ABSTRACT
The state of Nebraska has undertaken the task of assessing safety risk at highway-railroad grade crossings. HNTB Corporation developed a process that assesses risk and evaluates improvement alternatives at mainline railroad crossings. This paper examines the factors and methods used in the assessment process and reports on preliminary assessment findings on Nebraska's mainline railroad corridors.

Key Words: safety, railroad, highway, grade crossing

1.0 INTRODUCTION
Nebraska boasts more than 5,500 miles of railroad track and nearly 7,000 public and private grade crossings. An estimated 700 public crossings have over 40 train movements per day, with many crossings on mainline tracks seeing in excess of 100 trains per day. In 1997, 69 train-vehicle collisions occurred in the state, resulting in 11 injuries and 9 fatalities. Consequently, public safety at grade crossings is a statewide concern.

In 1997, the Nebraska Legislature passed Legislative Bill (LB) 255 that directed the Nebraska Department of Roads (NDOR) to "establish a process for assessing the risk to the public from particular grade crossings and for reducing or eliminating such risk in a cost-effective and timely manner." Responding to this directive, NDOR contracted with a team of engineering, design, public involvement, and economic analysis professionals lead by HNTB Corporation of Kansas City, Missouri. The purpose of this study was to develop a process to assess risk and to approximate the magnitude of measures required statewide to reduce risk at grade crossings.

2.0 PUBLIC INVOLVEMENT
The legislative mandate for this study specifically called for a broad-based public involvement program to provide input to the highway-railroad grade crossing safety assessment. The study team organized and conducted public information meetings, distributed comment forms, and completed a survey of local government officials. E-mail and postal addresses as well as a toll-free telephone hot line were also established to facilitate communication.

The most frequently identified concerns on the public comment forms were: 1) safety at crossings, 2) length of time crossings are blocked by trains, and 3) impeded emergency access. The most frequently cited concerns on the local government survey were: 1) crossing surface conditions, and 2) length of time crossings are blocked by trains.
The result of this input was the identification of study objectives, which were used as criteria for the assessment process. The objectives identified were:

**Safety:**
1. Reduce the number of collisions
2. Provide access for emergency response vehicles
3. Decrease time that roadways are blocked

**Economic:**
4. Consider local and regional productivity
5. Consider improvement costs

### 3.0 ASSESSMENT PROCESS

The recommended assessment process developed by the study team includes the six steps outlined below:

**I. Corridor Identification** - The process begins with the identification of corridors. It is recognized that changes made at one crossing will affect operational characteristics of adjacent crossings. For this reason, corridors, or groups of adjacent crossings, are identified for study. Identification is based on county and municipal jurisdictions because current Nebraska law provides local government with the authority to maintain or close public crossings. It also facilitates local government input to the process and facilitates future diagnostic review of crossings.

**II. Corridor Classification** - The purpose of this step is to group corridors with similar characteristics. The inputs to this step are community setting (rural or urban) and density of rail traffic (high, medium, or low). Classifying corridors assures that all corridors will be evaluated relative to similar corridors.

**III. Corridor Prioritization** - Corridors are prioritized based on study objectives related to existing safety conditions of collisions, emergency response, and blockage. The value for collisions is calculated from a modified U.S. Department of Transportation (US DOT) Accident Prediction Model. The model was modified to better describe occurrences unique to Nebraska. The output of the model is predicted accidents per year. Blockage is the probable amount of vehicle delay due to moving trains occupying the crossing. Emergency response is only a factor when a grade crossing is located within one or two blocks of an emergency facility. Emergency response is then calculated as the time the crossing is blocked by a moving train. These three factors are indexed and weighted to arrive at a prioritization index value. This prioritization is not an absolute ranking of corridors, but an indicator of need for further detailed diagnostic evaluation.

**IV. Corridor Improvement Identification** - Alternative corridor improvements including crossing closure, warning device upgrades, and grade-separation structures were identified. Multiple alternatives were identified for each corridor based on vehicular traffic, train count, and physical constraints of the local roadway network.

**V. Evaluation of Corridor Improvement Alternatives** - The alternatives for each corridor are compared in this step. Factors measuring the five study objectives are indexed and weighted in a matrix evaluation to determine a preliminary preferred solution for each corridor. The value for collisions is the predicted number of accidents per year within the corridor. Blockage is the probable amount of delay time at crossings due to passing trains plus the delay time due to out-of-direction travel required when a crossing is closed. Emergency response and economic significance values are ratings on a five-point scale ranging from adverse impacts to status quo to improved situation. Cost of improvement is the estimated dollar amount needed to construct the suggested improvements. The preliminary solution is then carried forward to determine the aggregate magnitude of crossing improvements needed in Nebraska and to aid in programming and project funding.
VI. Statewide Improvement Recommendations

The final step in the assessment process is to develop preliminary recommendations on the number and type of improvements needed at highway-railroad grade crossings and to identify potential funding options for those improvements.

3.1 Assessment Factors

The metrics for the five study objectives are further defined below.

Collisions

This factor is the total projected number of collisions per year at crossings within the corridor as based on modified US DOT Accident Prediction Equations. The accident prediction formula combines two independent calculations to produce an accident prediction value. The basic formula provides an initial prediction of accidents on the basis of a crossing’s characteristics including average daily traffic (ADT), total number of train movements per day, number of mainline tracks, and maximum timetable speed for trains. The second calculation utilizes the actual accident history at a crossing over a specified number of years to produce a final accident prediction value. This procedure assumes that future accidents per year at a crossing will be the same as the average historical accident rate over the time period used in the calculation.

Emergency Response

This factor seeks to characterize the potential significance of a corridor with respect to the spectrum of activities and issues that constitute emergency response. Emergency response is broadly defined and includes the following types of services and service providers: law enforcement, fire protection, emergency medical, hazardous materials, and utility service.

Emergency response considerations arise both in conjunction with accidents occurring at or near crossings and the crossing blockages that impede emergency response. Blockage of crossings, whether related to the passage of moving trains or a temporarily stopped train, can interfere with emergency service provider responsiveness to calls for assistance.

In order to quantify emergency response, a value is used to represent the net change from the base or existing conditions within a corridor. Alternative improvements for a given corridor are rated on a scale from 2.00 to 1.00 to denote a negative impact, status quo/no change, or positive impact on emergency response with the corridor.

Any alternative will create some affect on emergency response, but in many cases the changes will be subtle and difficult to assess. For example, the addition of gates at a crossing may increase slightly the amount of delay for local law enforcement at a particular crossing where numerous switching operations occur nearby. However, over a period of time, the cumulative effect is likely to be limited.

Blockage

This factor computes: 1) the probable delay time due to a crossing blocked by a passing train, and 2) out-of-direction travel to an alternate crossing because a crossing is closed.

Blockage due to a passing train is calculated in three steps. First, impedance of traffic (in minutes per day) is computed:

\[
\text{Impedance (I)} = \left(\frac{\text{train length}}{\text{train speed}} + \text{signal activation time}\right) \times \text{the number of trains per day}
\]

This is the amount of time during the day that a train will impede vehicles at a crossing. Next, the probable number of vehicles affected or stopped at the crossing is computed:

\[
\text{Number of Vehicles (N)} = \left(\frac{I}{840 \text{ min per day}}\right) \times \text{ADT}
\]
This assumes that 85% of ADT occurs within a 14 hour time period. Finally, the probable time delay of vehicles is calculated:

\[ Time (T) = N \times \left( \frac{\text{train length}}{\text{train speed}} \right) \]

Delay due to out-of-direction travel is equal to the number of vehicles forced to an alternate crossing times the distance traveled divided by the average vehicle speed:

\[ T_d = ADT \times \frac{D}{S} \]

where:  
- \( D \) = the distance to the next crossing and returning to the starting location measured along the existing or proposed roadway 
- \( S \) = the design speed of the alternative route

The delay due to out-of-direction travel will only be a value in alternative improvement scenarios where one or more crossings are closed and traffic is routed to a new location.

**Economic Significance**

This factor seeks to characterize a crossing's economic significance or contribution in terms of its current support or contribution to local and regional productivity. Several connotations of "economic significance" are possible including:

- General relationship to a nearby economic activity: to what extent is nearby activity (retail sales, employment, etc.) dependent upon traffic that uses a particular crossing.
- Specific relationship to a major economic activity: does the crossing serve a specific facility, plant or industrial park that is critical to the local economy.
- Potential loss of real estate property values: to what extent would construction of a grade separation or closure of a crossing adversely impact adjacent business sales volumes and property values.
- Significance of a crossing to regional trade and/or tourism: is the crossing located on a recognized commercial or tourism corridor.
- Significance of a crossing to regional agricultural productivity: to what extent does a particular crossing serve local/regional farm-to-market needs.

In order to quantify economic significance of a corridor of crossings, a single value is used to represent the net change from the base or existing conditions within a corridor. Alternative improvements for a given corridor will be rated on a scale from 1.50 to 1.00 to denote negative impacts, status quo/no major change, or positive impacts on local economics within the corridor. Alternatives involving only changes in warning devices would typically have little impact.

**Corridor Improvement Costs**

This factor quantifies the cost for construction of suggested improvements within a corridor. Possible improvements that would translate to dollar costs in the assessment of alternative solutions include:

- Improving from passive signing to flashing lights and gates
- Improving from flashing lights only to flashing lights and gates
- Addition of frontage roads to provide access due to the closure of a crossing
- Grade separation structure
- Crossing closure

Costs were assigned based on current information from the railroads and the Nebraska Department of Roads. Costs were estimated in raw construction dollars only with no allowances for contingencies or engineering design.

### 3.2 Prioritization of Corridors

Corridor prioritization utilizes only the three safety factors: collisions, emergency response, and blockage. The weights assigned to the three factors are the same as those used during alternative
evaluation multiplied by 1.25 to reach 100% weight total. Corridors within each classification were prioritized using the following formula:

\[
\text{Priority Index (PI)} = \frac{WaAi + WbBi + WeEi}{N}
\]

where:

- \( Wa \) = weight for collisions (50%)
- \( Ai \) = indexed accident prediction value
- \( Wb \) = weight for blockage (25%)
- \( Bi \) = indexed blockage value
- \( We \) = weight for emergency response (25%)
- \( Ei \) = indexed emergency response value
- \( N \) = number of crossings in the corridor

### 3.3 Multi-Criteria Analysis of Alternatives

Corridor alternatives are evaluated with a multi-criteria analysis. This type of analysis is useful in evaluation settings where the factors in the decision matrix are not on the same quantitative scale. The three-step process is as follows:

**Value Computation**

First, a value is computed for each of the five evaluation factors: collisions, emergency response, blockage, economic significance, and corridor costs for each alternative and the results are placed into the matrix shown in Figure 1.

**FIGURE 1**

**Evaluation Matrix**

<table>
<thead>
<tr>
<th>CORRIDOR NUMBER</th>
<th>WEIGHT</th>
<th>ALTERNATE 1</th>
<th>WEIGHTED ALT. 1</th>
<th>ALTERNATE 2</th>
<th>WEIGHTED ALT. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collision (accidents/yr.)</td>
<td>40%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Response</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blockage (minutes)</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic Significance</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement Cost</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
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</tbody>
</table>

**Value Indexing**

The alternatives are then indexed to the lowest value for each factor in the decision matrix. For example, if the predicted number of collisions per year is 0.35 for Alternative 1 and 0.23 for Alternative 2, and 0.31 for Alternative 3, the indexes would be 1.52, 1.00, and 1.35 respectively. Indexing produces a common scale that, when weighted, represents the generally agreed upon standing of an alternative.

**Weighting of Indexed Values**

Indexed values are weighted (80% for safety factors and 20% for economic factors) and totaled. The totals for alternatives are compared to each other, the lowest total matrix score being the preferred alternative.
4.0 PROCESS IMPLEMENTATION
Total track mileage in Nebraska was estimated at over 5,500 miles. Approximately 1,875 miles of mainline railroad track was identified for implementation of the assessment process. These mainlines contain a total of 2,431 crossings that were grouped into 227 corridors crossing 57 counties. These crossings equate to 37% of the total number of public and private crossings in Nebraska. The corridors were classified as shown in Table 1.

TABLE 1
Classification of Study Corridors

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number of Study Corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban-High Density</td>
<td>3</td>
</tr>
<tr>
<td>Urban-Medium Density</td>
<td>9</td>
</tr>
<tr>
<td>Urban-Low Density</td>
<td>8</td>
</tr>
<tr>
<td>Rural-High Density</td>
<td>12</td>
</tr>
<tr>
<td>Rural-Medium Density</td>
<td>98</td>
</tr>
<tr>
<td>Rural-Low Density</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>227</td>
</tr>
</tbody>
</table>

This classification was based on criteria described in Table 2:

TABLE 2
Definition of Classification Criteria

Community Setting:
- **Urban**: Incorporated cities having 5,000 or more residents, or, unincorporated areas located adjacent to the municipal boundary of either Lincoln or Omaha and having significant residential or industrial development.
- **Rural**: Incorporated cities, towns and villages with fewer than 5,000 residents and all other unincorporated areas of the state.

Density of Rail Traffic:
- **High Density**: Grade crossings with an average of over 100 train movements per day.
- **Medium Density**: Grade crossings with an average of 40-100 train movements per day.
- **Low Density**: Grade crossings with an average of 40 or fewer train movements per day.

4.1 Recommendations for All Study Corridors
An aggregation of preliminary preferred alternatives on Nebraska's mainline corridors totaled a recommendation of adding 83 grade separations, 88 gates and flashing lights and 32 miles of new frontage roads. It also recommends the closure of 395 public crossings (27% of the study public crossings and 10% of all Nebraska public crossings) and the closure of 400 private crossings (41% of the study private crossings and 14% of all Nebraska private crossings).

For the 2,431 public and private crossings on all study corridors, an accident prediction value of 55.29 was computed for existing conditions and 32.63 for the preliminary preferred alternatives. This represents a 41% reduction in the accident prediction for the study corridors and a 25% reduction in the statewide accident prediction.
The 2,431 crossings studied had an estimated aggregate existing vehicle delay time of 3,262 hours per day or about 50% of the total vehicle delay at highway-railroad grade crossings experienced in the State. This means that although mainline railroads in Nebraska have only 39% of the public crossings, they experience 50% of the vehicle delay.

If out-of-direction travel delay is included as a part of vehicle delay in the study, there is only a 20% reduction in delay gained through the preliminary preferred alternatives. However, it is likely that out-of-direction travel is not as severe as indicated in the study computations. Full traffic data and origin/destination data were not available for this overall look at grade crossings, but will be considered more fully at the diagnostic stage of study. If out-of-direction travel is removed from the study blockage equation and we look strictly at vehicle delay at crossings, the proposed alternatives offer a 63% reduction in the amount of vehicle delay due to passing trains on the mainlines in the study. This equates to a 32% reduction in vehicle delay statewide. The reality will most likely lie between these two estimates of blockage reduction.

The aggregate cost, not including incidentals and engineering costs, of study improvements on all mainline corridors is $440 million.

4.2 Top 10% Priorities
The study team also reviewed the top ten percent mainline corridor priorities based on the Priority Index. These 25 corridors represent the top priority subset of the 227 mainline corridors studied and are spread throughout 19 counties. They contain 149 public and private crossings (2% of Nebraska's total crossings).

Preliminary preferred alternative recommendations for the top 10% priorities indicated a need for the addition of 33 grade separations, 3 gates and flashing lights and 0.5 miles of new frontage road. It also included the closure of 27 public crossings (0.7% of statewide public crossings) and the closure of 7 private crossings (0.2% of statewide private crossings) for a total number of 34 crossing closures (0.5% of all crossings in Nebraska).

The existing accident prediction for the aggregate priority corridors is 5.84. With the preliminary proposed alternatives, the accident prediction decreases to 2.39, a 59% reduction in predicted accidents. This equates to a statewide reduction of almost 4%.

The 25 priority corridors identified produce an aggregate existing vehicle delay time of 1,228 hours. The preliminary proposed improvements reduce this vehicle delay to 647 hours including out of direction travel delays; a 47% reduction in the top 10% priority corridors (9% statewide). If out of direction travel is removed from the study computation, vehicle delay at crossings is reduced by 73% to 334 hours. This equates to a 14% reduction in vehicle delay due to passing trains at crossings statewide.

The estimated cost, not including incidentals and engineering costs, for the preliminary alternative improvements in the 25 top 10% priority corridors is $166 million.

5.0 CONCLUSION
The assessment process described in this paper enables an engineer to assess risk at highway-railroad grade crossings and approximate the magnitude of improvements needed to reduce risk at public and private crossings. However, there are many additional quantitative and qualitative factors that must be addressed during final diagnostic and engineering studies of crossing corridors.
The assessment process was successfully implemented on Nebraska's mainline railroad corridors; and preliminary statewide improvement needs and top priorities were identified for further study. This assessment process can be used in conjunction with a detailed diagnostic study to evaluate the merits of alternatives developed during a field review for a more complete and accurate safety assessment of highway-railroad grade crossings.

ACKNOWLEDGEMENTS
I would like to thank Mr. Ellis Tompkins, NDOR Intermodal Transportation Engineer, his staff, HNTB Corporation, Hammer Siler George Associates, and Richards & Associates for their contributions to this project.