Appendix D
Grade Crossing Safety and Delay Analysis

For grade crossing safety and grade crossing delays, the analyses focus on future conditions under the No-Action Alternative and under the Southern Rail Alternative and the Northern Rail Alternative. Specifically, the No-Action Alternative analysis was conducted for 2031, the future condition five years after the anticipated year of the Board's final decision. The No-Action Alternative reflects the projected train and vehicle traffic levels in the analysis year 2031 without the proposed line. The Southern Rail Alternative and Northern Rail Alternative analyses were also conducted for year 2031. For the purposes of the analysis, the two Build Alternatives and their effects are the same.

D.1 Approach

The following data source served as a basis for the grade crossing safety analysis and the grade crossing delay analysis:

- **Average Annual Daily Traffic (AADT) data are from the Texas Department of Transportation (TxDOT) Statewide Traffic Analysis and Reporting System (TxDOT 2024c)**. The AADT values are based on data that represent years ranging from 2013 to 2022. As such, there is a need to normalize the AADT values to a common year and then extrapolate the values to the existing year of 2024 and then to the analysis year of 2031. The general approach used to estimate 2024 AADT values and project to 2031 AADT values was to identify the most recent available AADT value, adjust that value to a common base year (in this case 2018), and then grow all values to the existing year of 2024 and the analysis year of 2031. Based on common industry practice, the specific approaches used to adjust historical AADT values to 2031 AADT values include:
    - If two years of historical traffic data are available and the volume for the more recent year is greater than the volume for the earlier year, then straight line growth is used to adjust the most recent AADT value to 2018.
    - If two years of historical traffic data are available and the volume for the more recent year is equal to or less than the volume for the earlier year, then a growth factor of 1.0 is used to adjust the most recent AADT value to 2018 (such as, assume most recent AADT as 2018 AADT).
    - If one year of historical traffic data are available, then data from the United States Census Bureau (Decennial Census data and American Community Survey data) are used to develop growth factors. Specifically, the growth factors are based on the ratio of the number trips to work by car, truck, or van from one year to another.
        - For historical AADT values from 2010 or older, the growth factor is based on the ratio of trips to work by car, truck, or van in 2018 compared to 2000. If the growth factor is less than or equal to 1.0, then no growth is assumed from the most recent year to 2018 (such as, assume most recent AADT as 2018 AADT).
        - For historical AADT values from 2011 or newer, the growth factor is based on the ratio of trips to work by car, truck, or van in 2018 compared to 2011. If the growth factor is

less than or equal to 1.0, then no growth is assumed from most recent year to 2018 (such as, assume most recent AADT as 2018 AADT).

- If 2022 traffic data are available, then these values are used instead of growing older values.
- A 2 percent annual growth rate is used to grow the AADT values to 2024 and then to 2031, starting with 2018 or 2022 AADT values as applicable.

Additionally, the following data source was used for the grade crossing safety analysis:

- **Crash data are from the Federal Railroad Administration (FRA) database**. During the latest five years (2019-2023), no train-vehicle crashes and no train-pedestrian crashes were reported at the seven grade crossings within the study area. FRA publishes statistics on the safety performance of more than 126,000 open public at-grade crossings in the U.S. that are not grade-separated (FRA 2024c). During the five-year period from 2019 to 2023, there were 9,108 total crashes at those at-grade crossings, representing an average of 0.014 crashes per crossing per year, or approximately one crash per crossing every 69.5 years, which is higher than the average crashes per grade crossing included in the safety analysis for this study.

Existing rail traffic (average number of trains per day, average train speeds, and average train length) is based on freight train activity as reported by Green Eagle Railroad (GER). GER estimated no change in train traffic at the grade crossings in the study area under the 2031 No-Action Alternative relative to current conditions. **Table D-1** presents an inventory of all seven public at-grade crossings within the study area. The table includes basic details for the crossing roadway and the railroad track, including AADT, train speed, train length, number of trains per day, and average gate down time. Separate values are presented for the 2024 existing conditions and the 2031 future conditions, the latter of which applies for both the No-Action Alternative and the build alternatives; for the purposes of grade crossing safety analysis, the Southern and Northern Rail Alternatives have the same results and are therefore combined in the tables. For subsequent tables in this appendix, the Crossing ID can be used to cross-reference grade crossings.

D.2 Grade Crossing Safety Analysis

D.2.1 Grade Crossing Safety Analysis Methods

The predicted crashes at highway/rail at-grade crossings are calculated using Equation (1) (FRA 2022).

$$NC = \frac{(a \times T_0) + N}{T_0 + 5} * adj \qquad (1)$$

Where:

NC = Predicted number of train-vehicle crashes per year at the grade crossing;

a = Initial predicted train-vehicle crashes per year (based on Equation (2));

T_0 = Weighting factor in the DOT crash prediction formula (based on Equation (3));

N = Number of train-vehicle crashes in previous five years at grade crossing; and

Adj = Coefficient to normalize predicted train-vehicle crashes in year with actual counts (current values are normalized for year 2013).

Table D-1. Summary of Public Grade Crossings

		AADT		Trains per Day		Average Train Length (ft)		Average Train Speed (mph)		Average Gate Down Time per Day (minutes)	
Street	**Crossing ID**	**2024 (Existing Conditions)**	**2031 (Future Conditions)**	**No-Action Alternative**	**Build Alternatives**	**No-Action Alternative**	**Build Alternatives**	**No-Action Alternative**	**Build Alternatives**	**No-Action Alternative**	**Build Alternatives**
Location: City of Eagle Pass, Texas											
5th Street	764104S	2347	2696	19	19	9300	9300	15	15	144	0
Ferry Street	764106F	3921	4504	19	19	9300	9300	15	15	144	0
2nd Street	912039X	2704	3106	19	19	9300	9300	15	15	144	0
Quarry Street	764107M	2515	2889	19	19	9300	9300	15	15	144	0
Rio Grande Street	764109B	1489	1710	19	19	9300	9300	15	15	144	0
Main Street	764108U	6073	6976	19	19	9300	9300	15	15	144	0
Industrial Park Boulevard	764113R	2180	2504	19	19	9300	9300	15	15	144	0

This method is similar to the method described in FRA's *Summary of the DOT Rail Highway Crossing Resource Allocation Procedure Revised* (Farr 1987), but with updated adjustment factors in Equation (1). The results include expected vehicle/train crash rates at all at-grade crossings in the study area under the 2031 No-Action Alternative and under the Southern and Northern Rail Alternatives.

The initial predicted train-vehicle crashes per year (a) is based on several factors as shown in Equation (2). **Table D-2** presents the values and formulas used to compute each of these factors based on the type of grade crossing control. The type of control includes passive, flashing lights, and lights and gates.

$$a = K * EI * DT * MS * MT * HP * HL \qquad (2)$$

Where:

K = Basic crash prediction formula constant;

EI = Exposure index factor (Expose = AADT * trains per day);

DT = Factor for the number of through trains per day during daylight (dthru = number of through trains per day during daylight), which is derived from train schedule in combination with train traffic;

MS = Factor for maximum freight timetable speed (ms = maximum timetable speed at crossing);

MT = Factor for number of main tracks (tracks = number of main tracks);

HL = Factor for number of roadway lanes (lanes = number of highway lanes);

HP = Factor for paved roadway (1 if highway is paved, 2 if unpaved); and

Adj = Coefficient to normalize predicted train-vehicle crashes in year with actual counts.

The weighting factor in the DOT crash prediction formula (T_0) is based on Equation (3).

$$T_0 = \frac{1}{0.05+a} \tag{3}$$

Where:

All terms as previously defined.

The predicted number of crashes by severity is based on the predicted number of train vehicle crashes per year (NC) at the grade crossing. The predicted crash frequency by severity is subdivided into two categories, fatal crashes and casualty crashes. Fatal crashes are those that result in at least one fatality, independent of injuries or property damage. Casualty crashes are those that result in at least one fatality or injury, independent of property damage. The predicted number of injury crashes is simply the difference between the predicted number of fatal crashes and predicted number of casualty crashes. The equations are based on the Rail Highway Crossing Resource Allocation Procedure User's Guide (FRA 1987).

Table D-2. Factors to Predict Train-Vehicle Crashes

Factor	Passive Control	Flashing Lights	Lights and Gates
K	0.0006938	0.0003351	0.0005745
EI	$\left(\frac{Expose+0.2}{0.2}\right)^{0.37}$	$\left(\frac{Expose+0.2}{0.2}\right)^{0.4106}$	$\left(\frac{Expose+0.2}{0.2}\right)^{0.2942}$
DT	$\left(\frac{dthru+0.2}{0.2}\right)^{0.1781}$	$\left(\frac{dthru+0.2}{0.2}\right)^{0.1131}$	$\left(\frac{dthru+0.2}{0.2}\right)^{0.1781}$
MS	$e^{0.0077*ms}$	1	1
MT	1	$e^{0.1917*tracks}$	$e^{0.1512*tracks}$
HL	1	$e^{0.1826*(lanes-1)}$	$e^{0.142*(lanes-1)}$
HP	$e^{-0.5966*(paved-1)}$	1	1
Adj	0.5086	0.3106	0.4846

The probability of a fatal crash, given a crash occurs, is based on Equation (4).

$$P(F|C) = \frac{1}{1+KF*MS^{-0.9981}*(TT+1)^{-0.0872}*(TS+1)^{0.0872}*e^{0.3571*UR}} \tag{4}$$

Where:

$P(F|C)$ = Probability of a fatal crash, given a crash occurs;

KF = Constant (440.9);

MS = Maximum freight timetable speed (mph);

TT = Number of thru trains per day;

TS = Number of switch trains per day; and

UR = Urban or rural crossing (urban = 1; otherwise, 0).

The predicted number of fatal crashes is based on Equation (5).

$$F = P(F|C) * NC \qquad (5)$$

Where:

F = Predicted fatal crashes per year;

$P(F|C)$ = Probability of a fatal crash, given a crash occurs; and

NC = Predicted number of train-vehicle crashes per year at the grade crossing.

The probability of a casualty crash, given a crash occurs, is based on Equation (6).

$$P(C|C) = \frac{1}{1+KC*MS^{-0.343}*e^{0.1153*TK}*e^{0.296*UR}} \qquad (6)$$

Where:

$P(C|C)$ = Probability of a casualty crash, given a crash occurs;

KC = Constant (4.481);

MS = Maximum freight timetable speed (mph);

TK = Number of tracks; and

UR = Urban or rural crossing (urban = 1; otherwise, 0).

The predicted number of casualty crashes is based on Equation (7).

$$C = P(C|C) * NC \qquad (7)$$

Where:

C = Predicted casualty crashes per year;

$P(C|C)$ = Probability of a casualty crash, given a crash occurs; and

NC = Predicted number of train-vehicle crashes per year at the grade crossing.

The predicted number of injury crashes is based on Equation (8).

$$I = C - F \qquad (8)$$

Where:

I = Predicted injury crashes per year;

C = Predicted casualty crashes per year; and

F = Predicted fatal crashes per year.

D.2.2 Grade Crossing Safety Analysis Results

Table D-3 presents the grade crossing safety analysis results by individual crossing for 2024 existing conditions, the 2031 No-Action Alternative, and the 2031 Southern and Northern Rail Alternatives. Train traffic (average number of trains per day, average train speeds, and average train length), the type of crossing protection, and safety-related performance measures are consistent for the 2024 existing conditions and the expected 2031 No-Action Alternative. Under the Southern and Northern Rail Alternatives, rail operations would be discontinued at all seven at-grade crossings in the study area, so the probability of train-vehicle and train-pedestrian crashes would be zero.

D.3 Grade Crossing Delay Analysis

D.3.1 Grade Crossing Delay Analysis Methods

The grade crossing delay analysis includes two general components, one focused on individual train crossings and one focused on cumulative events over an entire day. The performance measures for individual train crossings include blocked crossing time per train, crossing delay per stopped vehicle, and maximum vehicle queue. The performance measures for cumulative events over an entire day include number of vehicles delayed per day, average delay for all vehicles, and level of service (LOS) for vehicular traffic. For simplification purposes, it is assumed that both rail and road traffic are uniform throughout the day.

The blocked crossing time per train (T) includes the time for the train to pass and the time for any warning device to engage and disengage (FRA 2022). The blocked crossing time per train is based on Equation (9):

$$T = T_W + \frac{L}{V*88} \tag{9}$$

Where:

T = Blocked crossing time per train (minutes);

T_W = Lead time (assumed 0.6 minutes for gate closing and opening as well as for passive crossings at which point motorists would not venture a crossing);

L = Average train length (feet);

V = Average train speed (miles per hour); and

88 = Conversion factor from miles per hour to feet per minute.

Table D-3. Grade Crossing Safety for 2024 and 2031 Condition

		2024 Existing Conditions				2031 No-Action Alternative				2031 Build Alternatives			
Crossing ID	**Number of Roadway Lanes**	**AADT**	**Number of Train-Vehicle Crashes in Previous 5 Years**	**Predicted Number of Train-Vehicle Crashes per Year**	**Years between Crashes**	**AADT**	**Number of Train-Vehicle Crashes in Previous 5 Years (Assumed)**	**Predicted Number of Train-Vehicle Crashes per Year**	**Years between Crashes**	**AADT**	**Number of Train-Vehicle Crashes in Previous 5 Years (Assumed)**	**Predicted Number of Train-Vehicle Crashes per Year**	**Years between Crashes**
Location: City of Eagle Pass, Texas													
764104S	2	2,347	0	0.010	100	2,696	0	0.010	100	2,696	0	0	N/A
764106F	2	3,921	0	0.011	91	4,504	0	0.011	91	4,504	0	0	N/A
912039X	2	2,704	0	0.010	100	3,106	0	0.010	100	3,106	0	0	N/A
764107M	2	2,515	0	0.010	100	2,889	0	0.010	100	2,889	0	0	N/A
764109B	2	1,489	0	0.009	111	1,710	0	0.009	111	1,710	0	0	N/A
764108U	2	6,073	0	0.012	83	6,976	0	0.013	77	6,976	0	0	N/A
764113R	2	2,180	0	0.013	77	2,504	0	0.014	71	2,504	0	0	N/A
Average				0.01071	95			0.01100	93				
Total				0.07500				0.07700					

The number of vehicles delayed per day (N_V) is the number of vehicles that would be stopped for trains in a 24-hour period as shown in Equation (10).

$$N_V = \frac{T}{1{,}440} N * AADT \tag{10}$$

Where:

N_V = Number of vehicles delayed per day;

T = Blocked crossing time per train (minutes);

1,440 = Factor to convert vehicles per day to vehicles per minute;

N = Number of trains per day; and

AADT = Annual average daily traffic (vehicles per day).

The average delay per vehicle in a 24-hour period (D_V) is shown in Equation (11).

$$D_V = \frac{N_V}{AADT} * \frac{T * \frac{R_D}{R_D - R_A}}{2} \tag{11}$$

Where:

D_V = Average delay per vehicle in a 24-hour period (minutes);

N_V = Number of vehicles delayed per day;

T = Blocked crossing time per train (minutes);

R_D = Vehicle departure rate (vehicles per minute per lane), which can vary by location;[1]

R_A = Vehicle arrival rate (vehicles per minute per lane), which is based on AADT data;

AADT = annual average daily traffic volume for the highway at the grade crossing (in vehicles per day); and

2 = Averaging factor to account for vehicles that do not experience delays from the entire time the train blocks the crossing.

Total vehicle delay (D) is the product of average delay per vehicle (D_V) and the AADT as shown in Equation (12).

$$D = D_V * AADT \tag{12}$$

Where:

D = Total vehicle delay (minutes);

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[1] Vehicle departure rate varies by location based on factors such as number of lanes, lane width, grade, and sight distances. This information is not readily available for the grade crossings included in this analysis. As such, this analysis assumed common values based on the Highway Capacity Manual (National Academies of Sciences, Engineering, and Medicine, 2022). The assumed vehicle departure rates (in vehicles/minute/lane) are 30 for highways, 23.3 for arterials, 15 for collectors, and 11.7 for local roads.

D_V = Average delay per vehicle in a 24-hour period (minutes); and

AADT = annual average daily traffic volume for the highway at the grade crossing (in vehicles per day).

The LOS for vehicular traffic in this analysis is based on the average delay per vehicle at each grade crossing and the LOS criteria for signalized intersections from the 2022 Highway Capacity Manual (National Academies of Sciences, Engineering, and Medicine 2022). LOS is a qualitative measure of motor vehicle traffic flow, indicated by letters from A to F, where A represents free-flow conditions and F indicates extreme congestion. **Table D-4** presents the LOS categories along with the applicable ranges of average delay per vehicle and general descriptions.

Table D-4. Level of Service Designations

LOS	**Average Delay per Vehicle (DV) (seconds/vehicle)**	**General Description**
A	$DV \leq 10$	Free flow
B	$10 < DV \leq 20$	Stable flow (slight delays)
C	$20 < DV \leq 35$	Stable flow (acceptable delays)
D	$35 < DV \leq 55$	Approaching unstable flow
E	$55 < DV \leq 80$	Unstable flow
F	$80 < DV$	Forced flow (congested and queues fail to clear)

Source: National Academies of Sciences, Engineering, and Medicine, 2022

The maximum vehicle queue (Q) is the estimated length of the longest line of vehicles expected to occur at the grade crossing. It is assumed that the maximum vehicle queue would occur during the peak hour for vehicle traffic and that the peak-hour traffic represents 10 percent of the AADT. The calculation is given by Equation (13).

$$Q = AADT * \frac{0.1*0.6}{60} * \frac{T}{NL/2} \tag{13}$$

Where:

Q = Maximum vehicle queue length (in number of vehicles);

AADT = annual average daily traffic volume for the highway at the grade crossing (in vehicles per day);

0.1 = Factor to convert AADT (in vehicles per day) to peak-hour traffic (in vehicles per hour);

0.6 = Factor to convert two-way traffic to peak direction traffic, assuming traffic is split 60/40 during the peak hour;

60 = Factor to convert vehicles per hour to vehicles per minute;

T = Blocked crossing time per train (minutes);

NL = Number of highway lanes at the grade crossing, which was obtained from aerial imagery; and

2 = Factor to convert total lanes to lanes in peak direction.

D.3.2 Grade Crossing Delay Analysis Results

Table D-5 presents the grade crossing delay analysis results by individual crossing for the 2031 No-Action Alternative and the 2031 Southern and Northern Rail Alternatives. Train traffic (average number of trains per day, average train speeds, and average train length) and delay-related performance measures are consistent for the 2024 existing conditions and the expected 2031 No-Action Alternative with the exception of roadway traffic volumes. Under the Southern and Northern Rail Alternatives, through rail operations would be discontinued at all at-grade crossings in the study area, eliminating vehicular delay for the Southern and Northern Rail Alternatives. The expected impact of the proposed line is the difference between the performance measure for the Southern Rail Alternative or Northern Rail Alternative and the same performance measure for the No-Action Alternative.

Table D-5. Grade Crossing Delay for 2031 Conditions

							2031 No-Action Alternative						2031 Build Alternatives						Difference	
Street	Crossing ID	Projected 2031 AADT	Number of Roadway Lanes	Trains Per Day	Train Speed (mph)	Train Length (feet)	Number of Stopped Vehicles Delayed Per Day	Average Delay per Vehicle in 24-hour Period (seconds)	Total Delay in 24-hour Period (minutes)	Level of Service	Maximum Queue (vehicles)	Total Gate Down Time per Day (minutes)	Number of Stopped Vehicles Delayed Per Day	Average Delay per Vehicle in 24-hour Period (seconds)	Total Delay in 24-hour Period (minutes)	Level of Service	Maximum Queue (vehicles)	Total Gate Down Time per Day (minutes)	Average Delay per Vehicle (seconds)	Level of Service
Location: City of Eagle Pass, Texas																				
5th Street	764104S	2696	2	19	15	9300	270	24.8	1114.3	C	20	144	0	0.0	0.0	A	0	0.0	-24.8	C to A
Ferry Street	764106F	4504	2	19	15	9300	452	25.5	1914.2	C	34	144	0	0.0	0.0	A	0	0.0	-25.5	C to A
2nd Street	912039X	3106	2	19	15	9300	312	24.0	1242.4	C	24	144	0	0.0	0.0	A	0	0.0	-24.0	C to A
Quarry Street	764107M	2889	2	19	15	9300	290	24.5	1179.7	C	22	144	0	0.0	0.0	A	0	0.0	-24.5	C to A
Rio Grande Street	764109B	1710	2	19	15	9300	172	23.8	678.3	C	13	144	0	0.0	0.0	A	0	0.0	-23.8	C to A
Main Street	764108U	6976	2	19	15	9300	700	25.5	2964.8	C	53	144	0	0.0	0.0	A	0	0.0	-25.5	C to A
Industrial Park Boulevard	764113R	2504	2	19	15	9300	251	24.7	1030.8	C	19	144	0	0.0	0.0	A	0	0.0	-24.7	C to A