCD* standards by fixing the violations that were outlined in Section 4.1.2. Additionally, the following intersections have been identified for additional improvements:

- Crossing 052733M, River Road, should be further evaluated for closure. The road serves a single farm which has alternate access via Caldwell Road and Northfield Road.

- Crossing 052699H, Pleasant St, should be further evaluated for quad gates, because an elementary school neighbors the crossing. Quad gates would provide a higher level of safety for nearby school children.

- Crossing 052697B, Elm St, should be further evaluated for quad gates and traffic channelization devices and/or grade separation. This crossing is in South Deerfield’s commercial district, and a collision at this crossing would snarl traffic in the area. As train frequencies increase, queues are likely to build on both approaches to this crossing, so long-term plans for this intersection should evaluate whether grade separating the modes is viable.

- Crossing 052681X, Damon Road should be evaluated for quad gates with traffic channelization devices and/or grade separation. This crossing is in Northampton’s commercial district and a collision at this crossing would snarl traffic in the area. As train frequencies increase, queues are likely to build on both approaches to this crossing, so long-term plans for this intersection should evaluate whether grade separating the modes is viable.

- Crossing 052638S, Gatehouse Road, should be evaluated for closure. This crossing is on a public road that serves a handful of businesses that can be accessed from either side of the crossing.

4.3 Conclusions

Thirty-five crossings have been evaluated along the Knowledge Corridor in Massachusetts between Springfield and Northfield. These crossings are presently used infrequently by freight trains, but by the end of 2014, Amtrak will be operating two trains daily at speeds up to 79 mph along the track.

Providing safe transportation to vehicular operators and train passengers is a primary concern of the USDOT and state DOTs and these highway-rail grade crossings present a safety hazard. Standards exist to promote a minimum-level of safety at grade crossings, and these standards have been generally applied along the Knowledge Corridor. However, additional steps should be taken to bring all crossings into full compliance with the *MUTCD*. Some crossings warrant additional TCDs beyond *MUTCD* standards and this can be determined as a result of an engineering study.

Ultimately, all highway-rail grade crossings should be eliminated, but this will only occur if the Commonwealth routinely reviews the traffic and rail usage patterns to determine when and where rail crossings can be closed or the modes can be grade separated. Four crossings in this report have been identified for closure or grade-separation, which amounts to over ten percent of the crossings.

The Commonwealth has time to improve the safety of highway-rail grade crossings in the corridor but plans should be formulated now to ensure that all alternatives are evaluated sufficiently and improvements are implemented before the first Amtrak train rolls over the renewed track in 2014.

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