An accident prediction model for highway-rail interfaces
by Ross Duane Austin

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering
Montana State University

Abstract:
Safety levels at railroad/roadway interfaces continue to be of major concern despite an ever-increasing focus on improved design and appurtenance application practices. Despite the encouraging trend toward improved safety, many fatalities continue to occur. Accidents are even happening at public crossings where active warning devices (i.e., gates, lights, bells, etc.) are in place and functioning properly. This phenomenon speaks directly to the need to re-examine both safety evaluation (i.e., accident prediction) methods and design practices at highway-rail crossings.

With respect to safety evaluation methods, the U.S. Department of Transportation's (USDOT) Accident Prediction Formula, is most widely used although three other predominant accident prediction models exist: the Peabody Dimmick Formula, the New Hampshire Index and the National Cooperative Highway Research Program (NCHRP) Hazard Index. Each of these models has strengths, but their shortcomings are apparent.

The Peabody Dimmick Formula, the New Hampshire Index (in its original form) and the NCHRP model are all simple to apply but lack descriptive capabilities due to limited factor considerations. Surprisingly, many similarities exist between the USDOT Accident Prediction Model and the Negative Binomial model developed as part of this investigation with respect to the factors influencing highway-rail crossing accident frequency.

These similarities between the USDOT Accident Prediction Model and the negative binomial model developed here suggest that in fact a successful alternate model has resulted capable of predicting accident frequencies at highway-rail crossings. The benefit to be gained through the development of this alternate model is: (1) a greatly simplified, one-step estimation process, (2) comparable supporting data requirements, and (3) interpretation of both the magnitude and direction of the effect of the factors found to significantly influence highway-rail crossing accident frequencies. However, prior to widespread application of the negative binomial accident prediction model, the model form and estimated coefficients require validation to ensure accuracy in prediction.

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APPROVAL

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Ross Duane Austin

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Safety levels at railroad/roadway interfaces continue to be of major concern despite an ever-increasing focus on improved design and appurtenance application practices. Despite the encouraging trend toward improved safety, many fatalities continue to occur. Accidents are even happening at public crossings where active warning devices (i.e., gates, lights, bells, etc.) are in place and functioning properly. This phenomenon speaks directly to the need to re-examine both safety evaluation (i.e., accident prediction) methods and design practices at highway-rail crossings.

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These similarities between the USDOT Accident Prediction Model and the negative binomial model developed here suggest that in fact a successful alternate model has resulted capable of predicting accident frequencies at highway-rail crossings. The benefit to be gained through the development of this alternate model is: (1) a greatly simplified, one-step estimation process, (2) comparable supporting data requirements, and (3) interpretation of both the magnitude and direction of the effect of the factors found to significantly influence highway-rail crossing accident frequencies. However, prior to widespread application of the negative binomial accident prediction model, the model form and estimated coefficients require validation to ensure accuracy in prediction.

CHAPTER 1

INTRODUCTION

Safety levels at railroad/roadway interfaces continue to be of major concern despite an ever-increasing focus on improved design and appurtenance application practices. This Chapter details the magnitude of the problem, provides background information to further clarify the topic and describes this report's content and organization to assist the reader in navigating the document.

Problem Description

"From 1978 to 1993, wide-ranging, multidisciplinary safety improvement efforts sponsored and performed by the Federal Railroad Administration (FRA), in partnership with the various other agencies and industry groups, resulted in a 64 percent reduction in the number of grade crossing accidents" (1). Since 1993, this trend toward improved safety and reduced highway-rail crossing accidents has increased to a 69 percent reduction (2).

Despite the encouraging trend toward improved safety, the interface between railroads and roadways still resulted in 431 fatalities in 1998 alone (2). From an economic standpoint, the impact of these fatalities is significant. Using the cost-per-fatality (highway) estimate of $2.6 million established by the Federal Highway Administration (FHWA), the 431 fatalities associated with highway-rail crossings in

1998 amounted to over $1 billion in economic losses (3). The FHWA's cost-per-fatality estimate includes lost productivity and costs associated with property damage, medical care, insurance, funeral requirements, legal activities and other (3).

Perhaps the most disturbing characteristic of highway-rail crossing accidents is that over 50 percent occurred at public crossings where active warning devices (i.e., gates, lights, bells, etc.) were in place and functioning properly (4). This phenomenon speaks directly to the need to re-examine both safety evaluation (i.e., accident prediction) methods and design practices at highway-rail crossings.

With respect to safety evaluation methods, the U.S. Department of Transportation's (USDOT) Accident Prediction Formula, developed in the early 1980's, is most widely used although other accident prediction models exist. (The USDOT Accident Prediction Formula and other models are discussed in greater detail in Chapter 2 of this report.) While this complex, three-part formula comprehensively addresses characteristics that may influence a crossing's level of safety (i.e., train and traffic volumes, site and surface characteristics, road/rail-side appurtenances, etc.), the formula does not readily provide the magnitude to which each of the characteristics contribute to a crossing's level of safety. This shortcoming makes it difficult to identify or prioritize design or improvement activities that will most effectively address safety-related problems.

Background

A highway-rail crossing consists of both highway and railway components. Highway components include drivers, vehicles, the roadway, and pedestrians. Railway components include train and track elements (5). In addition to the components of the physical system, one must also consider historical legislation that has impacted or is currently impacting highway-rail crossings.

Highway Components

An important element in the highway system is the driver. Driver actions on the highway can occur in one of three zones:

(1) the approach zone,

(2) the non-recovery zone and/or

(3) the hazard zone.

In the approach zone, the driver recognizes a crossing ahead and considers the current conditions. In the non-recovery zone, the driver initiates a stopping maneuver while looking for more information concerning the location of the train. Once the driver is in the hazard zone, they must decide whether or not to proceed through the crossing (5).

A vehicle driver's responsibilities at a highway-rail crossing are defined by the Uniform Vehicle Code (UVC). This Code describes the various actions a driver must take at a crossing.

- "**Approach Speed (Sec. 11-801).** No person shall drive a vehicle at a speed greater than is reasonable and prudent under the conditions and having regard to the actual and potential hazards then existing. Consistent with the foregoing, every person shall drive at a safe and appropriate speed when approaching and crossing an intersection or railroad grade crossing…"
- "**Passing (Sec. 11-306).** No vehicle shall be driven on the left side of the roadway under the following conditions:
  - when approaching within 100 feet of or traversing any…rail highway crossing unless otherwise indicated by official traffic control devices…"
- "**Stopping (Sec. 11-701).** Obedience to signal indicating approach of train. Whenever any person driving a vehicle approaches a rail highway crossing under any of the circumstances stated in this section, the driver of such vehicle shall stop within 50 feet, but not less than 15 feet from the nearest rail of such railroad, and shall not proceed until he can do so safely. The foregoing requirements shall apply when:
  - a clearly visible electric or mechanical signal device gives warning of the train;
  - a crossing gate is lowered or when a human flagman gives or continues to give a signal of the approach or passage of a railroad train;
  - a railroad train approaching within approximately 1,500 feet of the highway crossing emits a signal audible from such distance and such railroad train, by reason of its speed or nearness to such crossing, is an immediate hazard and

– an approaching railroad train is plainly visible and is in hazardous proximity to such crossing" (5).

At highway-rail crossings, different types of vehicles and their related performance characteristics challenge these UVC guidelines. Various vehicle dimensions, braking performance, acceleration performance, and cargoes (i.e., bus passengers, hazardous materials, etc.) must be considered in the design or safety improvement process.

For the roadway approach to highway-rail crossings, many different considerations also exist. These include the following:

- location,
- traffic volumes,
- geometric features,
- number of lanes,
- alignment and sight distances,
- crossing surfaces,
- intersecting highways and
- illumination (5).

Pedestrians are the final consideration with respect to the highway component of highway-rail crossing safety and design. Their movements can be controlled through the use of fences, grade separations, education, enforcement, and additional signing (5).

Railroad Components

Railroad components include trains and tracks. Vast differences in train length, weight, number of engines, number of cars, and travel speeds challenges the accurate provision of safe day-to-day operations.

Tracks are not as variable. Six different classes describe railroad tracks. Class type is determined by maximum train speed allowed (see Table 1). Tracks are further described as main, branch, siding, and industry depending on train activity. Main tracks are used for through movements, while branch tracks typically provide the movement of freight to main lines. Siding and industry tracks are used to store, load, and unload rail cars (5).

This investigation focuses only on the safety effects of the physical road and rail infrastructure and site conditions. Vehicle and driver characteristics are more difficult to correct for and hence are not considered in any detail here.

Table 1. Railroad Track Classification

	Train Speed (MPH)	
Track Class	Passenger	Freight
6	110	110
5	90	80
4	80	60
3	60	40
2	30	25
1	15	10

Legislation

While physical infrastructure, site conditions, vehicle and driver characteristics have a direct effect on the level of safety experienced at highway-rail crossings, legislative activity, which can increase both focus and funding related to highway-rail crossings, is an important consideration for this investigation.

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Assistance Acts of 1978 and 1982 authorized federal funding to states for the purpose of improving safety at public rail-highway crossings. These Acts also provided money for the installation of active signal devices at the crossings. This spurred the U.S. Department of Transportation (DOT) to develop the DOT Rail-Highway Crossing Resource Allocation Procedure (DOT Procedure) (6). The DOT Procedure, using an accident prediction model and a resource allocation model, determines the "crossing safety improvements that result in the greatest accident reduction benefits based on consideration of predicted accidents at crossings, the costs and effectiveness of safety improvement options, and budget limits" (7).

The DOT Procedure simultaneously aids states in their compliance with the Federal Highway Program Manual (FHPM), which specifies that each state have a priority schedule that is based on:

- the potential reduction in the number and/or severity of accidents;
- the cost of the projects and the resources available;
- the relative hazard of public railroad-highway grade crossings based on a hazard index formula;

- on-site inspections of public crossings;
- the potential danger to large numbers of people at public crossings used on a regular basis by passenger trains, school buses, transit buses, pedestrians, bicyclists, or by trains and/or motor vehicles carrying hazardous materials and
- other criteria as appropriate in each State (5).

This investigation most directly addresses the first and third prioritization schedule requirements above: the potential reduction in accident frequency and severity and the development of a hazard index formula.

Report Purpose and Contents

The findings contained in this report respond to the three-part problem described previously and summarized here.

(1) While showing a positive declining trend, highway-rail crossing accidents continue to result in a high number of fatalities annually and therefore require further investigation beyond the state-of-the-practice.

(2) A high proportion of highway-rail crossing accidents occur at locations where active warning appurtenances are in place suggesting that existing strategies for improving safety are ineffective and require re-examination.

(3) Existing safety evaluation methods (i.e., accident prediction models) do not adequately describe design or other characteristics that are most detrimental to

highway-rail crossing safety thus preventing the prioritization or targeting of safety improvements.

This investigation provides for additional focus on highway-rail crossing safety and suggests an improved accident prediction model that allows for greater interpretation of the factors deemed both beneficial and detrimental to highway-rail crossing safety. Using advanced statistical modeling methods, not only can significant contributing factors be identified but the degree to which these factors affect safety at highway-rail crossings can also be determined. Lastly, this investigation will overcome the disjoint between safety-related findings and design or improvement decisions by actively integrating the two sets of information.

Following this introductory material, Chapter 2 examines literature related to: (1) existing accident prediction models, (2) highway-rail crossing design issues, and (3) traditional and advanced safety improvement strategies for highway-rail crossings. Chapter 3 describes the methodology followed as part of this investigation including data collection, reduction and analysis and accident prediction model development. Chapter 4 provides general descriptive statistics related to highway-rail crossing accident characteristics followed by a description of the accident prediction model results and the relationship between the accident prediction model findings and design and improvement decisions. This report concludes with a summary of finding and a series of suggested recommendations in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

A review of literature related to this investigation focused on: (1) previously developed highway-rail crossing accident prediction models, (2) traditional safety improvement measures at highway-rail crossings and (3) emerging or advanced safety improvement measures. Findings from the literature are detailed below.

Accident Prediction Models

A review of the literature revealed four predominant highway-rail crossing accident prediction models in use:

(1) United States Department of Transportation (USDOT) Accident Prediction Formula,

(2) Peabody Dimmick Formula,

(3) New Hampshire Index and

(4) National Cooperative Highway Research Program (NCHRP) Hazard Index.

In addition to these four, several states have developed their own highway-rail crossing accident prediction formula (5).

USDOT Accident Prediction Formula

The USDOT Accident Prediction Formula, developed in the early 1980's, is most widely used. This complex and comprehensive formula comprises three primary equations:

Equation 1: $$a = KxEIxDTxMSxMTxHPxHLxHT$$

Equation 2: $$B = \frac{T_o}{T_o + T}(a) + \frac{T}{T_o + T}\left(\frac{N}{T}\right)$$

Equation 3:

$$A = \{0.7159B\} \quad \text{For Passive Devices}$$
$$A = \{0.5292B\} \quad \text{For Flashing Lights}$$
$$A = \{0.4921B\} \quad \text{For Gates}$$

Equation 1 utilizes data elements contained in the Rail-Highway Crossing Inventory (described in greater detail in Chapter 3). Equation 2 introduces accident history as a factor, and combines this with the accident prediction value, *a*, obtained in Equation 1. Equation 3 introduces a normalizing constant that is multiplied by the value produced in Equation 2 (6). These normalizing constants are updated every two years to reflect changes in observed accident rates (8). Equations 1, 2 and 3 are discussed below.

Equation 1. The factors in Equation 1 each represents characteristics of crossings in the Rail-Highway Crossing Inventory (see Tables 2, 3 and 4). These factors were found to be statistically significant, using nonlinear multiple regression, in the prediction of accidents at highway-rail crossings. Notice some important characteristics, such as sight distance, are not included in Equation 1; factors such as sight distance are unavailable in the Rail-Highway Crossing Inventory. Using Table 2, the value calculated represents the factor's influence in the prediction of accidents at highway-rail crossings where:

c = number of highway vehicles per day

t = number of trains per day

mt = number of main tracks

d = number of through trains per day during daylight

hp = highway paved (yes = 1 and no = 2.0)

ms = maximum timetable speed in mph

h1 = number of highway lanes

ht = highway type factor (see Tables 3 and 4 below) (6).

Table 2. Variables for Equation 1 (USDOT Accident Prediction Model)

		Coefficient or Relationship		
Variable	Description	Passive Control	Flashing Lights	Gates
K	Formula Constant	0.002268	0.003646	0.001088
EI	Exposure Index Factor	$((ct+0.2)/0.2)^{0.3334}$	$((ct+0.2)/0.2)^{0.2953}$	$((ct+0.2)/0.2)^{0.3116}$
DT	Day Through Trains Factor	$((d + 0.2)/0.2)^{0.1336}$	$((d + 0.2)/0.2)^{0.0470}$	1.0
MS	Maximum Speed Factor	$e^{0.0077ms}$	1.0	1.0
MT	Main Tracks Factor	$e^{0.2094mt}$	$e^{0.1088mt}$	$e^{0.2912mt}$
HP	Highway Paved Factor	$e^{-0.6160(hp-1)}$	1.0	1.0
HL	Highway Lanes Factor	1.0	$e^{0.1380(hl-1)}$	$e^{0.1036(hl-1)}$
HT	Highway Type Factor	$e^{-0.1000(ht-1)}$	1.0	1.0

Table 3. Rural Highway Type Values (USDOT Accident Prediction Model)

Highway Type: Rural	Highway Type Factor (ht)
Interstate	1
Other principal arterial	2
Minor arterial	3
Major collector	4
Minor collector	5
Local	6

Table 4. Urban Highway Type Values (USDOT Accident Prediction Model)

Highway Type: Urban	Highway Type Factor (ht)
Interstate	1
Other freeway/expressway	2
Other principal arterial	3
Minor arterial	4
Collector	5
Local	6

Equation 2. Equation 2 adjusts the accident prediction value, a, from Equation 1 to reflect the actual accident history at the crossing (6). The variable, N, is the number of observed accidents in T years at the crossing, and T_0 is the formula weighting factor defined as:

$$T_0 = \frac{1.0}{(0.05 + a)}$$

Equation 3. In Equation 3 above, the normalizing coefficients reflect conditions in 1998 (7). These constants were developed to reflect more the recent accident experiences of highway-rail crossings with similar types of warning devices in place.

The derivation of the normalizing coefficients used in Equation 3 requires some additional dialogue. In essence, the USDOT Accident Prediction Formula is calibrated every two years by comparing a sample of the most recent year's predicted accident frequencies to the actual observed accident frequencies occurring over several previous years. "The process of determining the three new "normalizing constants" for 1998 is performed such that the 1997 accident prediction sum of the top 20 percent of the crossings is made to equal the sum of the observed number of accidents that occurred for those same 20 percent of crossings using the accident data for Calendar Years 1992 to 1996 (to predict 1997)" (2).

Table 5 and Figure 1 report both the most recent normalizing coefficients and normalizing coefficients from previous years. Note in both Table 5 and Figure 1 the steady reduction in normalizing coefficients over time, or in other words, the steady decline in accident prediction model accuracy as compared to observed values. For example, consider gated highway-rail crossings. The value predicted by the USDOT Accident Prediction Formula Equations 1 and 2 is reduced by more than half with the normalizing coefficient of 0.4921 to reflect actual observed safety levels.

Table 5. Normalizing Coefficients for Equation 3 (USDOT Accident Prediction Model)

WARNING DEVICE GROUPS	NEW	PRIOR YEARS			
	1998	1992	1990	1988	1986
(1) Passive	0.7159	0.8239	0.9417	0.8778	0.8644
(2) Flashing Lights	0.5292	0.6935	0.8345	0.8013	0.8887
(3) Gates	0.4921	0.6714	0.8901	0.8911	0.8131

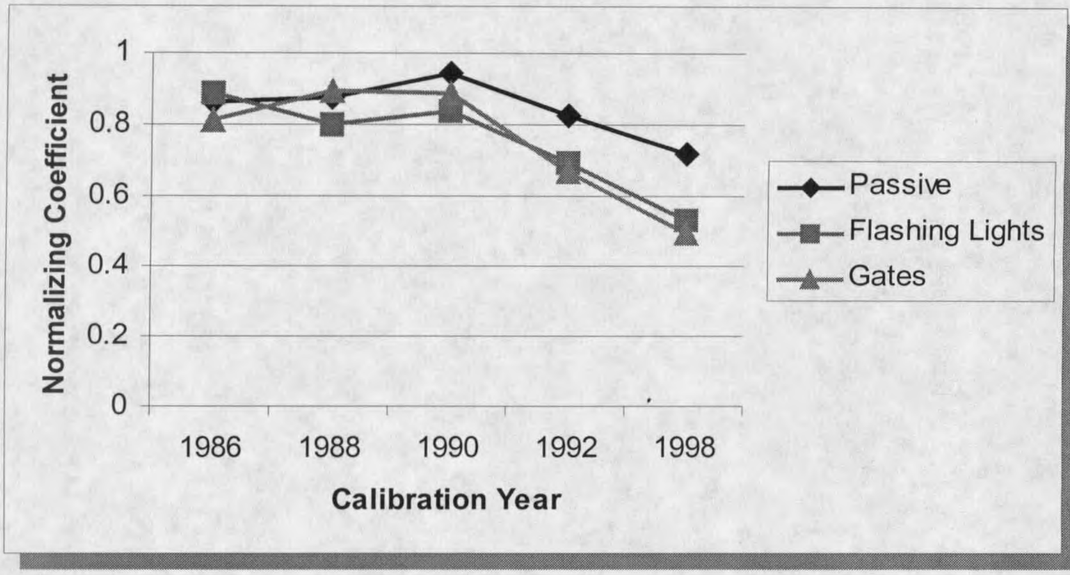

Figure 1. Trend in Normalizing Coefficients for Equation 3 (USDOT Accident Prediction Formula)

Peabody Dimmick Formula

The Peabody Dimmick Formula, also referred to as the Bureau of Public Roads Formula, was developed in 1941 and is used to predict the number of accidents over a five-year time period. This formula was the primary formula utilized from 1941 through the 1950's for resource allocation relating to highway-rail crossings. The specific relationship is as follows:

$$A_5 = 1.28\frac{\left(V^{0.170}T^{0.151}\right)}{P^{0.171}} + K$$

where:

A_5 = expected number of accidents in 5 years

V = average annual daily traffic (AADT)

T = average daily train traffic

P = protection coefficient (see Table 6)

K = additional parameter (see Figure 2).

In Figure 2 the unbalanced accident factor, I_u, is equal to the first half of the previously listed equation such that:

$$I_u = 1.28 \frac{\left(V^{0.170} T^{0.151}\right)}{P^{0.171}}$$

Table 6. Protection Coefficient Values (Peabody Dimmick Formula) (5)

Warning Device	Protection Coefficient P	Warning Device	Protection Coefficient P
Signs	1.65	Wigwag/Flashing Lights/Bells	2.35
Bells	1.78	Watchman, 8 Hours	2.27
Wigwag	1.99	Watchman, 16 Hours	2.43
Wigwag/Bells	2.03	Watchman, 24 Hours	2.52
Flashing Lights	2.18	Gates, 24 Hours	2.56
Flashing Lights/Bells	2.25	Gates, Automatic	2.70
Wigwag/Flashing Lights	2.27		

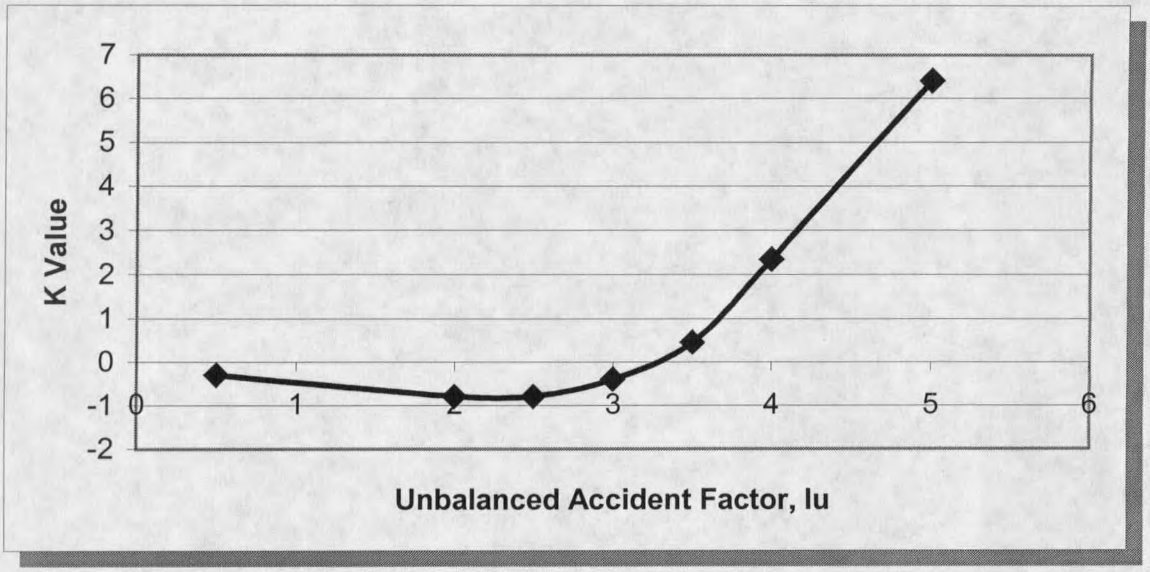

Figure 2. K Values (Peabody Dimmick Formula) (5)

When it was developed, the Peabody Dimmick Formula was based on accident data from rural crossings in 29 states. Non-representative sampling (only rural crossings) hinders the equation's validity. The age of the formula also presents a problem with respect to its ability to predict accidents at crossings where more recent technology is being used.

New Hampshire Index

The New Hampshire Index has a number of variations. The basic formula is:

$$HI = (V)(T)(P_f)$$

where:

HI = hazard index

V = average annual daily traffic (AADT)

T = average daily train traffic

P_f = protection factor.

Several states have developed their own variations of the New Hampshire Index. All utilize the basic equation with modifications to allow incorporation of other accident causative factors. Other factors included in various state formula versions are:

- train speed,
- highway speed,
- sight distance,
- crossing angle,
- crossing width,
- type of tracks,
- surface type,
- number of buses,
- number of passengers,
- and the number of accidents,
- number of tracks,
- nearby intersection,
- functional class of highway,
- vertical alignment,
- horizontal alignment,
- population,
- number of hazardous material trucks and
- number of school buses

Some states also vary the protection factor values:

automatic gates	0.13 or 0.10
flashing lights	0.33, 0.20 or 0.60
wigwags	0.67
traffic signal preemption	0.50
crossbucks	1.00.

Variations of the New Hampshire Index follow:

Variation 1:
$$HI = (V)(2T_f)(T_s)\frac{(SD + AN + NTR)}{4}$$

Variation 2:
$$HI = \frac{(V)(T)(A_5)}{P_f}$$

Variation 3:
$$HI = (V)(T)\frac{(TT + TTR + SD + AN + AL + L + G + VSD + W + LI)}{100}$$

Variation 4:
$$HI = \frac{(P_f)(V_f)(T)(TS)(NTR)}{160} + (70A_a)^2 + 1.2(SD) \qquad A_a = \left(V + \frac{SBP}{1.2}\right)(HM)$$

Variation 5:
$$HI = 0.1(P_f)(A_f)(T_l) + (AN)(NTR)(S)(0.5L) + TS\left((FC)(P) + \left(\frac{(V)(T)}{10{,}000}\right) + SB\right)$$

Variation 6:
$$HI = \frac{(V_f)(P_f)(T)}{(TR + TN + T_f + HS + G + SD + AN)}$$

Variation 7:
$$HI = 0.1(V)(T) + 0.1(HS)(TS) + (SD)(AN)(TR)(NTR)(AL) + (A_a{}^2 + 1)(RF)(LP)(P_f) + (SB)(SBP) + 10(HM)$$

Variation 8:
$$HI = \frac{(T)\sqrt{(V)}}{P_f}$$

where:

A_5 = number of accidents in five years

A_a = number of accidents per year

A_f = accident factor

AL = highway alignment factor

AN = approach angle factor

FC = functional class factor

G = approach grades factor

HI = hazard index

HM = hazardous material vehicles factor

HS = highway speed factor

L = number of lanes factor

LI = local interference factor

LP = local priority factor

NTR = number of tracks factor

P = population factor

P_f = protection factor

RF = rideability factor

S = surface type factor

SB = number of school buses

SBP=number of school bus passengers

SD = sight distance factor

T = average number of trains per day

T_f = number of fast trains

TN = number of night trains factor

TR = number and type of tracks factor

TS = train speeds factor

T_s = number of slow trains

TT = type of train movements factor

TTR = type of tracks factor

V = annual average daily traffic

V_f = annual average daily traffic factor

VSD = vertical sight distance factor

W = crossing width factor

The dissimilarity between the New Hampshire Index model variations raises concerns over its validity. While most of the discrepancies can be attributed to state preferences, concern is raised due to the lack of consistency. Depending on the variation chosen, prediction values vary considerably.

NCHRP Hazard Index

The National Cooperative Highway Research Program (NCHRP) Hazard Index, documented in NCHRP Report 50, was published in 1964 in a joint effort between the American Association of State Highway Officials (AASHO now AASHTO) and the Association of American Railroads (AAR) in response to the disproportionately high number of accidents occurring at highway-rail crossings. The NCHRP Hazard Index used accident data that spanned five years and was collected by the Interstate Commerce Commission, state agencies and others (9). The NCHRP Hazard Index closely resembles the basic formula of the New Hampshire Index described above:

$$EA = (A)(B)(CTD)$$

where:

EA = expected accident frequency (acc/yr)

A = vehicles per day factor (see Table 7)

B = existing devices factor (see Table 8)

CTD = current trains per day.

Table 7. Vehicles Per Day Factor (NCHRP Hazard Index) (5)

Vehicles per Day	A	Vehicles per Day	A
250	0.000347	9000	0.011435
500	0.000694	10000	0.012674
1000	0.001377	12000	0.015012
2000	0.002627	14000	0.017315
3000	0.003981	16000	0.019549
4000	0.005208	18000	0.021736
5000	0.006516	20000	0.023877
6000	0.007720	25000	0.029051
7000	0.009005	30000	0.034757
8000	0.010278		

Table 8. Existing Devices Factor (NCHRP Hazard Index) (5)

Existing Devices		B
A	Crossbucks, highway volume less than 500 per day	3.89
B	Crossbucks, urban	3.06
C	Crossbucks, rural	3.08
D	Stop signs, highways volume less than 500 per day	4.51
E	Stop signs	1.15
F	Wigwags	0.61
G	Flashing lights, urban	0.23
H	Flashing lights, rural	0.93
I	Gates, urban	0.08
J	Gates, rural	0.19

The NCHRP Hazard Index is concise and easy to use. Unfortunately, this is both its virtue and its vice. There are only three variables to calculate which makes it easy to use, but this limits it's descriptive capabilities. In addition, the determination of an urban versus rural crossing is left to interpretation. This is a key point when looking at the different factor values for flashing lights. A difference of 0.7 exists between the factors for urban and rural settings.

Traditional Safety Improvement Measures

When reviewing literature related to traditional highway-rail crossing safety improvements, one document predominates. The Railroad-Highway Grade Crossing Handbook was developed for the Federal Highway Administration to provide "general information on railroad-highway crossings, including characteristics of the crossing environment and users, and the physical and operational improvements for safe and efficient use by both highway and rail traffic" (5). As such, it has become an influential reference in the discussion of rail-highway crossings.

The Handbook describes five broad categories of design activities that improve the safety of highway-rail crossings:

(1) elimination (physical separation),

(2) passive traffic control devices,

(3) active traffic control devices,

(4) site and operational improvements and

(5) surface improvements (5).

Physical Separation

The physical separation of highway from rail provides the highest level of safety since it eliminates all traffic and train interactions. In addition to safety benefits, reduced delay and alleviated crossing maintenance costs are other advantages to at-grade highway-rail crossing elimination. To attain this physical separation, grade separation, highway and railroad relocation, closure, and abandonment are four options (5).

Grade separation – elevating either the highway or rail at the point of crossing - is attractive in areas of high vehicular traffic because it eliminates train-related stopped delay and reduces vehicular travel times. Grade separation also maintains the existing horizontal alignment and crossing location thereby eliminating driver frustration over changes in access. With grade separation, trains are also able to travel at much higher