7.0 AT-GRADE AUTO TRAFFIC DELAY ANALYSIS

Vehicular delays were examined for the at-grade railroad crossings along the Burlington Northern & Santa Fe (BNSF) railway and the Kansas City Southern (KCS) railway within Tupelo. This included quantification of the delay both in time and cost incurred.

7.1 DESCRIPTION OF CROSSINGS

The crossing information was based on the track charts obtained from BNSF and KCS. It includes the crossing milepost, crossing street name and crossing types (i.e. public or private, at-grade or grade separated (overpass or underpass)). The crossing locations were also compared to the Federal Railroad Administration (FRA) crossing inventory database. FRA crossing inventory includes crossing identification numbers, milepost, crossing roadway type and name, gate information, longitude and latitude and flasher information. The accuracy of the crossing information was verified by field inspection.

Once the crossing database was established, the number of crossings was revised by excluding all the private crossings and grade-separated crossings. Therefore, only the public at-grade crossing locations were included in this traffic delay study. Sixteen at-grade crossings were identified in the study area along both of the rail lines. On the BNSF line the crossings are at Lumpkin Ave., W Jackson St., Blair St., W Jefferson St., N Park St., N Gloster St., W Main St., S Church St., S Green St., S Spring St., E Elizabeth St., and E Eason Blvd. On the KCS line the crossings are at E Jefferson St., E Main St., W Elizabeth St., and W Eason Blvd. The crossing identification (ID) information obtained from the track charts of the two rail line companies is listed in **Table 7-1**.

The locations of the at-grade crossings are depicted on the aerial map of Tupelo, shown in **Figure 7-1**.

7.2 TRAFFIC DELAY ANALYSES

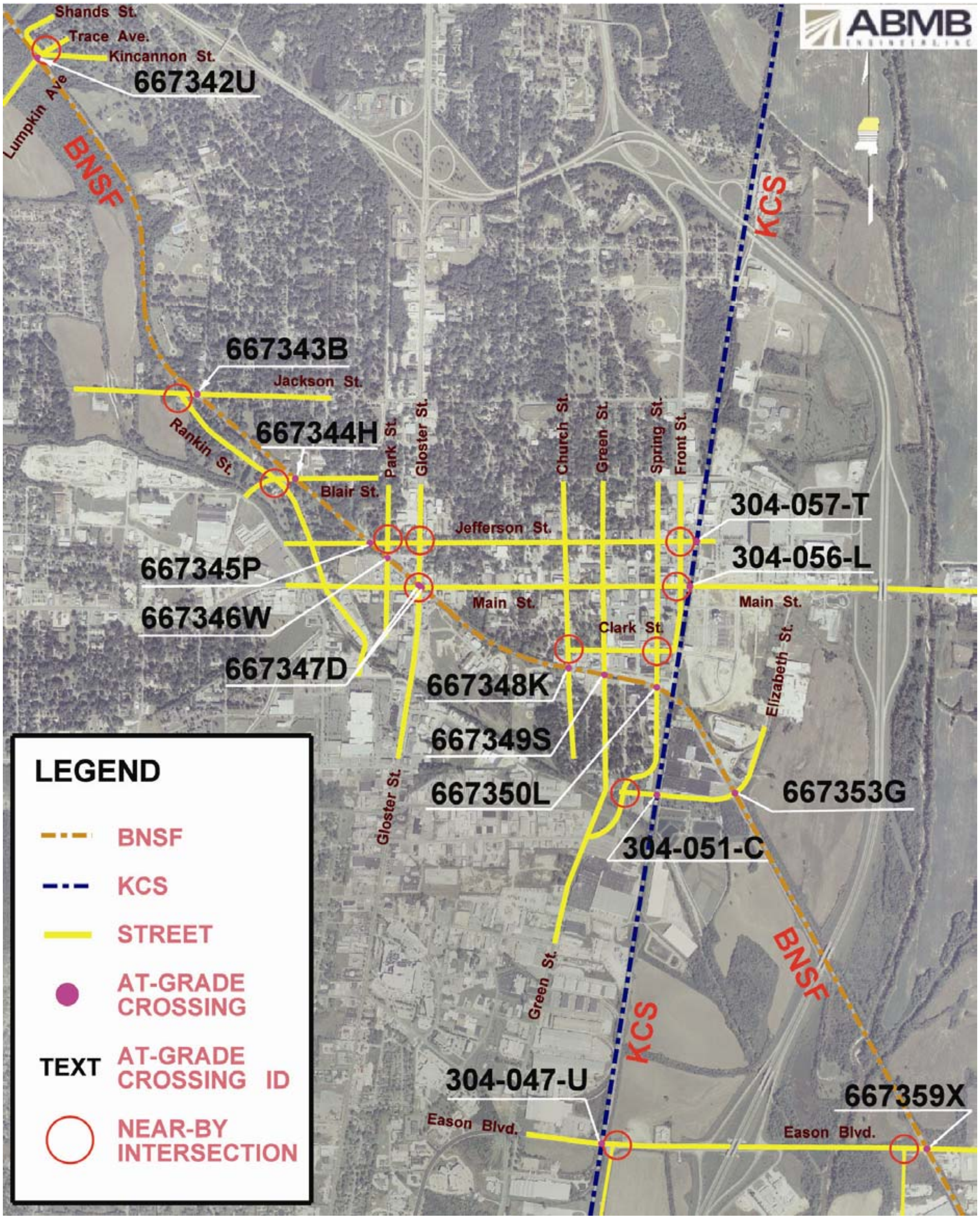
The at-grade crossing traffic analysis examined the vehicular traffic delay from the existing and future railroad operations. The major focus was placed on the following factors:

- Maximum queue vehicle Q_{max};
- Crossing vehicle delay;
- Intersection level of service and
- System cost of congestion.

Table 7-1
At-Grade Crossing ID Chart

Crossing ID	Crossing Street Name	Crossing Train Line
667342U	Lumpkin Ave.	BNSF
667343B	W Jackson St.	
667344H	Blair St.	
667345P	W Jefferson St.	
667346W	N Park St.	
667347D	S Gloster St.	
667347D	W Main St.	
667348K	Church St.	
667349S	Green St.	
667350L	S Spring St.	
667353G	W Elizabeth St.	
667359X	E Eason Blvd.	
304-047-U	W Eason Blvd.	KCS
304-051-C	E Elizabeth	
304-056-L	E Main St.	
304-057-T	E Jefferson St.	

Figure 7-1
At-Grade Crossing Location and Crossing ID



7.2.1 Data Collection and Process

7.2.1.1 Data Source

Sources of traffic data for this study include MDOT, Federal Railroad Administration (FRA), Mississippi Automated Resource Information System (MARIS), Mississippi Department of Environmental Quality (MDEQ), and local governments including Lee County, Union County, Pontotoc County, City of Tupelo, City of Verona, City of Sherman, City of Plantersville, and City of Saltillo. Where there is a need, the data can be obtained from the field as well.

7.2.1.2 Highway Data

<u>Annual Average Daily Traffic (AADT)</u>
To analyze the vehicular behavior over time, a typical day was divided into five time periods, which are morning time period (AM Peak), mid-day time period (MD Peak), afternoon time period (PM peak), day-off time period (DO Peak) and night-off time period (NO Peak). The five time periods and the divided hours are shown in **Table 7-2**.

The 20-year historical AADT data of Blair St., Front St., Gloster St., Jackson St., Main St., Eason Blvd. and Trace Ave. were provided by MDOT. The locations of the AADT collected and the count section numbers are shown in **Table 7-3** and **Figure 7-2**. The AADT of these roadway sections was used as control values for projecting the AADT of other unknown roadway sections.

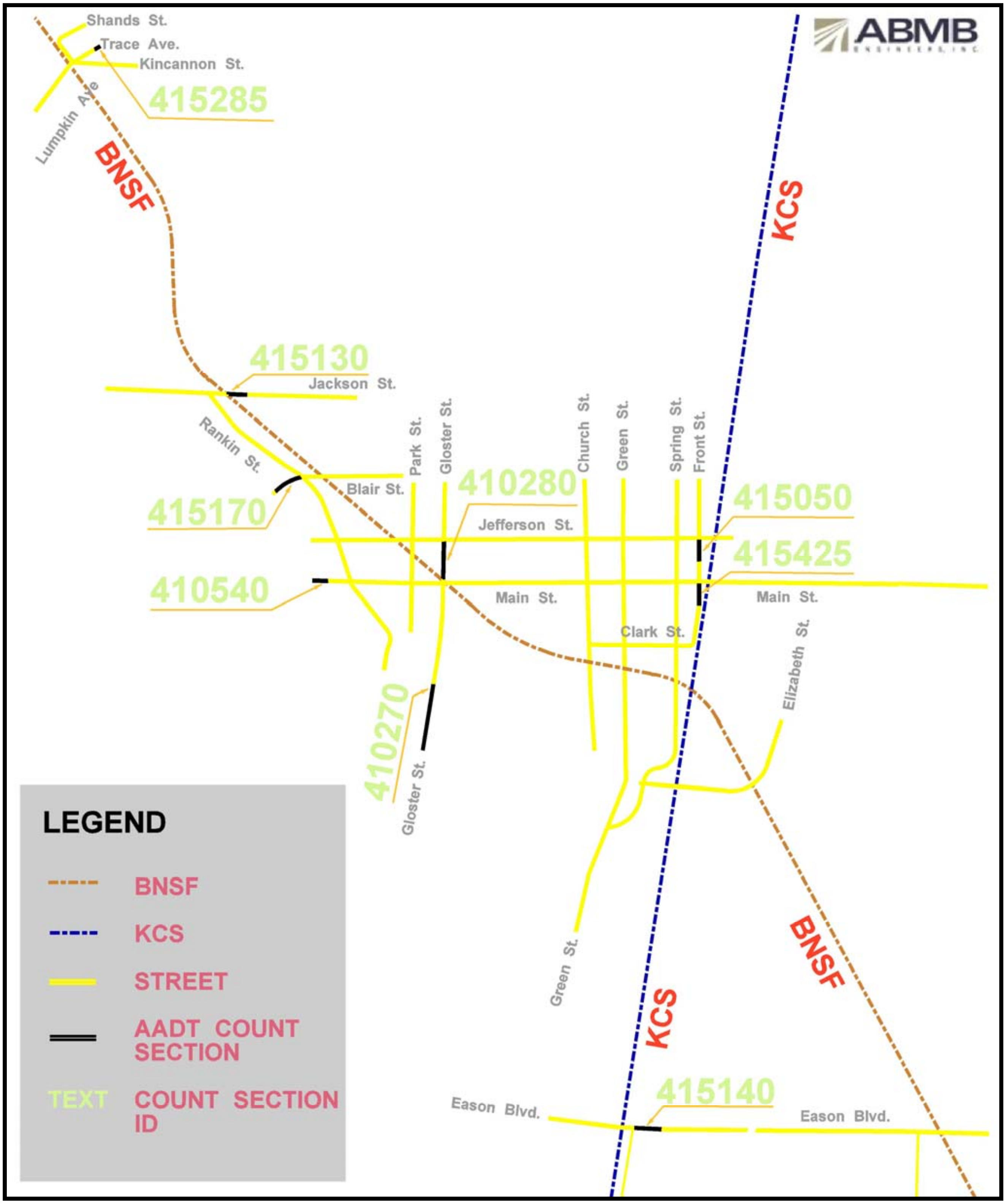
Table 7-2
Daily Time Periods

<table>
<tr><th colspan="2">Time Period</th><th>From</th><th>To</th><th colspan="3">Total Hours</th></tr>
<tr><td>Night-Off Peak</td><td>NO</td><td>Midnight</td><td>6:00 AM</td><td colspan="2">6</td><td rowspan="7">24</td></tr>
<tr><td>AM Peak</td><td>AM</td><td>6:00 AM</td><td>9:00 AM</td><td colspan="2">3</td></tr>
<tr><td rowspan="3">Day-Off Peak</td><td rowspan="3">DO</td><td>9:00 AM</td><td>11:00 AM</td><td>2</td><td rowspan="3">10</td></tr>
<tr><td>1:00 PM</td><td>4:00 PM</td><td>3</td></tr>
<tr><td>7:00 PM</td><td>Midnight</td><td>5</td></tr>
<tr><td>Mid-Day Peak</td><td>MD</td><td>11:00 AM</td><td>1:00 PM</td><td colspan="2">2</td></tr>
<tr><td>PM Peak</td><td>PM</td><td>4:00 PM</td><td>7:00 PM</td><td colspan="2">3</td></tr>
</table>

Table 7-3
20-Year Historical AADT Data Provided by MDOT

Count ID	Street Name	20-Year Historical AADT Data																			
		1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
415370	**Blair St.**	4220	4130	4170	4370	2780	3030	3050	2900	3000	3100	2800	2900	3000	2500	2500	2500	2500	2500	2300	2300
415050	**N Front St.**	3660	4730	5160	5200	3400	3500	3530	4600	4700	4800	5300	5500	5700	6600	6700	6700	5000	5000	5000	5300
415425	**S Front St.**	0	0	1500	1510	1520	3670	3700	3800	3400	3500	3600	3900	4000	4000	3700	3700	3700	2900	3000	3000
410270	**Gloster St.**	12760	12740	13890	14160	13350	13750	13860	12000	12000	12000	15000	16000	16000	15000	15000	17000	17000	17000	20000	20000
410280	**Gloster St.**	12850	12570	13700	13800	13910	16910	17050	18000	19000	20000	21000	19000	20000	20000	20000	20000	20000	20000	22000	22000
415130	**W Jackson St.**	3950	3860	4820	4850	4890	4810	4850	5000	4600	4700	4800	4400	4500	4500	6900	6900	6900	7600	7600	7700
410540	**W Main St.**	16400	15870	16030	16300	14730	14890	15460	18000	19000	20000	19000	19000	20000	18000	18000	18000	25000	25000	25000	25000
415285	**Trace Ave.**	60	280	280	290	210	230	230	230	240	250	230	240	250	250	250	250	300	300	300	360

Figure 7-2
AADT Count Sections & ID



Wherever existing traffic count data of a street in the study area was not available, AADT estimation was applied based on the following two conditions.

In the first condition, if the unknown roadway is close to a near-by control section, the AADT of the unknown roadway was estimated based on the proportion to the known AADT. To do so, 15-min turning movement count data was collected for each time period. After the 15-min count was collected, the 15-min volume was multiplied by four to represent the hourly volume. Based on the 15-min turning movement count, the turning percentage was also determined for each time period. The control AADT was divided into hourly volume based on peak-to-daily ratio. The turning percentage was then applied to indicate the proportion of the control hourly count to the unknown roadway hourly volume. The hourly volume for the unknown roadway was obtained by comparing it to the percentage of the control hourly volume. The hourly volume of one time period was then multiplied by the total number of hours that time period has to represent the total time period volume. Finally, the AADT of the unknown roadway was estimated by summing the five time periods' volume together.

This process was used for evaluating the traffic in the thirteen intersections which are shown below:

- Clark St. at Church St.
- S Gloster St. at W Main St.
- S Spring St. at Clark St.
- S Spring St. at Elizabeth St.
- S Front St. at E Main St.
- N Front St. at E Jefferson St.
- N Park St. at W Jefferson St.
- Blair St. at Rankin Blvd.
- W Jackson St. at Rankin Blvd.
- E Eason Blvd. at Ryder St.
- W Eason Blvd. at Whitaker Dr.
- Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.
- S Gloster St. at Jefferson St.

In the second condition, if the unknown roadway is not close to a near-by control section, the AADT was estimated by applying a Season Factor on the total traffic volume of all five time periods (i.e. ADT) collected from the turning movement counts. Since the 15-min count for each time period is the real traffic count, no axle correction needs to be applied.

Traffic Projection for Vehicles

The traffic growth projection was based on the historical AADT data provided by MDOT. To reflect the up-to-date traffic growth trend, only the most recent 10-year AADT data was used for traffic projection analysis, from year 1995 to year 2004. To represent the traffic characteristics in the study area, only the AADT of the streets in the study area were included.

A least squares regression analysis was performed to verify the trend of the traffic growth and to get the traffic growth rate over years.

The independent value is year and the dependent value is AADT of the year. The Analysis of Variance (ANOVA) table of the regression analysis is shown in **Table 7-4**.

Table 7-4
ANOVA Table of the Regression Analysis for Traffic Projection

Source	df	SS		MS		F	R^2
Regression	1	**SSR**	2.78E+09	**MSR**	2.78E+09	36.72329	0.821122
Error	n-2	**SSE**	6.05E+08	**MSE**	75679141		
Total	n-1	**SSTC**	3.38E+09				

The hypothesis of the regression analysis was:

H_0: the traffic growth rate = 0
H_1: the traffic growth rate ≠ 0

The confidence level was set to be 95% ($\alpha = 0.05$) as regular. Since the 10-year AADT data included in the analysis was from 1995 to 2004, the sample size n is equal to 10.

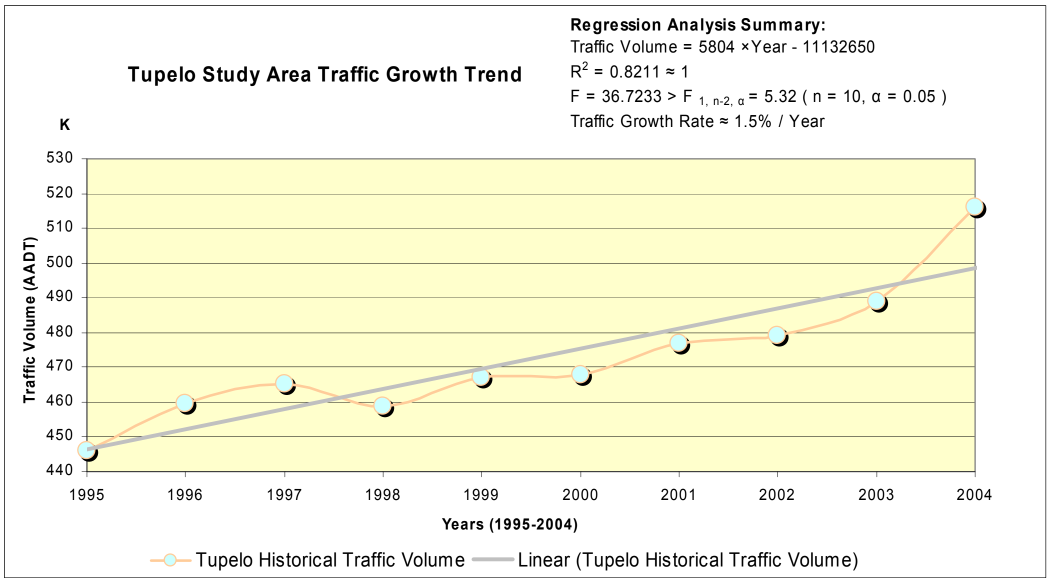
The F-test value is 36.72 which is larger than $F_{1, n-2, \alpha} = 5.32$. Therefore, the F-test value leads to reject H_0, i.e. the traffic growth rate is not equal to zero. Also, the least square value R^2 is equal to 0.82. R^2 value close to 1 represents a good linear fit.

From the testing results, a large F-test value combined with a R^2 value close to 1, it is 95% confident to conclude that there is a strong linear relationship between the year and the AADT in the study area.

The traffic growth rate is the slope of this linear relationship, which is 1.5% per year. The annual traffic growth amount is about 5,804 vehicles per year in the study area.

The 10-year historical AADT data was plotted along with the fitted regression line, as shown in **Figure 7-3**.

Figure 7-3
Traffic Growth Trend



The AADT volume for the future year is projected based on the traffic projection analysis and the current AADT data, which is shown in **Table 7-5**.

<u>Season Factor (SF)</u>
The 24-hour traffic count treated by axle correction was conducted by MDOT in the intersection of Gloster St. at Main St. The ADT of Gloster St. and Main St. was obtained by summing total volume of the 24-hour count on corresponding roadway approach. Also, AADT of these two streets are known factors.

The Season Factor (SF) was estimated by dividing AADT by ADT and Axle Correction Factor (ACF).

$$SF = \frac{AADT}{ADT \times ACF} \quad (1)$$

The SF is about 1.24 for the end of year.

Table 7-5
At-Grade Crossing Roadway Characteristics

Int'n No.	Approaching Street Name	Approaching Side To Int'n	At-Grade Crossing	Directional Value								Current Year No. of Lanes	One-way Or Two-way	Travel Speed (mph)	AADT	
				Directional AADT						Dir						
				Dir	2005	2030	Dir	2005	2030	Peak	D-Factor				2005	2030
1	Church St.	N		SB	546	804	NB	621	915	NB	53%	2	Two-way	30	1167	1719
		S	√	SB	631	929	NB	911	1342	NB	59%	2	Two-way	30	1542	2271
	Clark St.	E		WB	510	751	EB	85	125	WB	86%	2	Two-way	30	595	876
2	Gloster St.	N	√	SB	12163	17913	NB	12446	18329	NB	51%	4	Two-way	45	24609	36242
		S		SB	11437	16843	NB	11465	16885	NB	50%	4	Two-way	45	22902	33728
	Main St.	W		WB	11978	17640	EB	12809	18864	EB	52%	4	Two-way	35	24787	36504
		E	√	WB	10448	15387	EB	11024	16235	EB	51%	4	Two-way	35	21472	31622
3	Spring St.	N		SB	409	602	NB	492	725	NB	55%	2	Two-way	30	901	1327
		S	√	SB	1766	2601	NB	1002	1476	SB	64%	2	Two-way	30	2768	4076
	Clark St.	W		WB	457	673	EB	427	629	WB	52%	2	Two-way	30	884	1302
	Front St.	E		WB	1975	2909	EB	1098	1617	WB	64%	2	Two-way	30	3073	4526
4	Spring St.	N		SB	3539	5212	NB	1898	2795	SB	65%	4	Two-way	30	5437	8007
		S		SB	6110	8998	NB	7135	10508	NB	54%	4	Two-way	30	13245	19506
	Elizabeth St.	W		WB	320	471	-	-	-	WB	100%	2	One-way	30	320	471
		E	√	WB	2981	4390	EB	5327	7845	EB	64%	2	Two-way	30	8308	12235
5	Front St.	N		SB	3538	5210	NB	1596	2350	SB	69%	2	Two-way	40	5134	7561
		S		SB	2957	4355	NB	1215	1789	SB	71%	2	Two-way	30	4172	6144
	Main St.	W		WB	5457	8037	EB	4532	6674	WB	55%	4	Two-way	35	9989	14711
		E	√	WB	5885	8667	EB	5160	7599	SB	53%	4	Two-way	35	11045	16266
6	Front St.	N		SB	3627	5342	NB	1639	2414	SB	69%	4	Two-way	40	5266	7755
		S		SB	3589	5286	NB	1830	2695	SB	66%	4	Two-way	40	5419	7981
	Jefferson St.	W		WB	845	1244	EB	866	1275	EB	51%	2	Two-way	30	1711	2520
		E	√	WB	180	265	EB	430	633	EB	70%	4	Two-way	30	610	898

Table 7-5
At-Grade Crossing Roadway Characteristics - Continued

Int'n No.	Approaching Street Name	Approaching Side To The Int'n	At-Grade Crossing	Directional Value								Current Year No. of Lanes	One-way Or Two-way	Travel Speed (mph)	AADT	
				Directional AADT						Dir						
				Dir	2005	2030	Dir	2005	2030	Peak	D-Factor				2005	2030
7	Park St.	N		SB	1579	2325	NB	2125	3130	NB	57%	2	Two-way	30	3704	5455
		S	√	SB	3163	4658	NB	2948	4342	SB	52%	2	Two-way	30	6111	9000
	Jefferson St.	W	√	WB	990	1458	EB	980	1443	WB	50%	2	Two-way	30	1970	2901
		E		WB	2559	3769	EB	1788	2633	WB	59%	2	Two-way	30	4347	6402
8	Rankin St.	N		SB	803	1183	NB	370	545	SB	68%	2	Two-way	30	1173	1727
		S		SB	284	418	NB	326	480	NB	53%	2	Two-way	30	610	898
	Blair St.	W		WB	1252	1844	EB	1092	1608	WB	53%	2	Two-way	30	2344	3452
		E	√	WB	596	878	EB	911	1342	EB	60%	2	Two-way	30	1507	2219
9	Rankin St.	S		SB	1336	1968	NB	1070	1576	SB	56%	2	Two-way	30	2406	3543
	Jackson St.	W		WB	4124	6073	EB	3921	5774	WB	51%	2	Two-way	30	8045	11848
		E	√	WB	4142	6100	EB	3673	5409	WB	53%	2	Two-way	30	7815	11509
10	Ryder St.	S		SB	760	1119	NB	405	596	SB	65%	2	Two-way	30	1165	1716
	Eason Blvd.	W		WB	11630	17128	EB	9313	13715	WB	56%	2	Two-way	30	20943	30843
		E	√	WB	11715	17253	EB	9043	13318	WB	56%	2	Two-way	30	20758	30571
11	Whitaker St.	S		SB	547	806	NB	280	412	SB	66%	2	Two-way	30	827	1218
	Eason Blvd.	W	√	WB	13303	19591	EB	10247	15091	WB	56%	4	Two-way	45	23550	34682
		E		WB	13850	20397	EB	10527	15503	WB	57%	4	Two-way	45	24377	35900
12	Shands St.			SB	15	22	NB	63	93	NB	81%	2	Two-way	30	78	115
	Trace Ave.			SB	308	454	NB	78	115	SB	80%	2	Two-way	30	386	568
	Kincannon St.			WB	1694	2495	EB	1482	2183	WB	53%	2	Two-way	30	3176	4677
	Lumpkin Ave.		√	SB	2051	3021	NB	1597	2352	SB	56%	2	Two-way	30	3648	5372
13	Gloster St.	N		SB	12177	17933	NB	11674	17192	SB	51%	4	Two-way	45	23851	35126
		S		SB	10697	15754	NB	10273	15129	SB	51%	4	Two-way	45	20970	30883
	Jefferson St.	W		WB	2452	3611	EB	2343	3451	WB	51%	2	Two-way	30	4795	7062
		E		WB	2257	3324	EB	2227	3280	WB	50%	2	Two-way	30	4484	6604

Peak-to-Daily Ratio (p/d)
To interpret AADT into hourly volume, the peak-to-daily ratio (p/d ratio) was derived from the turning movement counts of the thirteen intersections in the study area. The turning movement was counted for 15-min within each of the time periods at each intersection. After the 15-min turning movement was collected, the 15-min count was multiplied by the number of 15-min intervals that time period has to represent the whole time period volume. For example, the AM time Period is made up of three hours in which there are twelve 15-min intervals. To represent the whole 3-hour AM time period volume, the 15-min count was multiplied by twelve. The volume of the five time periods was then summed to generate the daily traffic volume. The traffic volume in one time period was compared to the summed daily traffic to get the proportion. This proportion was then divided by the total period hours in that time period to get the p/d ratio.

The p/d ratios calculated from the thirteen intersections were averaged in the end to generate the average p/d ratio for the study area. The projected p/d ratio is shown in **Table 7-6**.

Table 7-6
Peak-to-Daily Ratio (p/d)

Time Period	AM (3 hrs)	Mid-Day (2 hrs)	PM (3 hrs)	Day-Off (10 hrs)	Night-Off (6 hrs)
p/d	0.0491	0.0632	0.0717	0.0458	0.0089

Therefore, p/d ratio should be understood as the proportion of hourly traffic to the daily total traffic by considering the total daily traffic as 1. The outcome of summing the products of multiplying p/d ratio in each time period by the total number of hours in that time period should be equal to 1, i.e.:

$1 = 3\times0.0491+2\times0.0632+3\times0.0717+10\times0.0458+6\times0.0089$.

Percentage of Heavy Vehicles, %
The assumed percentage of heavy vehicles on different types of roadway facilities is shown in **Table 7-7**.

Table 7-7
Assumed Percentage of Heavy Vehicles

Roadway Type	% Heavy Vehicles
Local	1%
Collector	1.50%
Minor Arterial	2%-3%
Major Arterial	2%-5%

The assumed percentage of heavy vehicles was checked by the on field traffic count. The adjusted percentage of heavy vehicles for the roadways in the study area is shown in **Table 7-8**.

Table 7-8
Adjusted Percentage of Heavy Vehicles

Crossing Street Name	Heavy Vehicle %	Crossing Street Name	Heavy Vehicle %
Lumpkin Ave.	0%	Green St.	1.50%
W Jackson St.	0%	S Spring St.	1.50%
Blair St.	0%	E Elizabeth St.	5%
W Jefferson St.	0%	E Eason Blvd.	7%
N Park St.	0%	W Eason Blvd.	8%
Gloster St.	1.20%	W Elizabeth St.	5%
W Main St.	1.50%	E Main St.	1.50%
Church St.	1.50%	E Jefferson St.	1.50%

7.2.1.3 Rail Data

<u>Train Volume and Distribution</u>
The current train volume is around 23 per day on the BNSF line and about 3 per day on the KCS line. The future train volumes in the year 2030 projected by the rail companies will be around 40 per day on the BNSF line and 4 per day on the KCS line.

The train volume between 2005 and 2030 was determined based on the current and the future train volume as discussed in Section 6.

The number of train cars was observed in the field for each of the five periods. Each train car was assumed to be 85 ft in length which is the length of one car plus the coupling.

Although the total train traffic volume was known, there is not a fixed train schedule, which means that the distribution of the trains throughout a day is not certain. In this study the train volume was assumed to be uniformly distributed throughout a day. This train distribution scenario has a uniform frequency of train events per hour throughout a day. The uniform scenario will indicate the cost of congestion on an average level.

The distribution of train schedule is displayed in **Figure 7-4**. The train traffic volume distribution for BNSF line and KCS line from Year 2004 to Year 2030 is shown in **Table 7-9**.

Figure 7-4
Train Traffic Distribution Illustration in the Year 2005

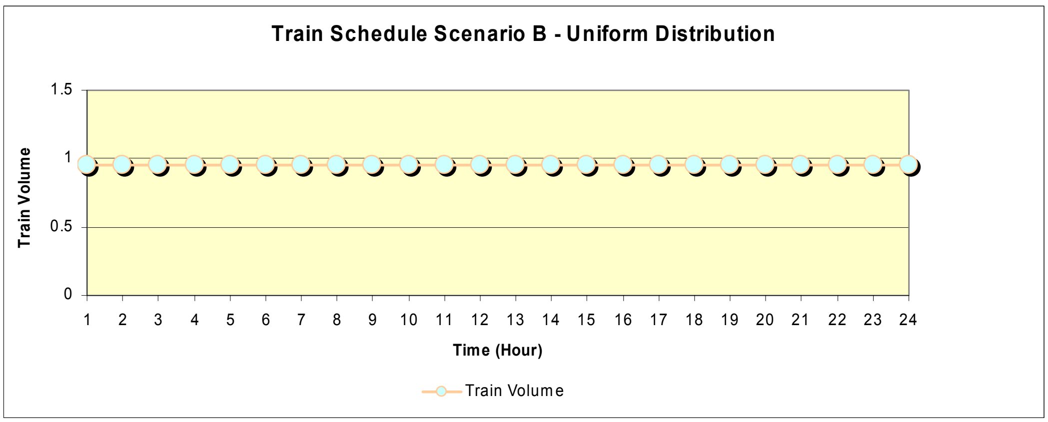


Table 7-9
Train Traffic Distribution (In the Year of 2004-2030)

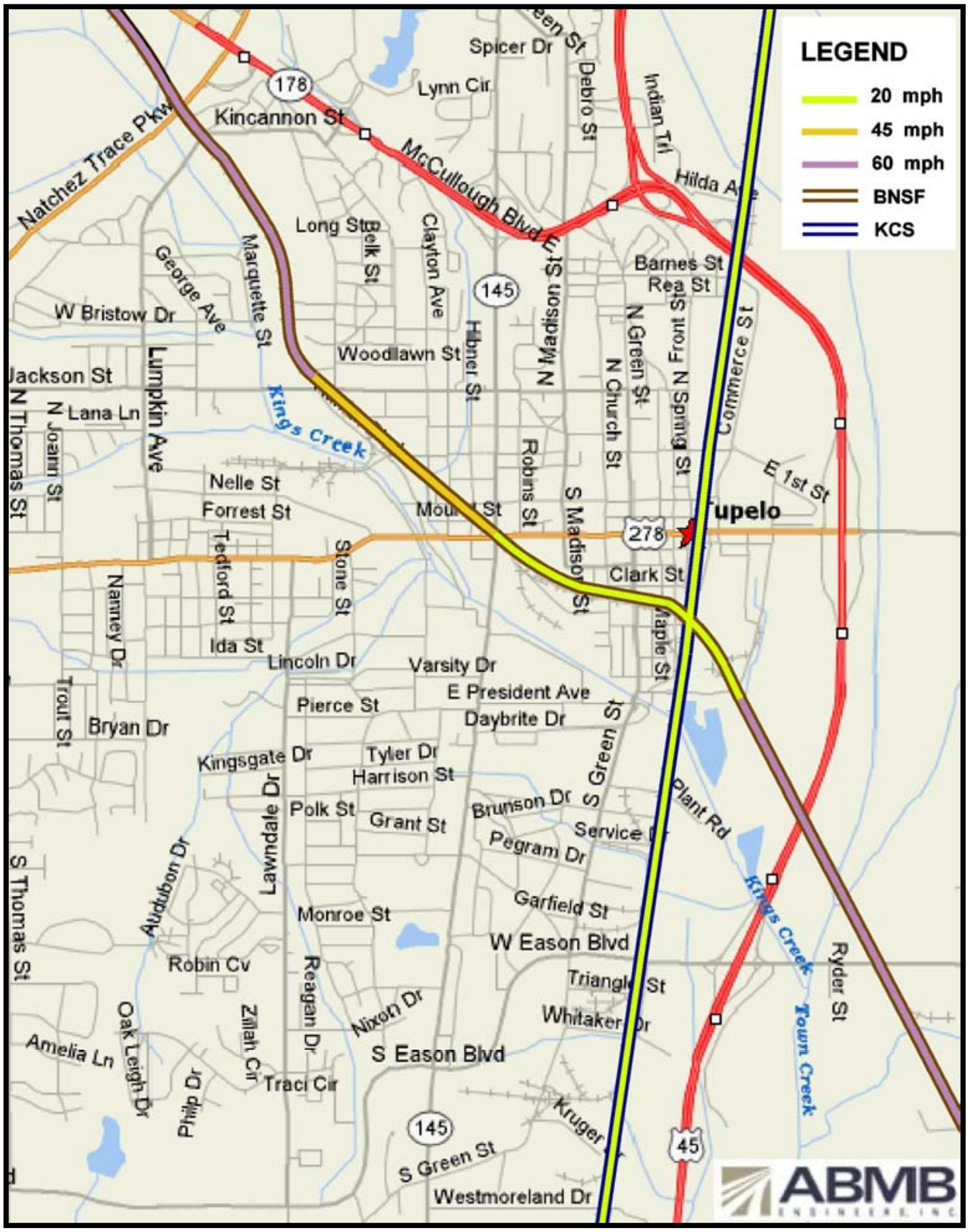
BNSF Line		Uniform Train Distribution					
Year		No. of Daily Train Events in Corresponding Time Period					
From	To	NO	AM	DO	MD	PM	Total
2004	2005	6	3	9	2	3	**23**
2006	2009	7	3	11	2	3	**26**
2010	2013	7	4	12	2	4	**29**
2014	2017	8	4	13	3	4	**32**
2018	2021	9	4	15	3	4	**35**
2022	2025	10	5	15	3	5	**38**
2026	2030	12	5	15	3	5	**40**
Train Length (train cars/train)		*98*	*91*	*44*	*40*	*102*	-

KCS Line		No. of Daily Train Events in Corresponding Time Period					
Year							
From	To	NO	AM	DO	MD	PM	Total
2004	2016	0	0	0	2	1	**3**
2017	2030	0	0	0	2	2	**4**
Train Length (train cars/train)		-			*20*	*20*	-

<u>Train Operating Speed</u>
The train operating speed shown in the track charts for both the BNSF and the KCS lines in the study area is shown in **Figure 7-5**. It can be seen in the figure that the operating speed is relatively slower when trains are passing through the downtown area.

Based on the field evaluation, 20 mph train operating speed was used for both BNSF and KCS lines in the analysis at the at-grade crossings.

Figure 7-5
Train Operating Speed in the Tupelo Study Area



7.2.2 Delay Analysis

7.2.2.1 Maximum queue, Q_{max}

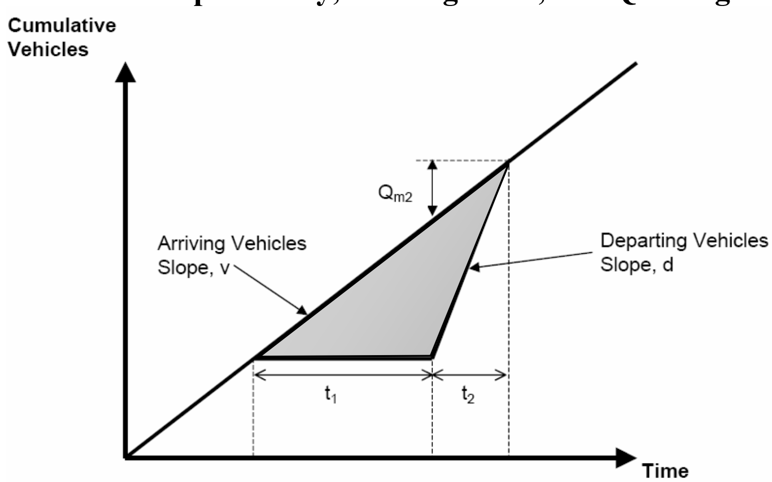
The queuing model is based on the procedures listed in the section of signalized intersections in the HCM 2000.

Arrival rate v (vph) of vehicles approaching the at-grade crossing location is assumed to be uniform. Vehicles start to back up when a train event happens at the location, which takes time t_1 (hours) for the entire train to clear the crossing. The queuing length at this point is Q_{m1} (veh). When the beginning of Q_{m1} queuing vehicles starts to pass through the crossing with departure rate d (vph), more vehicles with the same arrival rate v will continue back up at the end of Q_{m1}. It takes Q_{m1} queuing vehicles in queue clearance time t_2 (hours) to clear through the crossing. The queuing length of the additional arrived vehicles behind Q_{m1} in this t_2 time is called Q_{m2}. The maximum vehicle queue is the sum of the queuing length (Q_{m1}) arrived at the time t_1 when the train clears the crossing and the length of vehicles (Q_{m2}) arrived during the queue clearance time t_2, represented by the formula:

$$Q_{\max} = Q_{m1}\big|_{t=t_1} + Q_{m2}\big|_{t=t_2} \qquad (2)$$

The total vehicular delay is the triangular area between the arrival function and the departure function. The relationship between queuing vehicles, delay time and arriving/departing vehicle rate is shown in **Figure 7-6**.

Figure 7-6
Relationship of Delay, Waiting Time, and Queuing Length



v	Flow rate of arriving vehicles (veh/hr)
d	Flow rate of departing vehicles (veh/hr)
t_1	Total time roadway is blocked by the train crossing (hr)
t_2	Queue clearance time (hr)
Q_{m1}	Length of queue at the point when the train clears the crossing (veh)

Q_{m2} Additional queue that builds up during queue clearance time (t_2), extending the back of queue distance (veh)

In which,

$$t_1 = \frac{L_T}{V} + 0.00833 \qquad (3)$$

t_1 Blocked crossing time per train at the at-grade crossing (hr)
L_T Train length (miles)
V Train speed (mph)
0.0083 Time for gate closing and opening prior to and after train passage (hr)

$$t_2 = \frac{Q_{m1}}{d - v} \qquad (4)$$

t_2 Queue clearance time (hr)
v Flow rate of arriving vehicles (veh/hr)
d Flow rate of departing vehicles (veh/hr)

$$Q_{m1}\big|_{t=t_1} = v \times t_1 \qquad (5)$$

$$Q_{m2}\big|_{t=t_2} = v \times t_2 \qquad (6)$$

In addition to the train crossing events, a switching operation is done daily in the cross-town area in Tupelo. The purpose of switching operation is to allow train cars from the main line to go onto the spur tracks and to get to the local industry destinations. Due to the lack of electric lock switching, this operation typically takes 10 minutes to finish. During this time, the traffic in the downtown area is blocked at the at-grade crossing locations, which causes additional traffic delay. To reflect the vehicular delay incurred by train switching operation in the delay analysis, the switching time is modeled as s_1, which is typically 10 minutes. It is assumed to happen during the PM time period once a day. The vehicle queuing length accumulated during this time s_1 is modeled as $Q_{m1}\big|_{t=s_1}$. The queuing clearance time, during which the vehicles back up during time s_1 begin to depart until the vehicle departure rate reaches to the arrival rate, is modeled as s_2. The queue builds up during queuing clearance time s_2 is $Q_{m2}\big|_{t=s_2}$. The time s_2, queuing length $Q_{m1}\big|_{t=s_1}$ and $Q_{m2}\big|_{t=s_2}$ are also calculated by the method shown above.

7.2.2.2 Delay

Aggregate Delay (veh-hr)

Aggregate delay in veh-hr is the area of triangle between the arrival function and the departure function, calculated by:

$$UD = \frac{1}{2} \times t_1 \times v \times (t_1 + t_2) \qquad (7)$$

This gives the total vehicle-hours of delay incurred by all the vehicles arriving and discharging during the time of t_1 and t_2.

Average Delay (sec/veh)

The average delay experienced for each vehicle in the peak hour was derived by dividing the total vehicle-hours at-grade crossing delay of that peak hour by the arrival rate of vehicles.

7.2.2.3 Cost of Congestion

The cost of accumulated daily vehicular traffic delay resulting from at-grade rail crossing was calculated based on the TTI congestion cost methodology.

The congestion cost was associated with two basic components: delay cost and fuel cost, which are related to vehicle-hours delay. By classification, the congestion cost can be divided into passenger vehicle delay and commercial vehicle cost.

The average cost of time per person hour was assumed to be $13.45 as a constant in TTI method. Vehicle occupancy was assumed to be 1.25 persons per passenger vehicle. The unit cost of fuel was assumed to be $2.20/gallon. The number of annual workdays is assumed to be 250 workdays/year.

Commercial vehicle percentage was estimated based on the average percentage of heavy vehicles in the study area which is 2.44%. The percentage of commercial vehicles was assumed slightly over the percentage of heavy vehicles, since most of the heavy vehicles are commercial vehicles. Therefore, 5% was used as percentage of commercial vehicles.

7.2.2.4 Level of Service

At-Grade Crossing Level of Service

Each at-grade crossing was evaluated as a signalized intersection based on the 2000 Highway Capacity Manual. The level of service for each crossing is determined by the average delay in sec/veh and is shown in **Table 7-10**.

Table 7-10
Signalized Intersection LOS vs. Delay

LOS	Delay (sec/veh)
A	≤ 10.0
B	10.1 – 20.0
C	20.1 – 35.0
D	35.1 – 55.0
E	55.1 – 80.0
F	> 80.0

Near-by Intersection Level of Service
The motor vehicle roadway crossing intersections LOS were evaluated based on the intersection traffic control type. The signalized intersection LOS is evaluated based on the same criteria shown in **Table 7-10**. The un-signalized intersection LOS is shown in **Table 7-11**.

Table 7-11
Un-signalized Intersection LOS vs. Delay

LOS	Delay (sec/veh)
A	≤ 10.0
B	10.1 – 15.0
C	15.1 – 25.0
D	25.1 – 35.0
E	35.1 – 50.0
F	> 50.0

7.3 Traffic Delay Results

Vehicular delay related to at-grade rail crossing includes two components in this study.

The first component is the vehicular delay occurring at the at-grade crossing locations, which includes:

- Time in which vehicles wait for trains to clear through the crossings (t_1)
- Queue clearance time (t_2), in which vehicles accumulated during t_1 will begin to depart until the vehicle departure rate equals the arrival rate
- Time in which vehicles wait for the switching operation (s_1), which typically lasts 10 minutes and happens once a day, and the corresponding queue clearance time (s_2)

The second delay component is the vehicular delay as secondary impact in the intersections which are close to the at-grade crossing locations. The resulting vehicle queue back up at the at-grade crossing locations can extend into several intersections and potentially impede traffic flow on other streets in the network, which is considered a secondary delay related to train crossing events.

Therefore, the total cost of congestion is the sum of the delay cost at the at-grade crossing locations as the primary impact and the near-by intersections as a secondary impact.

All the cost of congestion reflects the 2030 currency value in this study, by applying (F,P,i,n) factor on the current currency value, in which interest rate is equal to 3%.

7.3.1 Cost of Congestion at the At-grade Crossing Locations

Summary from Year 2005 to Year 2030

The total cost of congestion at the at-grade crossings along the BNSF and the KCS lines in Tupelo downtown area from 2005 to 2030 is $402.6 millions USD in 2030 currency value. The delay cost for individual crossings is shown in **Table 7-12**.

To illustrate the crossing streets encountering the highest delay, the crossing streets were arranged by the order of total daily delay in vehicle-hours from the highest to the lowest. The rank is shown in **Table 7-13**. At-grade crossings at Eason Blvd., Gloster St. and Main St. along the BNSF line are the three locations that experience the highest vehicle-hours delay in both 2005 and 2030.

Table 7-12
Total At-Grade Crossing Cost of Congestion from 2005 to 2030

Cross Line	Street Name	Total At-Grade Crossing Delay Cost From 2005 to 2030 ($)
BNSF	Lumpkin Ave.	$8,845,800
	Jackson St.	$24,046,600
	Blair St.	$4,472,900
	Jefferson St.	$5,948,100
	Park St.	$16,359,300
	Gloster St.	$77,874,800
	Main St.	$64,465,000
	Church St.	$4,105,300
	Green St.	$13,933,000
	Spring St.	$7,702,100
	Elizabeth St.	$45,120,400
	Eason Blvd.	$92,660,100
KCS	Eason Blvd.	$18,724,100
	Elizabeth St.	$10,802,700
	Main St.	$7,419,900
	Jefferson St.	$141,700
Total		**$402,621,900**

Table 7-13
Rank of At-Grade Crossing by Highest Total Daily Delay (veh-hr)

Rank	2005		2030	
	Crossing St.	Crossing Line	Crossing St.	Crossing Line
1 - Highest	Eason Blvd.	BNSF	Eason Blvd.	BNSF
2	Gloster St.	BNSF	Gloster St.	BNSF
3	Main St,	BNSF	Main St.	BNSF
4	Elizabeth St.	BNSF	Elizabeth St.	BNSF
5	Eason Blvd.	KCS	Jackson St.	BNSF
6	Jackson St.	BNSF	Eason Blvd.	KCS
7	Park St.	BNSF	Park St.	BNSF
8	Elizabeth St.	KCS	Green St.	BNSF
9	Green St.	BNSF	Elizabeth St.	KCS
10	Main St.	KCS	Lumpkin Ave.	BNSF
11	Lumpkin Ave.	BNSF	Spring St.	BNSF
12	Spring St.	BNSF	Main St.	KCS
13	Jefferson St.	BNSF	Jefferson St.	BNSF
14	Blair St.	BNSF	Blair St.	BNSF
15	Church St.	BNSF	Church St.	BNSF
16 - Lowest	Jefferson St.	KCS	Jefferson St.	KCS

2005 Scenario

In this scenario, the 23 trains on BNSF line in 2005 were distributed evenly throughout a day. The 3 trains on KCS line were divided into 2 in MD time period and 1 in PM time period. Due to the even distribution of the train schedule, this scenario evaluates the average crossing performance under current traffic conditions.

The vehicular delay in the 2005 scenario are shown in **Table 7-14.** Total delay time of this model in the study area is 613.3 vehicle-hours per day at crossings and 10240 vehicles of maximum daily queuing length. The total annual workday delay cost is $7.8 million USD.

2030 Scenario

2030 scenario represents the average level of cost of congestion under the future year traffic condition. The 40 trains on BNSF line were assumed to be distributed evenly daily. On the KCS line, the 4 trains per day were divided into 2 for MD time period and 2 for PM time period.

Table 7-15 shows that in the study area the total daily delay is 1928.7 vehicle-hours at crossings and the total daily maximum queuing length is 24949 vehicles. The total annual workday delay cost is $24.6 million USD.

Average Delay Time and At-Grade Crossing Level of Service

The average vehicle delay experienced by vehicles at the at-grade crossings was calculated for each crossing. The crossing level of service was then determined and is shown in **Table 7-16**. The level of service is a quality measurement describing the operational conditions. From the crossing level of service column, it can be seen that the crossing conditions along BNSF line worsens when more vehicles and more trains show up in the future year, especially at Eason Blvd., Gloster St. and Elizabeth St. The crossing level of service was plotted in **Figure 7-7** through **Figure 7-10.**

Table 7-14
Current Year of 2005 At-Grade Crossing Cost of Congestion

2005 Scenario										Total Annual Workday (250 days / year)		Annual Workday Cost of Congestion (250 days / year)			
Crossing Line	Street Name	Daily Directional						Daily Total				Annual Passenger Vehicle		Annual Commercial Cost ($)	Total Delay Cost ($)
		Dir	Q_{max} (veh)	Delay (veh-hr)	Dir	Q_{max} (veh)	Delay (veh-hr)	Q_{max} (veh)	Delay (veh-hr)	Q_{max} (veh)	Delay (veh-hr)	Delay Cost ($)	Fuel Cost ($)		
BNSF	Lumpkin Ave.	SB	143	7.6	NB	114	6.1	257	13.6	64339	3402.9	$117,200	$28,200	$26,100	$171,500
	Jackson St.	WB	330	18.9	EB	309	18.4	639	37.3	159822	9320.5	$321,000	$77,300	$71,400	$469,800
	Blair St.	WB	46	2.7	EB	71	4.6	117	7.2	29237	1806.8	$62,200	$15,000	$13,800	$91,100
	Jefferson St.	WB	92	6.8	EB	62	2.8	154	9.6	38561	2393.4	$82,400	$19,900	$18,300	$120,600
	Park St.	SB	226	12.4	NB	226	13.8	452	26.2	113074	6543.6	$225,400	$54,300	$50,100	$329,800
	Gloster St.	SB	967	50.3	NB	1023	63.0	1990	113.3	497604	28329.4	$975,800	$286,600	$217,000	$1,479,400
	Main St.	WB	757	42.2	EB	955	54.5	1712	96.7	428000	24171.2	$832,600	$217,300	$185,200	$1,235,000
	Church St.	SB	65	4.3	NB	48	2.2	114	6.5	28414	1621.4	$55,800	$13,500	$12,400	$81,700
	Green St.	SB	189	11.0	NB	189	11.0	378	21.9	94380	5481.4	$188,800	$45,500	$42,000	$276,300
	Spring St.	SB	127	6.5	NB	83	5.6	211	12.2	52716	3043.7	$104,800	$25,200	$23,300	$153,400
	Elizabeth St.	WB	230	11.3	EB	697	54.1	927	65.4	231724	16356.6	$563,400	$135,700	$125,300	$824,400
	Eason Blvd.	WB	1048	47.2	EB	1112	76.6	2160	123.8	539969	30951.5	$1,066,100	$256,800	$237,100	$1,560,000
KCS	Eason Blvd.	WB	213	13.5	EB	368	26.3	581	39.8	145243	9960.4	$343,100	$100,800	$76,300	$520,200
	Elizabeth St.	WB	35	2.4	EB	263	19.9	298	22.3	74563	5565.3	$191,700	$46,200	$42,600	$280,500
	Main St.	WB	120	8.4	EB	122	8.7	242	17.2	60424	4289.3	$147,700	$38,600	$32,900	$219,200
	Jefferson St.	WB	2	0.1	EB	5	0.2	7	0.3	1828	86.0	$3,000	$700	$700	$4,300
Total								**10240**	**613.3**	**2559897**	**153323.4**	**$5,281,300**	**$1,361,200**	**$1,174,700**	**$7,817,200**

Table 7-15
Future Year of 2030 At-Grade Crossing Cost of Congestion

		2030 Scenario								Total Annual Workday (250 days / year)		Annual Workday Cost of Congestion (250 days / year)			
		Daily Directional						Daily Total				Annual Passenger Vehicle		Annual Commercial Cost ($)	Total Delay Cost ($)
		Dir	Q_{max} (veh)	Delay (veh-hr)	Dir	Q_{max} (veh)	Delay (veh-hr)	Q_{max} (veh)	Delay (veh-hr)	Q_{max} (veh)	Delay (veh-hr)	Delay Cost ($)	Fuel Cost ($)		
BNSF	Lumpkin Ave.	SB	322	22.7	NB	256	18.6	578	41.3	144514	10316.4	$355,300	$85,600	$79,000	$520,000
	Jackson St.	WB	761	57.9	EB	705	54.5	1466	112.4	366484	28100.5	$967,900	$233,100	$215,300	$1,416,300
	Blair St.	WB	103	8.0	EB	151	12.4	254	20.4	63592	5109.2	$176,000	$42,400	$39,100	$257,500
	Jefferson St.	WB	197	18.3	EB	140	8.9	338	27.3	84414	6820.8	$234,900	$56,600	$52,300	$343,800
	Park St.	SB	505	35.7	NB	500	38.6	1005	74.3	251341	18563.3	$639,400	$154,000	$142,200	$935,600
	Gloster St.	SB	2319	162.9	NB	2436	195.1	4755	358.0	1188655	89504.6	$3,083,000	$905,400	$685,700	$4,674,100
	Main St.	WB	1762	130.1	EB	2264	170.2	4026	300.2	1006410	75055.7	$2,585,300	$674,700	$575,000	$3,835,000
	Church St.	SB	145	12.7	NB	106	6.4	250	19.1	62607	4771.7	$164,400	$39,600	$36,600	$240,500
	Green St.	SB	422	32.2	NB	422	32.2	844	64.4	210946	16093.8	$554,300	$133,500	$123,300	$811,200
	Spring St.	SB	288	20.4	NB	178	15.1	466	35.5	116509	8881.3	$305,900	$73,700	$68,000	$447,600
	Elizabeth St.	WB	540	37.2	EB	1993	196.5	2534	233.8	633410	58437.6	$2,012,900	$484,800	$447,700	$2,945,400
	Eason Blvd.	WB	2926	176.9	EB	3390	314.1	6316	491.1	1579012	122772.0	$4,228,900	$1,018,500	$940,600	$6,187,900
KCS	Eason Blvd.	WB	367	23.3	EB	708	51.1	1075	74.4	268650	18604.4	$640,800	$188,200	$142,500	$971,600
	Elizabeth St.	WB	56	3.8	EB	577	43.9	633	47.7	158348	11936.6	$411,200	$99,000	$91,400	$601,600
	Main St.	WB	197	13.9	EB	201	14.4	398	28.3	99475	7084.6	$244,000	$63,700	$54,300	$362,000
	Jefferson St.	WB	3	0.2	EB	8	0.4	11	0.5	2767	132.8	$4,600	$1,100	$1,000	$6,700
Total								**24949**	**1928.7**	**6237135**	**482185.2**	**$16,608,800**	**$4,253,800**	**$3,694,200**	**$24,556,700**

Table 7-16
Year 2005 and Year 2030 At-Grade Crossing Average Delay and LOS in PM Peak Hour

Crossing Line	Crossing Street Name	2005 PM Peak Hour				2030 PM Peak Hour			
		Without Switching Operation		With Switching Operation		Without Switching Operation		With Switching Operation	
		Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
BNSF	Lumpkin Ave.	15.5	B	125.7	F	41.1	D	189.8	F
	Jackson St.	17.3	B	139.6	F	48.2	D	222.7	F
	Blair St.	15.2	B	123.2	F	39.9	D	184.2	F
	Jefferson St.	15.4	B	124.5	F	40.6	D	187.3	F
	Park St.	16.6	B	134.5	F	45.5	D	210.2	F
	Gloster St.	18.6	B	150.1	F	54.3	D	250.9	F
	Main St.	18.0	B	145.2	F	51.4	D	237.4	F
	Church St.	15.1	B	122.5	F	39.6	D	182.6	F
	Green St.	16.2	B	131.2	F	43.9	D	202.4	F
	Spring St.	15.5	B	125.6	F	41.1	D	189.6	F
	Elizabeth St.	20.2	C	163.1	F	66.2	E	305.4	F
	Eason Blvd.	23.8	C	192.5	F	89.9	F	415.2	F
KCS	Eason Blvd.	0.4	A	78.3	E	1.0	A	98.7	F
	Elizabeth St.	0.5	A	80.3	F	1.1	A	108.4	F
	Main St.	0.4	A	66.5	E	0.8	A	75.2	E
	Jefferson St.	0.3	A	58.7	E	0.7	A	62.3	E

Figure 7-7
2005 PM Peak Hour Crossing Level of Service (Without Switching Operation)

Figure 7-8
2005 PM Peak Hour Crossing Level of Service (With Switching Operation)

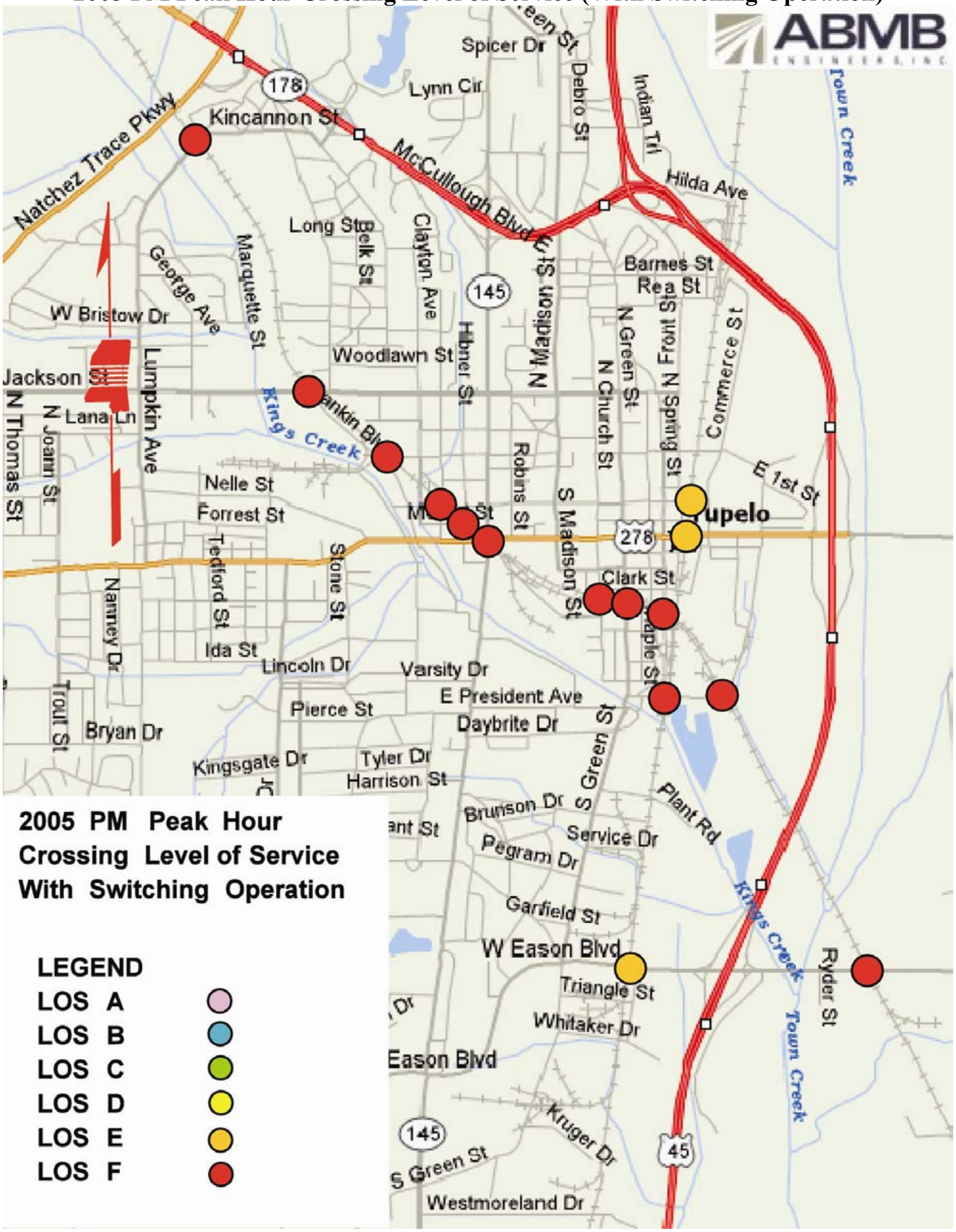
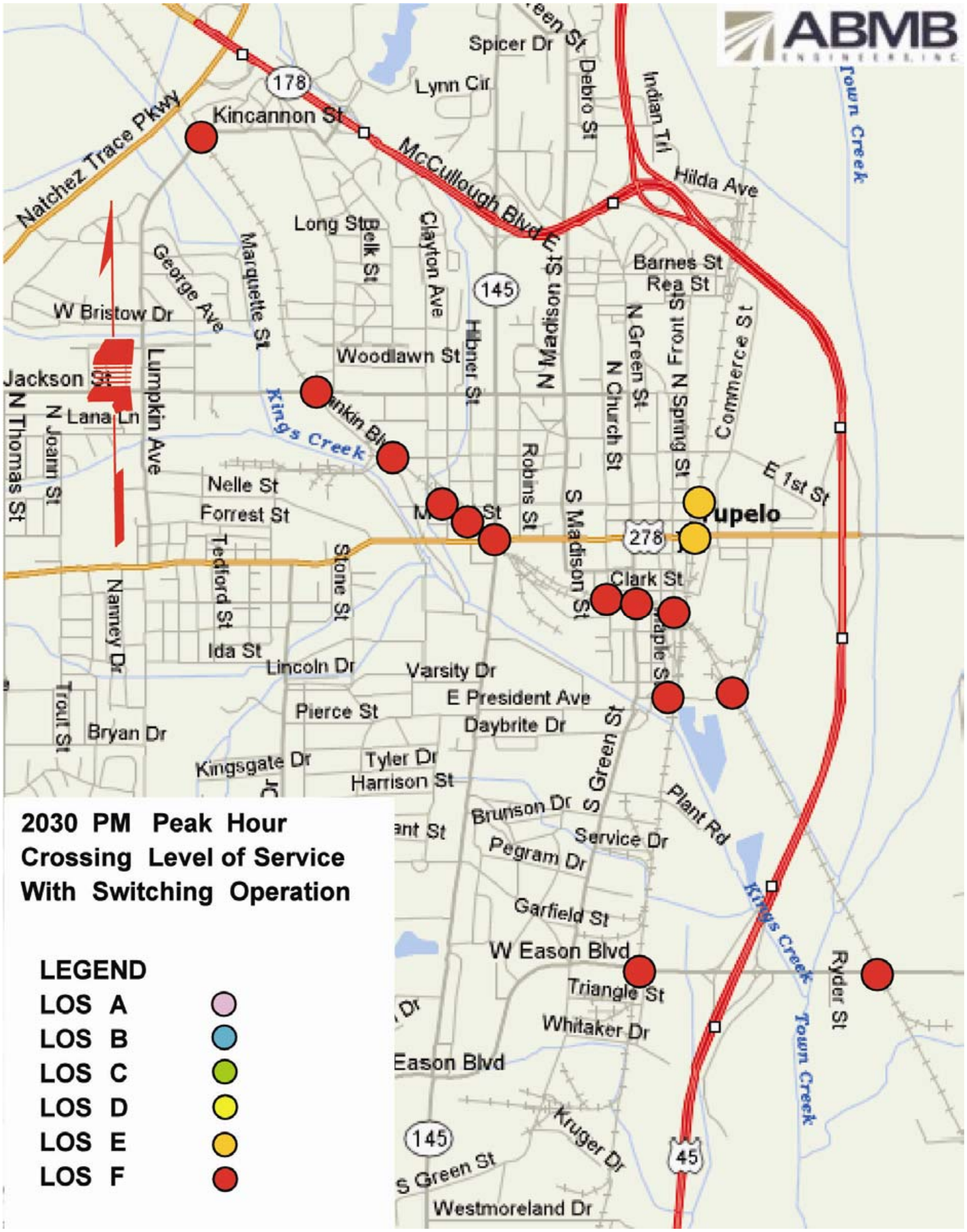


Figure 7-9
2030 PM Peak Hour Crossing Level of Service (Without Switching Operation)

Figure 7-10
2030 PM Peak Hour Crossing Level of Service (With Switching Operation)



7.3.2 Cost of Congestion at the Near-by Intersections

To evaluate the secondary impact on the near-by intersections by the at-grade railroad crossings, VISSIM computer traffic simulation software was used to evaluate the roadway network performance.

The simulations for a network of thirteen near-by intersections in the Tupelo downtown area were done for both year 2005 and year 2030 during PM time period. A scenario using no train traffic was simulated to forecast the rail relocated situation. This scenario can be used to compare the results generated by the with train scenario to focus only on the rail related impacts instead of the inefficiency caused by intersection control itself. Turning movement percentage for each of the thirteen intersections in 2005 and 2030 simulation models adopted the on-field turning percentage counts. The 2030 projected traffic volume was applied in the future year models. The models being simulated by VISSIM were:

- 2005 PM Time Period with Train Traffic;
- 2005 PM Time Period without Train Traffic;
- 2030 PM Time Period with Train Traffic; and
- 2030 PM Time Period without Train Traffic.

Each simulation model was run for 3 hours, and the total travel time (hr) and total delay time (hr) generated were then averaged into one hour for each model. The results of the overall network performance of the thirteen (13) near-by intersections are shown in **Table 7-17**.

The average vehicle delay (sec/veh) for each individual intersection in year 2005 and year 2030 in PM peak hour was also evaluated with VISSIM. The results are shown in **Table 7-18** and **Table 7-19**. **Figures 7-11 through 7-14** provide visual indication of the queuing occurred during PM peak hour of some of the crossing locations.

Table 7-17
Overall Near-by Intersections Network Performance Simulation Results

Overall Near-by Intersections Network Performance	2005 PM Peak Hour		2030 PM Peak Hour	
	No Train Traffic	With Train	No Train Traffic	With Train
Total Travel Time (hr)	208.1	318.5	498.8	940.2
Average Speed (mph)	24.7	16.2	14.7	7.5
Total Delay Time (hr)	47.3	157.3	270	720.6
Average Delay Time per Vehicle (sec)	15.8	52.6	62.7	170.9

Table 7-18
Year 2005 Near-by Intersections Delay and LOS in PM Peak Hour

No.	Intersection	Intersection Traffic Control	2005 PM Peak Hour						
			No Train Traffic		With Train Traffic		Estimated Max Delay Range (min)		
			Intersection Average Delay (sec/veh)	Intersection LOS	Intersection Average Delay (sec/veh)	Intersection LOS			
1	Clark St. at Church St.	Un-signalized	3.8	A	22.6	C	4	-	5
2	Gloster St. at Main St.	Signalized	33.8	C	125.3	F	7	-	8
3	Clark St. at Spring St.	Un-signalized	9.5	A	18.1	C	3	-	4
4	Spring St. at Elizabeth St.	Un-signalized	1.0	A	12.8	B	3	-	4
5	Front St. at Main St.	Signalized	12	B	13.2	B	2	-	3
6	Front St. at Jefferson St.	Signalized	7.6	A	8.8	A	1	-	2
7	Park St. at Jefferson St.	Signalized	15.7	B	47.2	D	5	-	6
8	Rankin St. at Blair St.	Signalized	7.0	A	17.0	B	3	-	7
9	Rankin St. at Jackson St.	Un-signalized	1.1	A	21.3	C	5	-	6
10	Eason St. at Ryder St.	Un-signalized	1.5	A	16.3	C	4	-	5
11	Eason St. at Whitaker St.	Un-signalized	0.8	A	1.2	A	1	-	2
12	Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.	Un-signalized	8.9	A	18.1	C	2	-	3
13	Gloster St. at Jefferson St.	Signalized	8.7	A	17.8	B	3	-	6

Table 7-19
Year 2030 Near-by Intersections Delay and LOS in PM Peak Hour

No.	Intersection	Intersection Traffic Control	2030 PM Peak Hour						
			No Train Traffic		With Train		Estimated Max Delay Range (min)		
			Intersection Average Delay (sec/veh)	Intersection LOS	Intersection Average Delay (sec/veh)	Intersection LOS			
1	Clark St. at Church St.	Unsignalized	4.0	A	28.1	D	4	-	5
2	Gloster St. at Main St.	Signalized	180.4	F	514.1	F	11	-	26
3	Clark St. at Spring St.	Unsignalized	10.4	B	32.1	D	4	-	5
4	Spring St. at Elizabeth St.	Unsignalized	1.5	A	25.6	D	4	-	5
5	Front St. at Main St.	Signalized	13.4	B	15.3	B	2	-	3
6	Front St. at Jefferson St.	Signalized	11.1	B	12.7	B	2	-	3
7	Park St. at Jefferson St.	Signalized	20.4	C	76.9	E	7	-	8
8	Rankin St. at Blair St.	Signalized	7.8	A	22.4	C	4	-	7
9	Rankin St. at Jackson St.	Unsignalized	1.4	A	37.9	E	5	-	6
10	Eason St. at Ryder St.	Unsignalized	2.2	A	22.3	C	5	-	6
11	Eason St. at Whitaker St.	Unsignalized	1.2	A	2.5	A	1	-	2
12	Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.	Unsignalized	9.6	A	23.0	C	2	-	5
13	Gloster St. at Jefferson St.	Signalized	12.9	B	87.0	F	6	-	11

The cost of congestion experienced in the thirteen near-by intersections was calculated and shown in **Table 7-20** for year 2005 and **Table 7-21** for year 2030. The total cost of congestion for year 2005 at the thirteen near-by intersections is $10.5 million USD and for year 2030 is $57.4 million USD.

To get the cost of congestion at the near-by intersections, first of all, at each intersection, the PM average delay (sec/veh) related only to train impact was obtained by subtracting the intersection average delay in 'with train scenario' from 'no train scenario'. By doing so, the average delay caused by intersection traffic control was excluded out. The only train related average delay during each of the other time periods was calculated based on the train volume, train length and intersection average delay at PM peak hour. For example, in year 2005, VISSIM determines that intersection one encounters an only train related average delay of 18.8 sec/veh during PM peak hour, in which it has 102 train cars per hour. During 2005 AM peak hour, there are 91 train cars per hour. The only train related intersection average delay in 2005 AM peak hour was obtained by dividing the PM average delay by the number of train cars per PM peak hour then multiplying the number of train cars per AM peak hour. It is equal to 16.8 sec/veh (=18.8/102×91). Then, at each intersection, the only train related average delay (sec/veh) during each time period was multiplied by the vehicle arrival rate at each intersection to get the aggregate delay (veh-hr). The 2005 daily aggregate delay was obtained by summing the aggregate delay of five periods during one day. To get the annual 250-workday aggregate delay, the daily delay value was multiplied by 250. This calculation procedure was done separately for 2030 scenario as well. After the annual workday aggregate delay was obtained, the calculation of delay cost followed the Texas Transportation Institute (TTI) congestion cost methodology as well. In each intersection, 5% of total motor vehicles were assumed to be commercial vehicles.

After generating the delay cost of year 2005 and year 2030, the total cumulative cost of congestion from 2005 and 2030 was calculated by integrating the trapezoid area along the time line with the two thresholds defined by year 2005 delay cost value and year 2030 delay cost value.

The cumulative cost of congestion from 2005 and 2030 at the thirteen near-by intersections as secondary impact by the at-grade train crossing is $848.2 million USD, which is summarized in **Table 7-22**.

Table 7-20
Current Year of 2005 Near-by Intersections Cost of Congestion

2005			Daily Aggregate Delay (veh-hr)	Annual 250 Work-Day Aggregate Delay (veh-hr)	Annual Passenger Vehicle		Annual Commercial Cost ($)	Total Delay Cost ($)
No.	**Intersection**	**Int'n Speed (mph)**			**Annual Passenger Vehicle Delay Cost ($)**	**Annual Passenger Vehicle Fuel Cost ($)**		
1	Clark St. at Church St.	30	5.9	1469.1	$50,600	$2,000	$11,300	**$63,900**
2	Gloster St. at Main St.	45	735.2	183796.6	$6,330,800	$330,500	$1,408,100	**$8,069,500**
3	Clark St. at Spring St.	30	5.7	1425.1	$49,100	$1,600	$10,900	**$61,600**
4	Spring St. at Elizabeth St.	30	30.4	7597.7	$261,700	$8,400	$58,200	**$328,300**
5	Front St. at Main St.	35	3.2	795.3	$27,400	$600	$6,100	**$34,100**
6	Front St. at Jefferson St.	30	1.3	313.1	$10,800	$200	$2,400	**$13,400**
7	Park St. at Jefferson St.	30	41.6	10387.9	$357,800	$17,200	$79,600	**$454,600**
8	Rankin St. at Blair St.	30	4.9	1223.4	$42,100	$2,400	$9,400	**$53,900**
9	Rankin St. at Jackson St.	30	31.0	7754.1	$267,100	$12,900	$59,400	**$339,400**
10	Eason St. at Ryder St.	30	49.3	12324.4	$424,500	$17,000	$94,400	**$536,000**
11	Eason St. at Whitaker St.	45	1.7	423.2	$14,600	$200	$3,200	**$18,000**
12	Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.	30	5.7	1421.2	$49,000	$1,200	$10,900	**$61,000**
13	Gloster St. at Jefferson St.	45	39.8	9949.4	$342,700	$13,400	$76,200	**$432,400**
Total			**955.5**	**238880.6**	**$8,228,200**	**$407,600**	**$1,830,100**	**$10,466,100**

Table 7-21
Future Year of 2030 Near-by Intersections Cost of Congestion

2030			Daily Aggregate Delay (veh-hr)	Annual 250 Work-Day Aggregate Delay (veh-hr)	Annual Passenger Vehicle		Annual Commercial Cost ($)	Total Delay Cost ($)
No.	**Intersection**	**Int'n Speed (mph)**			**Annual Passenger Vehicle Delay Cost ($)**	**Annual Passenger Vehicle Fuel Cost ($)**		
1	Clark St. at Church St.	30	11.1	2778.6	$95,700	$3,800	$21,300	**$120,800**
2	Gloster St. at Main St.	45	3921.3	980335.6	$33,767,500	$5,729,900	$7,510,600	**$47,008,000**
3	Clark St. at Spring St.	30	21.0	5262.4	$181,300	$7,300	$40,300	**$228,900**
4	Spring St. at Elizabeth St.	30	90.4	22587.8	$778,000	$31,200	$173,100	**$982,300**
5	Front St. at Main St.	35	7.4	1841.9	$63,400	$1,400	$14,100	**$79,000**
6	Front St. at Jefferson St.	30	2.4	609.2	$21,000	$500	$4,700	**$26,200**
7	Park St. at Jefferson St.	30	107.9	26977.2	$929,200	$59,700	$206,700	**$1,195,600**
8	Rankin St. at Blair St.	30	10.4	2604.8	$89,700	$5,000	$20,000	**$114,700**
9	Rankin St. at Jackson St.	30	85.4	21347.4	$735,300	$35,400	$163,500	**$934,300**
10	Eason St. at Ryder St.	30	107.6	26888.4	$926,200	$44,600	$206,000	**$1,176,800**
11	Eason St. at Whitaker St.	45	8.0	2012.3	$69,300	$900	$15,400	**$85,600**
12	Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.	30	12.2	3058.2	$105,300	$4,200	$23,400	**$133,000**
13	Gloster St. at Jefferson St.	45	475.9	118965.5	$4,097,700	$294,200	$911,400	**$5,303,400**
Total			**4861.1**	**1215269.3**	**$41,859,600**	**$6,218,100**	**$9,310,500**	**$57,388,600**

Table 7-22
From Current Year 2005 to Future Year of 2030 Near-by Intersections Cost of Congestion

From 2005 to 2030		Annual Passenger Vehicle		Annual Commercial Cost ($)	Total Delay Cost ($)
No.	**Intersection**	**Annual Passenger Vehicle Delay Cost ($)**	**Annual Passenger Vehicle Fuel Cost ($)**		
1	Clark St. at Church St.	$1,828,750	$72,500	$407,500	**$2,308,750**
2	Gloster St. at Main St.	$501,228,750	$75,755,000	$111,483,750	**$688,468,750**
3	Clark St. at Spring St.	$2,880,000	$111,250	$640,000	**$3,631,250**
4	Spring St. at Elizabeth St.	$12,996,250	$495,000	$2,891,250	**$16,382,500**
5	Front St. at Main St.	$1,135,000	$25,000	$252,500	**$1,413,750**
6	Front St. at Jefferson St.	$397,500	$8,750	$88,750	**$495,000**
7	Park St. at Jefferson St.	$16,087,500	$961,250	$3,578,750	**$20,627,500**
8	Rankin St. at Blair St.	$1,647,500	$92,500	$367,500	**$2,107,500**
9	Rankin St. at Jackson St.	$12,530,000	$603,750	$2,786,250	**$15,921,250**
10	Eason St. at Ryder St.	$16,883,750	$770,000	$3,755,000	**$21,410,000**
11	Eason St. at Whitaker St.	$1,048,750	$13,750	$232,500	**$1,295,000**
12	Lumpkin Ave. at Shands St./Trace Ave./Kincannon St.	$1,928,750	$67,500	$428,750	**$2,425,000**
13	Gloster St. at Jefferson St.	$55,505,000	$3,845,000	$12,345,000	**$71,697,500**
Total		**$626,097,500**	**$82,821,250**	**$139,257,500**	**$848,183,750**

Figure 7-11
Year 2005 PM Peak Hour BNSF Train Crossing Eason Blvd. at Ryder St.

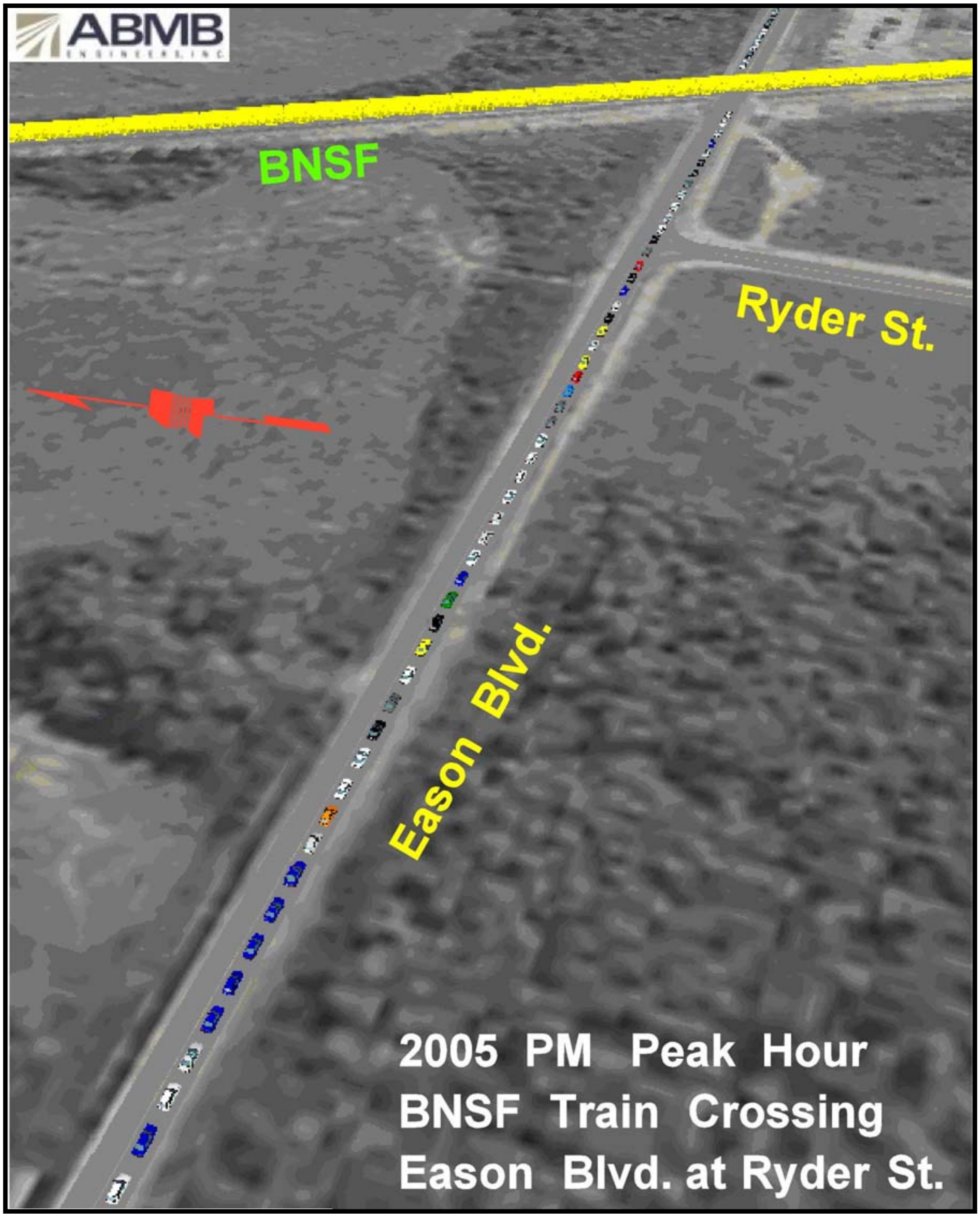


Figure 7-12
Year 2030 PM Peak Hour BNSF Train Crossing Gloster St. at Main St. & Park St. at Jefferson St.

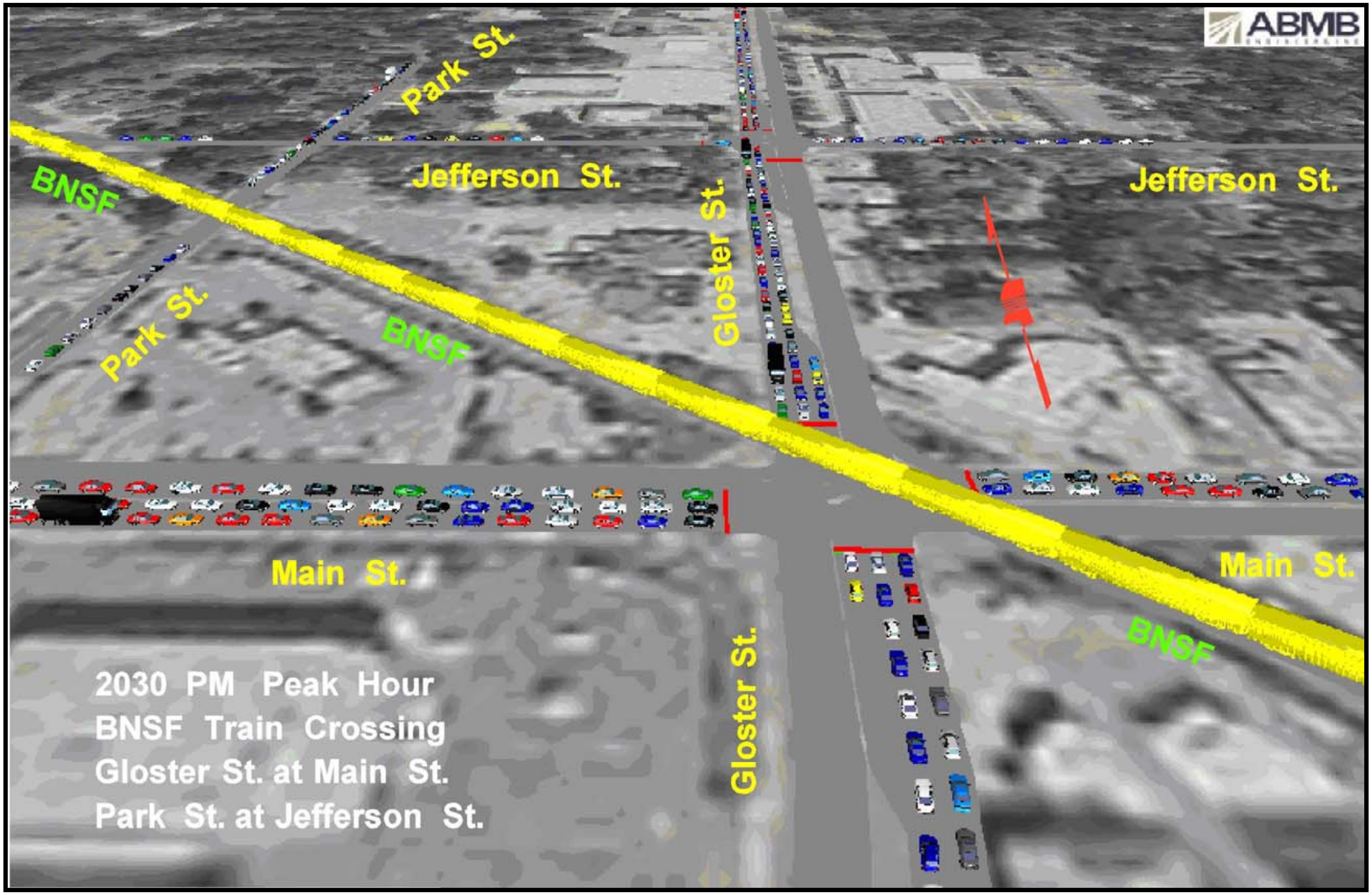


Figure 7-13
Year 2030 PM Peak Hour BNSF Train Crossing Elizabeth St. at Spring St.

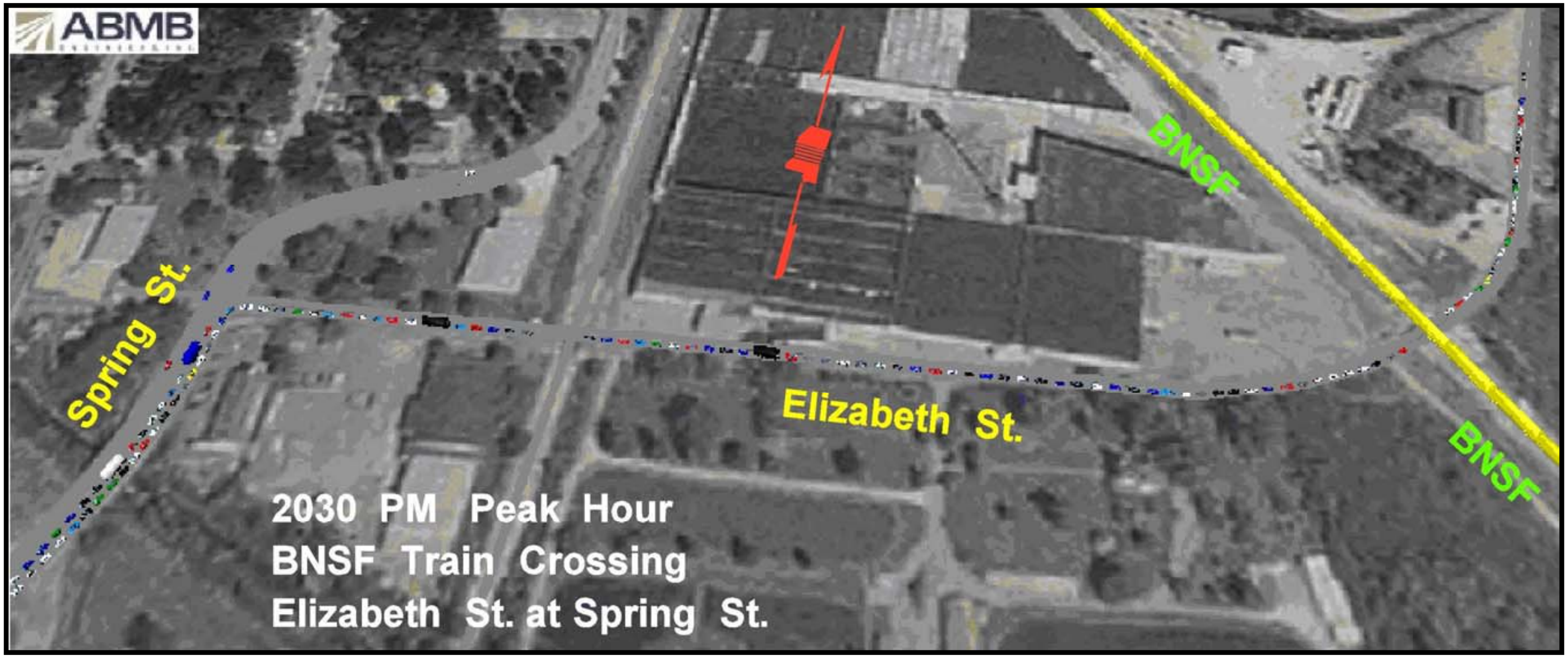
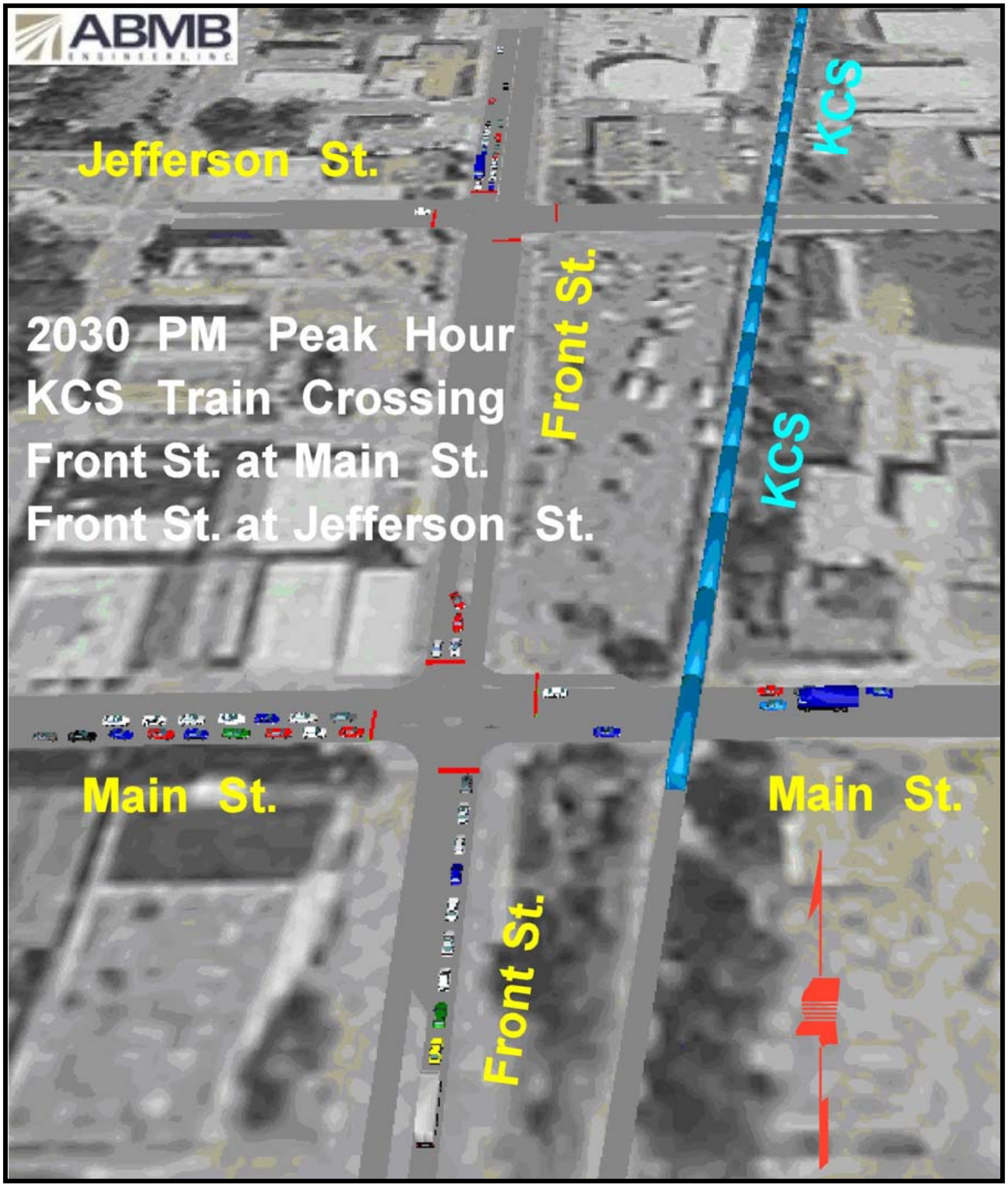


Figure 7-14
Year 2030 PM Peak Hour KCS Train Crossing Front St. at Main St. & Front St. at Jefferson St.



7.4 SUMMARY OF AT-GRADE CROSSING TRAFFIC DELAY STUDY

The traffic delay at the at-grade crossings in downtown Tupelo was calculated in two components based on train volume. The first component was the at-grade crossing vehicle delay and the second component was the delay caused at near-by intersections as a result of delay at the at-grade crossings. The current year 2005 condition and future year 2030 condition were modeled for both of the components.

The total train volume for each of the two rail lines were 23 BNSF trains per day and 3 KCS trains per day in the current year 2005, and 40 BNSF trains per day and 4 KCS trains per day in the future year 2030. While the train schedules are not fixed, they are crucial to the vehicle delay outcome. The train volume distribution for both BNSF line and KCS line was assumed as a uniform distribution with the total train events evenly distributed throughout the day. This distribution will result in an average cost of congestion incurred by the at-grade crossings. More detailed information of the train schedule distribution scenarios was provided in **Section 7.2.1.3.**

For the first component, i.e. the at-grade crossing vehicle delay which is documented in **Section 7.3.1**, the calculation of the at-grade crossings was followed by the uniform delay method, which assumes the arrival rate of vehicles is uniform during a period of a day. The departure rate of vehicles is reduced by the percentage of heavy vehicles based upon roadway type at the at-grade crossings from the ideal saturation flow rate at a signalized intersection. The ideal saturation flow is 1900 passenger cars per hour per lane for multilane highway with free-flow speed of 45 mph or lower, based on the Highway Capacity Manual (HCM) 2000. The corresponding cost of congestion at the at-grade crossings was calculated based on the Texas Transportation Institute (TTI) congestion cost methodology. The at-grade crossing level of service (LOS) was evaluated based on the signalized intersection LOS threshold stated in the HCM 2000. More detailed information concerning the methodology and results are provided in **Section 7.2** and **Section 7.3.1**.

Table 7-23 shows the summarized results for the level of service at the at-grade crossings.

Table 7-23
Summary of Level of Service at the At-Grade Crossings in the Year 2005 and Year 2030 during PM Peak Hour

Crossing Line	Crossing Street Name	2005 Peak Hour		2030 Peak Hour	
		Without Switching Operation	With Switching Operation	Without Switching Operation	With Switching Operation
		Crossing Level of Service			
BNSF	Lumpkin Ave.	B	F	D	F
	Jackson St.	B	F	D	F
	Blair St.	B	F	D	F
	Jefferson St.	B	F	D	F
	Park St.	B	F	D	F
	Gloster St.	B	F	D	F
	Main St.	B	F	D	F
	Church St.	B	F	D	F
	Green St.	B	F	D	F
	Spring St.	B	F	D	F
	Elizabeth St.	C	F	E	F
	Eason Blvd.	C	F	F	F
KCS	Eason Blvd.	A	E	A	F
	Elizabeth St.	A	F	A	F
	Main St.	A	E	A	E
	Jefferson St.	A	E	A	E

For the second component, i.e. the delay on the near-by intersections caused by the at-grade crossings as a secondary impact, time and queuing length as well as level of service were modeled by the VISSIM traffic simulation computer software during PM peak hour. The train scenario was modeled under both current year 2005 PM traffic condition and future year 2030 PM traffic condition.

The results are depicted in **Table 7-24**. The "No Train Traffic" columns in this table represent the railroad relocated situation for both year 2005 and year 2030, respectively.

Table 7-24
Summary of Level of Service for the Near-by Intersections during PM Peak Hour in the Year 2005 and Year 2030

No.	Intersection	2005 PM Peak Hour		2030 PM Peak Hour	
		No Train Traffic	With Train	No Train Traffic	With Train
		LOS	LOS	LOS	LOS
1	Clark St. at Church St.	A	C	A	D
2	Gloster St. at Main St.	C	F	F	F
3	Clark St. at Spring St.	A	C	B	D
4	Spring St. at Elizabeth St.	A	B	A	D
5	Front St. at Main St.	B	B	B	B
6	Front St. at Jefferson St.	A	A	B	B
7	Park St. at Jefferson St.	B	D	C	E
8	Rankin St. at Blair St.	A	B	A	C
9	Rankin St. at Jackson St.	A	C	A	E
10	Eason St. at Ryder St.	A	C	A	C
11	Eason St. at Whitaker St.	A	A	A	A
12	Lumpkin Ave./Shands St./ Trace Ave./Kincannon St.	A	C	A	C
13	Gloster St. at Jefferson St.	A	B	B	F

The total cost of congestion at both the at-grade crossings and near-by intersections for year 2005 and year 2030 is summarized in **Table 7-25**. The cumulative cost of congestion from year 2005 to year 2030 is summarized in **Table 7-26**.

Table 7-25
Annual Cost of Congestion for Year 2005 and Year 2030

Year	At-Grade Crossing	Near-by Intersections as Secondary Impact	Total Cost of Congestion
2005	$7,817,200	$10,466,100	**$18,283,300**
2030	$24,556,700	$57,388,600	**$81,945,300**

Table 7-26
Cumulative Cost of Congestion from Year 2005 to Year 2030

From 2005 to 2030	At-Grade Crossing	Near-by Intersections as Secondary Impact	Total Cost of Congestion
	$402,621,900	$848,183,750	**$1,250,805,650**

7.5 GENERAL CONCLUSIONS

The following conclusions are made from the at-grade traffic delay analysis and traffic simulation analysis for downtown Tupelo.

- The locations selected for simulation were chosen due to the proximity of the BNSF and KCS lines to these highly congested streets and intersections.
- The 2030 "no train" model indicates that the intersection of Gloster St. at Main St. is projected to be over capacity during the PM peak hour even without disruption of any train crossing.
- The length of a typical BNSF train is from 3400 ft to 8670 ft, which extends nearly half of the Tupelo downtown area. Traffic in half of the downtown going across the BNSF rail track will have to stop simultaneously.
- The at-grade crossings raise a safety concern for local schools close to the crossing section, such as Milam Elementary School, located on West Jefferson St. right next to Gloster St.
- The delays and queues caused by the at-grade crossing at the intersection of Gloster St. and Main St. causes overflow delays in the intersection of Gloster St. and Jefferson St.
- If the rail remains through Tupelo, grade separation at Gloster St. will be necessary to reduce the near-by intersections delay time, such as the intersection of Gloster St. at Main St., and intersection of Gloster St. at Jefferson St.
- The intersection signal timing in the intersection of Main St. at Front St. needs to be considered to give more maximum green time on Main St. The signal itself is currently more sensitive to the less traffic approach from Front St. and causes overflow delay in Main St. from both westbound and eastbound approaches even without train interruption. Especially for vehicles coming from the westbound approach on Main St. which need to cross the rail track before entering the intersection, vehicles remain on the rail track due to inadequate green time to clear through when there are only few vehicles to call the signal to change on the Front St. southbound.
- The stopped vehicles on rail track cause potential safety concerns and has caused train-vehicle collision accidents in the past.