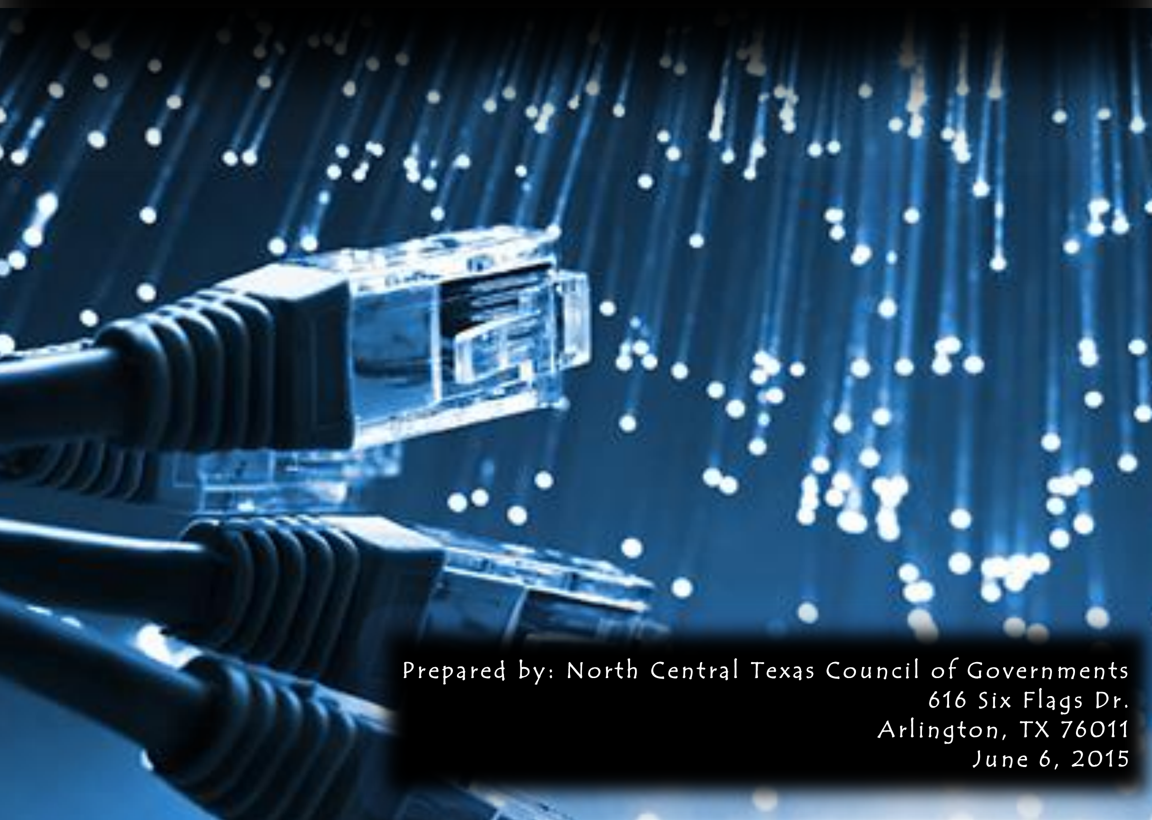
Application for 2015 TIGER Discretionary Grant

Appendix A
Benefit Cost Calculation



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June 6, 2015

BENEFIT COST METHODOLOGY, ANALYSIS AND CALCULATIONS

The following description provides the methodology for various sections within the Benefit Cost Analysis (BCA) including an overall benefit of all facilities for the years 2020 through 2040, for each cost and benefit factor. Benefits are assumed to occur after project completion in January 2020 for a 20 year life span of the projects to 2040.

Benefits

Using output from the DFW Regional Travel Model, NCTCOG utilized the following post-processing technique to calculate the non-recurrent and recurrent congestion to analyze the Benefit Cost Analysis for this project. An overall cost-benefit summary sheet was prepared. Costs are calculated from 2018 to 2040. All monetized estimates were discounted at 3% and 7% rates to 2015, and Benefit to Cost ratios were calculated for the values based on 3% and 7%. The detail tables (Excel) include a Constants (tab) to list the multipliers used in the analysis.

Mobility Benefits

Post-Processing Technique, Task 1: Travel time reduction due to mitigation of non-recurrent congestion

Reduction in non-recurrent congestion per day on congested freeways (vehicle hours/weekday) = Vehicle hours of congestion delay on freeways per weekday x Percentage of freeway centerline miles that are congested x Percentage of non-recurrent congestion eliminated on congested freeways with ITS deployment during peak hours.

Reduction in non-recurrent congestion per day on uncongested freeways (vehicle hours/weekday) = Vehicle hours of congestion delay on freeways per weekday x Percentage of freeway centerline miles that are uncongested x Percentage of non-recurrent congestion eliminated on uncongested freeways with ITS deployment during peak hours.

Total reduction in non-recurrent congestion per day (vehicle hours/weekday) = Reduction in non-recurrent congestion per day on congested freeways + Reduction in non-recurrent congestion per day on uncongested freeways.

Annual Saving of Non-Recurrent Congestion ($/year) = Total reduction in non-recurrent congestion per day x Vehicle occupancy x Number of weekdays per year x Value of time.

Post-Processing Technique, Task 2: Travel time reduction due to mitigation of recurrent congestion

Reduction in recurrent congestion per day on congested freeways (vehicle hours/weekday) = Vehicle hours of congestion delay on freeways per weekday x Percentage of freeway centerline miles that are congested x Percentage of recurrent congestion eliminated on congested freeways with ITS deployment during peak hours.

Reduction in recurrent congestion per day on uncongested freeways (vehicle hours/weekday) = Vehicle hours of congestion delay on freeways per weekday x Percentage of freeway centerline miles that are uncongested x Percentage of recurrent congestion eliminated on uncongested freeways with ITS deployment during peak hours.

Total reduction in recurrent congestion per day (vehicle hours/weekday) = Reduction in recurrent congestion per day on congested freeways + Reduction in recurrent congestion per day on uncongested freeways.

Annual Saving of Recurrent Congestion ($/year) = Reduction in total recurrent congestion per day x Vehicle occupancy x Number of weekdays per year x Value of time.

Total Annual Saving ($/Year) = Annual Saving of Non-Recurrent Congestion ($/year) + Annual Saving of Recurrent Congestion ($/year).

Assumptions:

Vehicle hours of congestion delay on freeways per weekday provided by the DFW Regional Travel Model.

Percentage of freeway centerline miles congested (LOS D, E, and F) and uncongested (LOS A, B, and C) provided by DFW Regional Travel Model.

Percentage of non-recurrent congestion eliminated on congested freeways with ITS deployment during peak hours = 0.048 (48%[1] of non-recurrent congestion eliminated on congested freeways with ITS deployment and 10% of daily traffic is assumed to occur during the peak hour).

Percentage of non-recurrent congestion eliminated on uncongested freeways with ITS deployment during peak hours = 0.023 (23%[1] of non-recurrent congestion eliminated on uncongested freeways with ITS deployment and 10% of daily traffic is assumed to occur during the peak hour).

Percentage of recurrent congestion eliminated on congested freeways with ITS deployment during peak hours = 0.03 (30%[11] of recurrent congestion eliminated on congested freeways with ITS deployment and 10% of daily traffic is assumed to occur during the peak hour).

Percentage of recurrent congestion eliminated on uncongested freeways with ITS deployment during peak hours = 0.005 (5%[1] of recurrent congestion eliminated on uncongested freeways with ITS deployment and 10% of daily traffic is assumed to occur during the peak hour).

Vehicle occupancy provided by the Mobility 2035 – 2014 Amendment = 1.35
Number of weekdays per year provided by the Mobility 2035 – 2014 Amendment = 251
Value of time provided by the 2015 TIGER Discretionary Grant = $19.00

Air Quality Benefits

Air Quality Benefits were calculated based on the total vehicle hours of congestion delay on freeways per weekday and MoSERS methodologies used for the 2013 Transportation Conformity process.[2] A detailed methodology on the calculation of Nitrogen Oxides (NO_X), Volatile Organic Compounds (VOC), and Carbon Dioxide (CO_2) are available at the web link in the reference. The Recommended Monetized Values of the above air quality benefits provided by the BCA Online Supplement were used to estimate the value of emission benefits. The following outlines the methodology.

Change in estimated NO_x, VOC and CO_2 Emissions from alleviating peak hour non-recurrent congestion (tons/day) = Total NO_x, VOC and CO_2 generated during the peak period in tons per day x Percentage of freeway emissions caused by peak hour non-recurrent congestion x Percentage of freeway coverage with ITS deployment x Percentage of non-recurrent congestion eliminated on freeways with ITS deployment

Change in estimated NO_x, VOC and CO_2 Emissions from alleviating peak hour recurrent congestion (tons/day) = Total NO_x, VOC and CO_2 generated during the peak period in tons per day x Percentage of freeway emissions caused by peak hour recurrent congestion x Percentage of freeway coverage with ITS deployment

Change in estimated Total NO_x, VOC and CO_2 Emissions from alleviating peak hour congestion (tons/day) = Change in estimated NO_x, VOC and CO_2 Emissions from alleviating peak hour non-recurrent congestion (tons/day) + Change in estimated NO_x, VOC and CO_2 Emissions from alleviating peak hour recurrent congestion (tons/day)

ASSUMPTIONS:

Total emissions (NO_x, VOC and CO_2) generated in the four county areas is developed through the Environmental Protection Agency's Motor Vehicle Emissions Simulator Percentage of freeway coverage with ITS deployment which is obtained from the DFW ITS Map (total centerline miles with ITS deployment / total centerline miles).

Percentage of freeway emissions caused by peak hour non-recurrent congestion = 0.049 [1] (49% of urban freeways are congested due to an incident and 10% of daily traffic is assumed to occur during the peak hour).

Percentage of non-recurrent congestion eliminated on freeways with ITS deployment = 48%. [1]

Percentage of recurrent congestion eliminated on freeways with ITS deployment = 5%. [1]

Safety

Crash data were used to measure the impact this project is expected to have on the number of crashes. Crash data were obtained in the project area for the five-year period from January 2010 through December 2014, and were used as the basis for predicting the expected number of crashes in the future. Over this five-year period, there were a total of 6,832 accidents in the project area.

The impact of the project on the number of crashes on the regional network in four counties was determined using methods outlined in Part D of the *Highway Safety Manual* (American Association of State Highway and Transportation Officials, First Edition, 2010). The method uses Crash Modification Factors (CMFs). A CMF is a factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. It is defined as the ratio of expected crash frequency with improvement over the situation without improvement. The numbers of existing crashes along the roadway network were multiplied by CMF to determine the number of crashes that could be expected after the project is complete. CMF for this analysis were obtained on the Crash Modification Factors Clearinghouse website (http://www.cmfclearinghouse.org/). The data on that website indicates that ITS projects like the one in this proposal that improve real-time traffic information, reduce injury accidents on a corridor by 44% (CMF = 0.56).

Injury and fatality numbers used for this calculation were drawn from the TxDOT Crash Record Information System (CRIS) (2014). A modification factor was applied to the accident data due to the impact of the proposed project. This data was converted to Abbreviated Injury Scale (AIS) using KABCO scale accident numbers, and then the formula provided in the TIGER Benefit-Cost Analysis Resource Guide was applied. The dollar benefit of reduction in injury and fatal crashes was estimated using the DOT's monetized values of a statistical life (2013). The 2013 monetized values were converted to 2015 monetized values using the Consumer Price Index (CPI).

Likelihood Multiplier

The mobility, air quality and safety benefits were determined for the region. In order to determine benefits of the baseline and proposed project separately, it was assumed that the baseline infrastructure provide benefits proportional to the total existing fiber optic coverage and total existing connections. This number was multiplied by the 21% increase in coverage for filling in gaps and the 56% increase in new connections was applied. These percentages were calculated as outlined below to create a likelihood multiplier of 0.12. In other words, the baseline system is assumed to provide 88% of the total benefits and the proposed TIGER Grant funds project to provide 12% of the total benefit.

Percent new coverage

134 new miles / (134 new miles +498 existing miles) = 21%

Percent new connections

13 new connections / (13 new connections +10 existing connections) = 56%

Likelihood Multiplier = Mobility Benefit x 0.21 x 0.56

Air Quality Benefit x 0.21 x 0.56

Safety Benefit x 0.21 x 0.56

[1] Texas Transportation Institute, "Dallas Area Wide Intelligent Transportation Plan", July 1996.

[2] MoSERS Methodology/ Calculation Description http://www.nctcog.org/trans/air/conformity/2009/Ap919.pdf

Benefit Cost Analysis - Summary of Costs and Benefits

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)
		Project Costs					**Project Benefits**											
		Annual Project Costs			**Net Present Value (NPV) Discounted to 2015**		**Annual Project Benefits**				**Net Present Value (NPV) Discounted to 2015**		**CO2 Emission Reduction Benefit**		**TOTAL BENEFIT**		**NET BENEFIT**	
Analysis Year	**Calendar Year**	**Project Cost**	**Operation and Maintenance Cost**	**TOTAL ANNUAL COST**	**NPV of Project Costs (3% Discount Rate)**	**NPV of Project Costs (7% Discount Rate)**	**Non-CO2 Emissions Benefit**	**Total Safety Benefit**	**Total Mobility Benefit**	**Annual Benefit Subtotal**	**NPV of Project Benefits (3% Discount Rate)**	**NPV of Project Benefits (7% Discount Rate)**	**CO2 Emission Reduction Benefit**	**NPV of CO2 Emission Reduction Benefit (3% Discount Rate)**	**TOTAL ANNUAL BENEFIT (3% Discount Rate)**	**TOTAL ANNUAL BENEFIT (7% Discount Rate)**	**NET BENEFIIT (3% Discount Rate)**	**NET BENEFIT (7% Discount Rate)**
3	2018*	$5,000,000		$5,000,000	$4,575,708	$4,081,489	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$4,575,708	-$4,081,489
4	2019	$5,000,000		$5,000,000	$4,442,435	$3,814,476	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$4,442,435	-$3,814,476
5	2020	$5,000,000	$1,500,000	$6,500,000	$5,606,957	$4,634,410	$1,033,292	$61,015,467	$24,021,353	$86,070,112	$74,244,835	$61,366,801	$7,260,295	$6,262,794	$80,507,629	$67,629,595	$74,900,672	$62,995,185
6	2021		$1,500,000	$1,500,000	$1,256,226	$999,513	$1,007,666	$61,015,467	$24,815,586	$86,838,719	$72,726,060	$57,864,305	$7,341,766	$6,148,613	$78,874,674	$64,012,919	$77,618,447	$63,013,406
7	2022		$1,500,000	$1,500,000	$1,219,637	$934,125	$982,039	$61,015,467	$25,923,147	$87,920,654	$71,487,537	$54,752,564	$7,422,601	$6,035,254	$77,522,791	$60,787,818	$76,303,154	$59,853,694
8	2023		$1,500,000	$1,500,000	$1,184,114	$873,014	$956,413	$61,015,467	$26,721,569	$88,693,449	$70,015,428	$51,620,395	$7,500,292	$5,920,800	$75,936,227	$57,541,195	$74,752,114	$56,668,181
9	2024		$1,500,000	$1,500,000	$1,149,625	$815,901	$930,786	$61,015,467	$27,516,915	$89,463,169	$68,566,069	$48,662,036	$7,577,385	$5,807,435	$74,373,504	$54,469,471	$73,223,879	$53,653,570
10	2025		$1,500,000	$1,500,000	$1,116,141	$762,524	$905,160	$61,015,467	$28,656,604	$90,577,232	$67,397,967	$46,044,872	$7,781,418	$5,790,106	$73,188,073	$51,834,977	$72,071,932	$51,072,453
11	2026		$1,500,000	$1,500,000	$1,083,632	$712,639	$879,534	$61,015,467	$29,456,139	$91,351,140	$65,994,007	$43,400,269	$7,853,761	$5,673,724	$71,667,731	$49,073,993	$70,584,100	$48,361,354
12	2027		$1,500,000	$1,500,000	$1,052,070	$666,018	$853,907	$61,015,467	$30,620,693	$92,490,067	$64,870,672	$41,066,696	$7,924,201	$5,557,875	$70,428,547	$46,624,571	$69,376,477	$45,958,553
13	2028		$1,500,000	$1,500,000	$1,021,427	$622,447	$828,281	$61,015,467	$31,424,416	$93,268,164	$63,511,081	$38,702,972	$7,991,425	$5,441,772	$68,952,853	$44,144,744	$67,931,426	$43,522,297
14	2029		$1,500,000	$1,500,000	$991,677	$581,726	$802,653	$61,015,467	$32,815,515	$94,633,636	$62,563,982	$36,700,555	$7,931,694	$5,243,784	$67,807,766	$41,944,340	$66,816,089	$41,362,614
15	2030		$1,500,000	$1,500,000	$962,793	$543,669	$777,027	$61,015,467	$34,225,870	$96,018,364	$61,630,534	$34,801,474	$8,121,574	$5,212,929	$66,843,463	$40,014,403	$65,880,671	$39,470,734
16	2031		$1,500,000	$1,500,000	$934,750	$508,102	$751,401	$61,015,467	$35,236,997	$97,003,865	$60,449,602	$32,858,565	$8,184,351	$5,100,217	$65,549,819	$37,958,782	$64,615,068	$37,450,680
17	2032		$1,500,000	$1,500,000	$907,525	$474,862	$725,774	$61,015,467	$36,672,511	$98,413,752	$59,541,939	$31,155,274	$8,245,290	$4,988,536	$64,530,475	$36,143,810	$63,622,950	$35,668,948
18	2033		$1,500,000	$1,500,000	$881,092	$443,796	$700,148	$61,015,467	$38,127,280	$99,842,895	$58,647,178	$29,539,910	$8,303,125	$4,877,211	$63,524,389	$34,417,121	$62,643,297	$33,973,325
19	2034		$1,500,000	$1,500,000	$855,429	$414,762	$674,521	$61,015,467	$39,601,304	$101,291,292	$57,765,009	$28,007,886	$8,360,197	$4,767,704	$62,532,712	$32,775,590	$61,677,283	$32,360,827
20	2035		$1,500,000	$1,500,000	$830,514	$387,629	$648,895	$61,015,467	$42,121,884	$103,786,246	$57,463,928	$26,820,338	$8,534,912	$4,725,574	$62,189,502	$31,545,912	$61,358,988	$31,158,284
21	2036		$1,500,000	$1,500,000	$806,324	$362,270	$623,269	$61,015,467	$43,640,322	$105,279,058	$56,592,681	$25,426,270	$8,587,304	$4,616,099	$61,208,781	$30,042,369	$60,402,457	$29,680,100
22	2037		$1,500,000	$1,500,000	$782,839	$338,570	$597,642	$61,015,467	$45,178,015	$106,791,124	$55,733,487	$24,104,163	$8,636,555	$4,507,353	$60,240,840	$28,611,516	$59,458,001	$28,272,946
23	2038		$1,500,000	$1,500,000	$760,038	$316,420	$572,015	$61,015,467	$46,209,681	$107,797,163	$54,619,933	$22,739,476	$8,685,149	$4,400,693	$59,020,626	$27,140,169	$58,260,589	$26,823,749
24	2039		$1,500,000	$1,500,000	$737,901	$295,720	$546,388	$61,015,467	$47,772,533	$109,334,389	$53,785,274	$21,554,905	$8,847,546	$4,352,406	$58,137,681	$25,907,312	$57,399,780	$25,611,592
25	2040		$1,500,000	$1,500,000	$716,408	$276,374	$520,762	$61,015,467	$49,354,641	$110,890,870	$52,962,097	$20,431,552	$8,891,313	$4,246,541	$57,208,638	$24,678,092	$56,492,229	$24,401,718
		$15,000,000	*$31,500,000*	*$46,500,000*	*$33,875,261*	*$23,860,454*	*$16,317,573*	*$1,281,324,812*	*$740,112,976*	*$2,037,755,361*	*$1,310,569,301*	*$777,621,278*	*$169,982,154*	*$109,677,420*	*$1,420,246,721*	*$887,298,698*	*$1,395,389,603*	*$871,334,209*
			TOTAL COST	**$46,500,000**	**$33,875,261**	**$23,860,454**								**TOTAL BENEFIT**	**$1,420,246,721**	**$887,298,698**	**$1,386,371,460**	**$863,438,243**

BENEFIT-COST RATIO	
Total Values	
3% Discount Rate	**41.9**
7% Discount Rate	**37.2**

*** No costs or benefits before 2018**

Benefit Cost Analysis - Costs

Year	Project Cost	Operation and Maintenance Cost	Total Cost	Years from Start	Discounted to 2015: 3%	Discounted to 2015: 7%
2018	$5,000,000		$5,000,000	3	$ 4,575,708	$ 4,081,489
2019	$5,000,000		$5,000,000	4	$ 4,442,435	$ 3,814,476
2020	$5,000,000	$1,500,000	$6,500,000	5	$ 5,606,957	$ 4,634,410
2021		$1,500,000	$1,500,000	6	$ 1,256,226	$ 999,513
2022		$1,500,000	$1,500,000	7	$ 1,219,637	$ 934,125
2023		$1,500,000	$1,500,000	8	$ 1,184,114	$ 873,014
2024		$1,500,000	$1,500,000	9	$ 1,149,625	$ 815,901
2025		$1,500,000	$1,500,000	10	$ 1,116,141	$ 762,524
2026		$1,500,000	$1,500,000	11	$ 1,083,632	$ 712,639
2027		$1,500,000	$1,500,000	12	$ 1,052,070	$ 666,018
2028		$1,500,000	$1,500,000	13	$ 1,021,427	$ 622,447
2029		$1,500,000	$1,500,000	14	$ 991,677	$ 581,726
2030		$1,500,000	$1,500,000	15	$ 962,793	$ 543,669
2031		$1,500,000	$1,500,000	16	$ 934,750	$ 508,102
2032		$1,500,000	$1,500,000	17	$ 907,525	$ 474,862
2033		$1,500,000	$1,500,000	18	$ 881,092	$ 443,796
2034		$1,500,000	$1,500,000	19	$ 855,429	$ 414,762
2035		$1,500,000	$1,500,000	20	$ 830,514	$ 387,629
2036		$1,500,000	$1,500,000	21	$ 806,324	$ 362,270
2037		$1,500,000	$1,500,000	22	$ 782,839	$ 338,570
2038		$1,500,000	$1,500,000	23	$ 760,038	$ 316,420
2039		$1,500,000	$1,500,000	24	$ 737,901	$ 295,720
2040		$1,500,000	$1,500,000	25	$ 716,408	$ 276,374
Total	**$15,000,000**	**$31,500,000**	**$46,500,000**		**$33,875,261**	**$23,860,454**

Total cost	$15,000,000	
Start	End	Yrs
2018	2020	3
Per year	$5,000,000.00	

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NO_X (lbs/day)	6,465	6,301	6,136	5,971	5,807	5,642	5,478	5,313	5,149	4,984	4,819
NO_X (lbs/year)	2,359,826	2,299,749	2,239,672	2,179,595	2,119,518	2,059,441	1,999,364	1,939,287	1,879,210	1,819,133	1,759,056
VOC (lbs/day)	1,068	1,058	1,048	1,039	1,029	1,019	1,010	1,000	990	980	971
VOC (lbs/year)	389,812	386,257	382,702	379,148	375,593	372,038	368,484	364,929	361,374	357,819	354,265
CO_2 (lbs/day)	6,794,753	6,746,817	6,698,880	6,650,944	6,603,007	6,555,071	6,507,134	6,459,198	6,411,261	6,363,324	6,315,388
CO_2 (lbs/year)	2,480,084,959	2,462,588,121	2,445,091,282	2,427,594,444	2,410,097,606	2,392,600,768	2,375,103,929	2,357,607,091	2,340,110,253	2,322,613,415	2,305,116,576
Likelihood Multiplier	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
NO_X (lbs/year)	277,515	270,450	263,385	256,320	249,255	242,190	235,125	228,060	220,995	213,930	206,865
VOC (lbs/year)	45,842	45,424	45,006	44,588	44,170	43,752	43,334	42,916	42,498	42,080	41,662
CO_2 (lbs/year)	291,657,991	289,600,363	287,542,735	285,485,107	283,427,478	281,369,850	279,312,222	277,254,594	275,196,966	273,139,338	271,081,709

	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
NO_X (lbs/day)	4,655	4,490	4,326	4,161	3,996	3,832	3,667	3,503	3,338	3,173
NO_X (lbs/year)	1,698,979	1,638,902	1,578,825	1,518,748	1,458,671	1,398,594	1,338,518	1,278,441	1,218,364	1,158,287
VOC (lbs/day)	961	951	941	932	922	912	902	893	883	873
VOC (lbs/year)	350,710	347,155	343,601	340,046	336,491	332,937	329,382	325,827	322,273	318,718
CO_2 (lbs/day)	6,267,451	6,219,515	6,171,578	6,123,642	6,075,705	6,027,769	5,979,832	5,931,896	5,883,959	5,836,022
CO_2 (lbs/year)	2,287,619,738	2,270,122,900	2,252,626,062	2,235,129,224	2,217,632,385	2,200,135,547	2,182,638,709	2,165,141,871	2,147,645,032	2,130,148,194
Likelihood Multiplier	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
NO_X (lbs/year)	199,800	192,735	185,670	178,605	171,540	164,475	157,410	150,345	143,280	136,215
VOC (lbs/year)	41,244	40,825	40,407	39,989	39,571	39,153	38,735	38,317	37,899	37,481
CO_2 (lbs/year)	269,024,081	266,966,453	264,908,825	262,851,197	260,793,569	258,735,940	256,678,312	254,620,684	252,563,056	250,505,428

	Annual Nox Reduction		Cost of Emissions (2014$)	Emission Reduction Benefit	Annual VOC Reduction		Cost of Emissions (2014$)	Emission Reduction Benefit	Non-CO2 Emissions Benefit	YEARS from 2015	Discounted (to 2015)	
	lbs/year	longtons/year	$ 8,005		lbs/year	longtons/year	$ 2,031				3%	7%
2020	277,515	123.89		991,718.93	45,842	20.47		41,573.38	$ 1,033,292	7	$840,161	$643,482
2021	270,450	120.74		966,471.54	45,424	20.28		41,194.28	$ 1,007,666	8	$795,461	$586,471
2022	263,385	117.58		941,224.15	45,006	20.09		40,815.17	$ 982,039	9	$752,651	$534,164
2023	256,320	114.43		915,976.75	44,588	19.91		40,436.07	$ 956,413	10	$711,661	$486,192
2024	249,255	111.27		890,729.36	44,170	19.72		40,056.96	$ 930,786	11	$672,420	$442,210
2025	242,190	108.12		865,481.96	43,752	19.53		39,677.85	$ 905,160	12	$634,861	$401,902
2026	235,125	104.97		840,234.57	43,334	19.35		39,298.75	$ 879,534	13	$598,920	$364,975
2027	228,060	101.81		814,987.17	42,916	19.16		38,919.64	$ 853,907	14	$564,533	$331,160
2028	220,995	98.66		789,739.78	42,498	18.97		38,540.54	$ 828,281	15	$531,642	$300,207
2029	213,930	95.50		764,492.39	42,080	18.79		38,161.43	$ 802,653	16	$500,187	$271,886
2030	206,865	92.35		739,244.99	41,662	18.60		37,782.32	$ 777,027	17	$470,114	$245,987
2031	199,800	89.20		713,997.60	41,244	18.41		37,403.22	$ 751,401	18	$441,369	$222,312
2032	192,735	86.04		688,750.20	40,825	18.23		37,024.11	$ 725,774	19	$413,899	$200,683
2033	185,670	82.89		663,502.81	40,407	18.04		36,645.00	$ 700,148	20	$387,655	$180,932
2034	178,605	79.73		638,255.42	39,989	17.85		36,265.90	$ 674,521	21	$362,588	$162,906
2035	171,540	76.58		613,008.02	39,571	17.67		35,886.79	$ 648,895	22	$338,653	$146,464
2036	164,475	73.43		587,760.63	39,153	17.48		35,507.69	$ 623,269	23	$315,805	$131,477
2037	157,410	70.27		562,513.23	38,735	17.29		35,128.58	$ 597,642	24	$294,000	$117,823
2038	150,345	67.12		537,265.84	38,317	17.11		34,749.47	$ 572,015	25	$273,198	$105,393
2039	143,280	63.96		512,018.44	37,899	16.92		34,370.37	$ 546,388	26	$253,357	$94,086
2040	136,215	60.81		486,771.05	37,481	16.73		33,991.26	$ 520,762	27	$234,441	$83,806
	4,344,165	1,939		15,524,145	874,892	391		793,429	16,317,573	**Total**	**$10,387,577**	**$6,054,518**

	Annual CO2 Reduction		Social Cost of Carbon (2013$)	Emission Reduction Benefit ($2014)	CO2 Emission Reduction Benefit (2014$)	YEARS from 2015	Discounted (to 2015)	Discounted (to 2015)
	lbs/year	metric tons/year					**3%**	**7%**
2020	291,657,991	132,294	54	54.88	7,260,295	7	$ 5,903,284	$ 4,521,347
2021	289,600,363	131,361	55	55.89	7,341,766	8	$ 5,795,658	$ 4,272,975
2022	287,542,735	130,427	56	56.91	7,422,601	9	$ 5,688,806	$ 4,037,403
2023	285,485,107	129,494	57	57.92	7,500,292	10	$ 5,580,922	$ 3,812,768
2024	283,427,478	128,561	58	58.94	7,577,385	11	$ 5,474,064	$ 3,599,961
2025	281,369,850	127,627	60	60.97	7,781,418	12	$ 5,457,730	$ 3,455,043
2026	279,312,222	126,694	61	61.99	7,853,761	13	$ 5,348,029	$ 3,259,032
2027	277,254,594	125,761	62	63.01	7,924,201	14	$ 5,238,830	$ 3,073,142
2028	275,196,966	124,827	63	64.02	7,991,425	15	$ 5,129,392	$ 2,896,460
2029	273,139,338	123,894	63	64.02	7,931,694	16	$ 4,942,769	$ 2,686,739
2030	271,081,709	122,961	65	66.05	8,121,574	17	$ 4,913,686	$ 2,571,082
2031	269,024,081	122,027	66	67.07	8,184,351	18	$ 4,807,444	$ 2,421,454
2032	266,966,453	121,094	67	68.09	8,245,290	19	$ 4,702,174	$ 2,279,891
2033	264,908,825	120,161	68	69.10	8,303,125	20	$ 4,597,239	$ 2,145,685
2034	262,851,197	119,227	69	70.12	8,360,197	21	$ 4,494,018	$ 2,019,097
2035	260,793,569	118,294	71	72.15	8,534,912	22	$ 4,454,307	$ 1,926,442
2036	258,735,940	117,361	72	73.17	8,587,304	23	$ 4,351,116	$ 1,811,465
2037	256,678,312	116,427	73	74.18	8,636,555	24	$ 4,248,613	$ 1,702,668
2038	254,620,684	115,494	74	75.20	8,685,149	25	$ 4,148,076	$ 1,600,232
2039	252,563,056	114,561	76	77.23	8,847,546	26	$ 4,102,560	$ 1,523,508
2040	250,505,428	113,627	77	78.25	8,891,313	27	$ 4,002,772	$ 1,430,882
	5,692,715,897	2,582,174		1,389	169,982,154	**Total**	**$ 103,381,487**	**$ 57,047,275**

	BLS CPI
YEAR	**CPI**
2013	232.957
2014	236.736
Nox ($2013)	$7,877
VOC ($2013)	$1,999

Nox, VOC, and Co2 Monetized values based on BCA online supplement

Benefit Cost Analysis - Safety Benefits

Year	# Crashes	# Not Injured	# of Possible Injury	# of Non-Incapacitating	# of Incapacitating Injury	# Fatalities	# Unknown Injury Crashes
2014	**8,192**	5,189	1,574	958	225	58	188
2013	**7,999**	4,868	1,625	1,032	225	63	186
2012	**7,269**	4,242	1,563	1,028	243	59	134
2011	**6,397**	3,718	1,399	925	207	43	105
2010	**6,781**	3,942	1,490	932	239	63	115
Total Crashes		**21,959**	**7,651**	**4,875**	**1,139**	**286**	**728**
Annual Crash Rate		4391.80000	1530.20000	975.00000	227.80000	57.20000	145.60000
Likelihood Factor*Crash Modification Factor		0.06586	0.06586	0.06586	0.06586	0.06586	0.06586
Crashes Reduced		289.22638	100.77285	64.20960	15.00200	3.76696	9.58863

KABCO Accident Classification System

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)
KABCO Type →	**O No Injury**		**C Possible Injury**		**B Non-Incapacitating**		**A Incapacitating**		**K Killed**		**U Injured Severity Unknown**		**Annual Crash Reduction**
AIS Rating System	**Number**	**Factor**	**Number**	**Factor**	**Number**	**Factor**	**Number**	**Factor**	**Number**	**Factor**	**Number**	**Factor**	
0		0.92534		0.23437		0.08347		0.03437		0.00000		0.21538	299.19127
1		0.07257		0.68946		0.76843		0.55449		0.00000		0.62728	154.14181
2		0.00198		0.06391		0.10898		0.20908		0.00000		0.10400	18.14446
3	289.22638	0.00008	100.77285	0.01071	64.20960	0.03191	15.00200	0.14437	3.76696	0.00000	9.58863	0.03858	5.68711
4		0.00000		0.00142		0.00620		0.03986		0.00000		0.00442	1.18156
5		0.00003		0.00013		0.00101		0.01783		0.00000		0.01034	0.45326
Fatal		0.00000		0.00000		0.00000		0.00000		1.00000		0.00000	3.76696

MONETIZED VALUES FROM GDP DEFLATOR TAB						
CELL G9	CELL G3	CELL G4	CELL G5	CELL G6	CELL G7	CELL G8
$ 3,991	$ 28,657	$ 448,967	$ 1,003,011	$ 2,540,961	$ 5,664,624	$ 9,552,486

ANNUAL REDUCTION IN CRASHES (BY AIS Rating Category)

YEAR	0	1	2	3	4	5	Fatal
2020	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2021	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2022	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2023	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2024	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2025	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2026	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2027	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2028	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2029	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2030	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2031	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2032	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2033	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2034	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2035	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2036	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2037	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2038	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2039	299.19	154.14	18.14	5.69	1.18	0.45	3.77
2040	299.19	154.14	18.14	5.69	1.18	0.45	3.77

ANNUAL CRASH REDUCTION BENEFIT (BY AIS Rating Category)									**Discounted (to 2015)**	
0	**1**	**2**	**3**	**4**	**5**	**Fatal**	**TOTAL CRASH REDUCTION BENEFIT**	**YEARS from 2015**	**3%**	**7%**
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	5	$ 52,632,478	$ 43,503,185
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	6	$ 51,099,493	$ 40,657,182
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	7	$ 49,611,158	$ 37,997,366
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	8	$ 48,166,173	$ 35,511,557
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	9	$ 46,763,275	$ 33,188,371
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	10	$ 45,401,238	$ 31,017,170
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	11	$ 44,078,872	$ 28,988,009
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	12	$ 42,795,021	$ 27,091,597
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	13	$ 41,548,564	$ 25,319,250
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	14	$ 40,338,412	$ 23,662,850
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	15	$ 39,163,507	$ 22,114,813
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	16	$ 38,022,822	$ 20,668,050
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	17	$ 36,915,361	$ 19,315,934
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	18	$ 35,840,156	$ 18,052,275
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	19	$ 34,796,268	$ 16,871,285
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	20	$ 33,782,785	$ 15,767,556
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	21	$ 32,798,820	$ 14,736,034
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	22	$ 31,843,515	$ 13,771,994
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	23	$ 30,916,034	$ 12,871,023
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	24	$ 30,015,567	$ 12,028,993
$ 1,193,984	$ 4,417,312	$ 8,146,261	$ 5,704,234	$ 3,002,298	$ 2,567,547	$ 35,983,831	$ 61,015,467	25	$ 29,141,327	$ 11,242,050
							$ 1,281,324,812		**$ 835,670,847**	**$ 504,376,545**

Benefit Cost Analysis - Mobility Benefits

Analysis Year	Vehicle Hours of Congestion Delay on Freeways	Percentage of Congested Freeways	Percentage of Uncongested Freeways	Percentage of Non-Recurrent Congestion Eliminated on Congested Freeways with ITS Deployment*0.1	Percentage of Non-Recurrent Congestion Eliminated on Uncongested with ITS Deployment*0.1	Reduction in Non-Recurrent Congestion Per Day on Congested Freeways (Vehicle Hrs/Day)	Reduction in Non-Recurrent Congestion Per Day on Uncongested Freeways (Vehicle Hrs/Day)	Total Reduction Non Recurrent Congestion Per Day (Vehicle Hours/Weekday)	Annual Saving of Non-Recurrent Congestion ($/Year)	Percentage of Recurrent Congestion Eliminated on Congested Freeways with ITS Deployment*0.1	Percentage of Recurrent Congestion Eliminated on Uncongested with ITS Deployment*0.1	Reduction in Recurrent Congestion Per Day on Congested Freeways (Vehicle Hrs/Day)	Reduction in Recurrent Congestion Per Day on Uncongested Freeways (Vehicle Hrs/Day)	Total Reduction Recurrent Congestion Per Day (Vehicle Hours/Weekday)	Annual Saving of Recurrent Congestion ($/Year)	Total Annual Savings based on Likelihood Multiplier	Year From 2015	Discounted to 2015 (3%)	Discounted to 2015 (7%)
2020	500,758	70%	30%	4.8%	2.3%	16,825	3,478	20,304	$130,718,393	3.0%	0.5%	10,516	756	11,272	$72,571,179	$23,906,854	5	$ 20,622,262	$ 17,045,256
2021	518,263	70%	30%	4.8%	2.3%	17,414	3,552	20,966	$134,981,140	3.0%	0.5%	10,884	772	11,656	$75,041,426	$24,698,654	6	$ 20,684,734	$ 16,457,756
2022	535,769	71%	29%	4.8%	2.3%	18,259	3,623	21,882	$140,878,842	3.0%	0.5%	11,412	788	12,199	$78,541,972	$25,803,888	7	$ 20,980,922	$ 16,069,364
2023	553,275	71%	29%	4.8%	2.3%	18,856	3,690	22,546	$145,154,212	3.0%	0.5%	11,785	802	12,587	$81,037,014	$26,600,088	8	$ 20,998,355	$ 15,481,493
2024	570,781	71%	29%	4.8%	2.3%	19,452	3,755	23,207	$149,408,843	3.0%	0.5%	12,158	816	12,974	$83,527,547	$27,393,319	9	$ 20,994,698	$ 14,900,151
2025	588,286	72%	28%	4.8%	2.3%	20,331	3,816	24,147	$155,460,725	3.0%	0.5%	12,707	829	13,536	$87,149,815	$28,531,000	10	$ 21,229,743	$ 14,503,713
2026	605,792	72%	28%	4.8%	2.3%	20,936	3,873	24,810	$159,727,980	3.0%	0.5%	13,085	842	13,927	$89,665,143	$29,328,631	11	$ 21,187,627	$ 13,933,821
2027	623,298	73%	27%	4.8%	2.3%	21,840	3,928	25,768	$165,900,682	3.0%	0.5%	13,650	854	14,504	$93,379,828	$30,491,388	12	$ 21,386,046	$ 13,538,541
2028	640,804	73%	27%	4.8%	2.3%	22,454	3,979	26,433	$170,180,559	3.0%	0.5%	14,034	865	14,899	$95,919,951	$31,293,420	13	$ 21,309,296	$ 12,985,657
2029	663,409	74%	26%	4.8%	2.3%	23,564	4,005	27,570	$177,497,420	3.0%	0.5%	14,728	871	15,598	$100,424,907	$32,683,666	14	$ 21,607,753	$ 12,675,289
2030	686,015	75%	26%	4.8%	2.3%	24,697	4,023	28,720	$184,903,787	3.0%	0.5%	15,435	875	16,310	$105,006,271	$34,093,423	15	$ 21,883,271	$ 12,357,025
2031	708,621	75%	25%	4.8%	2.3%	25,510	4,034	29,544	$190,209,802	3.0%	0.5%	15,944	877	16,821	$108,295,381	$35,104,209	16	$ 21,875,783	$ 11,891,010
2032	731,226	76%	24%	4.8%	2.3%	26,675	4,036	30,712	$197,725,323	3.0%	0.5%	16,672	877	17,549	$112,985,899	$36,539,640	17	$ 22,107,083	$ 11,567,514
2033	753,832	77%	23%	4.8%	2.3%	27,862	4,031	31,893	$205,330,352	3.0%	0.5%	17,414	876	18,290	$117,752,825	$37,994,582	18	$ 22,317,812	$ 11,241,226
2034	776,438	78%	23%	4.8%	2.3%	29,070	4,018	33,088	$213,024,886	3.0%	0.5%	18,169	873	19,042	$122,596,159	$39,469,035	19	$ 22,508,639	$ 10,913,517
2035	821,649	79%	21%	4.8%	2.3%	31,157	3,969	35,126	$226,143,322	3.0%	0.5%	19,473	863	20,336	$130,925,081	$41,991,244	20	$ 23,249,534	$ 10,851,335
2036	844,255	80%	20%	4.8%	2.3%	32,419	3,932	36,352	$234,036,518	3.0%	0.5%	20,262	855	21,117	$135,953,978	$43,510,882	21	$ 23,389,243	$ 10,508,447
2037	866,861	81%	20%	4.8%	2.3%	33,704	3,888	37,591	$242,019,220	3.0%	0.5%	21,065	845	21,910	$141,059,283	$45,050,032	22	$ 23,511,274	$ 10,168,385
2038	889,467	81%	19%	4.8%	2.3%	34,582	3,836	38,418	$247,342,700	3.0%	0.5%	21,614	834	22,448	$144,523,039	$46,083,411	23	$ 23,350,084	$ 9,721,152
2039	912,072	82%	18%	4.8%	2.3%	35,899	3,776	39,675	$255,434,556	3.0%	0.5%	22,437	821	23,258	$149,737,498	$47,648,234	24	$ 23,439,774	$ 9,393,688
2040	934,678	83%	17%	4.8%	2.3%	37,238	3,708	40,946	$263,615,919	3.0%	0.5%	23,273	806	24,080	$155,028,365	$49,232,568	25	$ 23,513,749	$ 9,071,060
TOTAL	**14,725,550**					**$ 538,744**	**$ 80,952**	**$ 619,696**	**$ 3,989,695,181**			**336,715**	**17,598**	**354,313**	**$2,281,122,564**	**$737,448,167**		**$ 462,147,683**	**$ 265,275,404**

Vehicle Occupancy	1.35
Weekdays Per Year (2015)	251
Intercity Travel Value of Time (All Purposes)	$19.00
Likelihood Multiplier = Total Annual Savings *0.21* 0.56	

Benefit Cost Analysis - Jobs

Long Term Jobs

	Total Estimated Economic Impact (Total $)	Job-Years Created (jobs-year)	Project Lifetime (years)	Jobs Created (jobs) per year	Median Income ($,2013)	Median Income ($,2014)	Annual Benefit ($,year)
Job Creation and Economic Impact	$1,420,246,721	18469	20	923.5	$65,812	$66,880	$61,763,680

Short Term Jobs by Qurter

		Construction Spending	JOB-YEARS BY QUARTER	JOBS BY QUARTER	Payroll By Quarter	1.5 Multiplier Effect	Spending Benefit
2018	Q1	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2018	Q2	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2018	Q3	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2018	Q4	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	$ 2,608,320
2019	Q1	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2019	Q2	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2019	Q3	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2019	Q4	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	$ 2,608,320
2020	Q1	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
2020	Q2	$ 1,500,000	20	78	$ 1,304,160	$ 652,080	
							$ 1,304,160
							$ -
							$ -
							$ -
							$ -
			195	780			$6,520,800

BLS CPI

Table Area Year	National Index
2013	232.957
2014	236.736

		Quarters	Per Quarter
Total Budget	$15,000,000	10	$1,500,000.00