TIGER Benefit Cost Analysis:
22 Fillmore Transit Priority Project

Prepared For:

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Maryland – California – Texas

EXECUTIVE SUMMARY

The SFMTA operates Muni, the oldest and largest transit system in the San Francisco Bay Area, providing over 40 percent of all transit trips in the region. In addition, it is the eighth largest transit system in the nation based on boardings, carrying more than 225 million passengers annually. Through the Muni Forward initiative, the SFMTA is modernizing the Muni network to make it safer and more reliable. This includes creating a Rapid Network that will make it more efficient to travel on our most heavily used routes. In addition to service changes, the SFMTA is implementing capital Transit Priority Projects to address transit delay, improve reliability, and increase safety and comfort.

Results:

It is the conclusion of this study that the benefits of the Project outweigh the costs and that the project provides a promising investment of public funds.

Project Costs:

Capital Cost: $67.1 million

Present-value-discounted SFMTA estimates over 30 years:

- $68.3 million at a 3% discount rate
- $57.3 million at a 7 % discount rate

Estimated monetized benefits:

- $577.9 million at a 3% discount rate
- $348.0 million at a 7 % discount rate

Benefit-cost ratio:

- 8.46 at a 3% discount rate
- 6.07 at a 7 % discount rate

The 22 Fillmore Transit Priority Project

The 22 Fillmore Transit Priority Project includes both service changes and capital investments on 16th Street, from Church Street to Third Street. The transit priority and pedestrian safety improvements include: transit-only lanes, transit bulbs, new traffic and pedestrian signals, and new streetscape amenities. The project will also include extending the overhead contact system (OCS) on 16th Street from Kansas Street to Third Street to allow for zero-emission transit service into Mission Bay. These and other improvements should reduce travel time, increase transit service and improve safety along the corridor. They include enhancements to modernize the aging overhead wire system and the relocation of the bicycle route to 17th Street for safer and attractive parallel bike travel.

The 22 Fillmore is a key east-west connection and as one of the first Transit Priority Projects to be completed, is critical in demonstrating the viability and benefits of the larger network both in San Francisco and other cities around the U.S.

Estimated Project Costs

ES-1: Project Capital Costs - $67.1 Million

Phase	Features	Units	Unit Cost	Extension
Construction Only	Tranist Bulbs	25	200,000	5,000,000
	Streetscape elements on bulbs	25	75,000	1,875,000
	Pedestrian bulbs	25	70,000	1,750,000
	Curb Ramps	5	5,000	25,000
	Relocate Hydrants	7	50,000	350,000
	Catch Basins	50	7,260	363,000
	Signal upgrade	5	200,000	1,000,000
	New signal	8	400,000	3,200,000
	Streetscape	1	2,000,000	2,000,000
	OCS duckbank underground	1	3,150,000	3,150,000
	OCS -foundation and poles	1	1,367,300	1,367,300
	OCS - overground	1	-	3,149,420
	Repave Church to 7th		-	5,000,000
	Final Striping	500,000	1	500,000
	Bike Share Stations		-	100,000
	17 th street bike lanes		-	200,000
	Others- Allowance, mob/demob, hazard material management, traffic control, permits (15%)		-	4,324,458
	Total Core Project		-	**33,354,178**
Soft Costs	Environmental and Planning Out reach 5%		-	1,667,709
	Predevelopment 2%		-	667,084
	CER 7%		-	2,334,792
	Detail Design 15%		-	5,003,127
	Construction Support 20%		-	6,670,836
	Project Contengincy 35%		-	17,394,204
Total	**Total**			**67,091,929**

ES-2: Expected Operations and Maintenance Costs

Item	Unit Cost	Units	Quantity	Years of Implementation	Total Cost	Maintenance Schedule
Traffic Signal Conduits	$ 100,000	intersection	11	2040	$ 1,100,000	Replace every 20 years; new with project, 19 original signals + 6 new with project
Full Signal Upgrade	$ 350,000	intersection	0	n/a	$ -	Replace every 40 years; all signals upgrades as part of project and not upgraded during this study period
Transit Signal Priority	$ 30,000	intersection	75	25 intersections in 2030, 2040	$ 2,250,000	One upgrade implemented in project; update every 10 years; 25 intersections x 3 cycles = 75
Signage	$ 2,000	block	111	37 blocks in 2030, 2040	$ 222,000	As needed - signs typically last 10 years; $200 per sign (inclusive of labor, etc.); consider average of 10 signs per block
Lighting						Replace Bulbs 3-5 years and fixture life cycle 15 year, poles 50 years
Curb Return	$ 60,000	intersection	0	n/a	$ -	Part of project
Sewer	$ 3,750,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 100 years
Potable Water	$ 1,250,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 50 years
AWSS (fire hydrant water)	$ 2,500,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 50 years
Red Transit only Lane Paint	$ 35,000	blocks	111	Painted in 2030, 2040, 2047	$ 3,885,000	Would be repainted when paving treated (cycle below); $5/sq ft for paint installation; lane approx. 12 ft. x 600 ft. per block
OCS Pole and Duct Bank Replacement	$ 18,600	pole, foundation and grounding	0	n/a	$ -	New poles have a 50 year life cycle and all poles needing upgrades would be included in the project for the Church to Valencia and Kansas/17th Street segments
OCS Wire Replacement	$ 50	linear foot	46400	2040	$ 2,320,000	Every 20 years, start 2040 as new wire installed as part of project; corridor is 11,600 feet long, need 2 lengths in each direction; 11600 x 4 = 46,400
OCS Wire Retensioning	$ 6,000	year	10	Every three years	$ 60,000	Every 10-15 years for the Church to Valencia and Kansas/17th Street segments, start 2020; inspection and retensioning the wires every 3 years; 35 years/3 = 12
OCS Inspection and Debris Removal	$ 3,000	year	10	Every three years	$ 30,000	Every 10-15 years for the segment on Kansas and 17th Street (OCS Overhead Feeder System*), start 2020; inspection and retensioning the wires every 3 years
OCS Special Work	$ 6,000	year	10	Every three years	$ 60,000	Every 2 years; adjusts the switches and enables turns for the buses (7 intersections with turns plus 3 more where the 22 Fillmore intersects with other trolley lines), start 2015; assume same level of effort as wire retensioning
Paving and Striping	$ 21,600	blocks	37	2030	$ 799,200	Project area first preservation in 2030
	$ 21,600	blocks	37	2040	$ 799,200	Project area second preservation in 2040
	$ 120,000	blocks	37	2047	$ 4,440,000	Project area repaved in 2047
TOTAL:					**$ 15,965,400**	

ES-3: Projected Capital Funding

Individual Funding Source	Funding Type	Total Amount
TIGER Grant Request	Federal	$20,000,000
FTA Section 5337 Fixed Guideway Funds	Other Federal	$3,000,000
Eastern Neighborhoods Development Impact Fees	Local	$14,151,000
Proposition K Transportation Sales Tax	Local	$7,096,063
San Francisco General Obligation Bond	Local	$21,600,000
Proposition B 2014 Charter Amendment	Local	$1,252,937
TOTAL		**$67,100,000**

Benefit-Cost Analysis

Benefit-Cost Analysis (BCA) is essential for public infrastructure investment decision making. A BCA must consider benefits and costs to all parties to ensure transportation planners and others make fully informed decisions when developing, expanding or maintaining transportation infrastructure.

This BCA identifies the different impacts and societal benefits the project and its alternatives will have on the city including the societal benefits as defined in the FY2015 TIGER Grant Notice of Funding Availability. These include, but are not limited to, the following: travel time savings; operating and maintenance cost savings; environmental benefits: reduction of long-term maintenance and repair costs; safety; property value increases; improved transportation options; and mode shift.

Project Matrix

Exhibit ES-4 provides a project matrix describing the project and what it changes. The first column provides a description of the current infrastructure baseline (including anticipated changes over the analysis period) and identifies the problem that the project will address. The second column describes how the project would change the current infrastructure baseline. The third and fourth columns describe the impact of that change and the corresponding population that it affects. The fifth column identifies the economic nature of those benefits. The last columns summarize the results and reference where in the analysis the benefits are calculated.

Exhibit ES-4: Project Matrix

Current Status/Baseline & Problem to be Addressed	Changes Implemented	Types of Impact	Population Affected by Impacts	Long Term Outcome & Economic Benefit	Summary of Results	Chapter and Pages
Long bus dwelling times; missing safety refuges for pedestrians; Buses remain in congestion; few street lights; lack of accessibility	Construction of new street lights, pedestrian and bus bulb-outs, exclusive bus lanes, safety refuges	Shorter dwelling times, travel times, higher accessibility, better lit and safer streets, higher livability in corridor, less congestion	30,407 housing units and their owners/residents with in a 1/4 mile of the project area, as well as all people using transit throughout 16th Street Corridor	*Quality of Life:* Property Values will increase by approximately 1.5% over the years following completion of the project	**$56.5 million at a 3% discount rate or $66.5 million at a 7% discount rate** in long-term increases of property values, net of Travel Time Savings and Reliability to avoid double counting	Chapter 4 **Quality of Life** Pages 27-32
Increased travel time caused by recurring and non-recurring congestion	Exclusive lanes for buses and cars	Reduced travel times for all transit users; less congestion	8 to 10 million trips per year for transit users taking approximately 20 minutes to travel through 16th Street corridor	*Economic Competitiveness:* The weighted average transit travel time savings is 6.4 minutes per trip for the length of the corridor, with personal travel is valued at $16.28 and business travel is valued at $26.65.	**$139.6 million at a 3% discount rate or $74.8 million at a 7% discount rate** in travel time savings; can be used in order to create other benefits	Chapter 5 **Travel Time Savings** Pages 33-42
Unreliable transit service leading to high variability in wait and travel times	Exclusive lanes for buses and cars, bus bulb-outs, and new and upgraded traffic, transit and pedestrian signals	Reliable service and reduced wait times for all transit users; less congestion	8 to 10 million trips per year with an average of 8.46 minutes of "buffer" time needed for transit users travelling through 16th Street corridor	*Economic Competitiveness:* transit travel reliability will improve by approximately 13.5% following the complete of the project	**$49.8 million at a 3% discount rate or $26.7 million at a 7% discount rate** in wait time savings	Chapter 6 **Reliability Improvements** Pages 43-49
Congestion in corridor slows traffic flow of autos and transit.	Use of transit-only lanes, electric-powered trolleys	Increased transit speeds, mode changes and reduced auto traffic	Transit passengers would be able to use a trolley coach line, reducing approximately 20,000-30,000 operating hours of motor coach service; also transit is more attractive and motorists drive approximately 5,500 fewer miles in corridor	*Economic Competitiveness:* More efficient movement of transit passengers reduced the number of hours for motor coach service on the corridor, operated at $197.16/hour, and number of auto miles at 57.5 cents/mile	**$79.9 million at a 3% discount rate or $43.1 million at a 7% discount rate** in reduced auto miles, operating expenses, and transit operating cost savings	Chapter 7 **Operating Cost Savings** Pages 50-57
Corridor has a high level of accidents among bikers, pedestrians and motorists.	Install series of improvements & countermeasures to traffic lanes, intersections and sidewalks. Upgrade, relocate, and improve signals, transit lanes. Relocate bike lanes to parallel street. Improve lighting.	Reduction of crashes resulting in fatalities, injuries and property damage.	All motorists, pedestrians, bicyclists, and transit passengers; there were 661 injury collisions in the project area from 2007-2012.	*Safety:* using the federal Value of Statistical Life injury categories, value of injury for those collisions is over $45 million a year	**$227.4 million at a 3% discount rate or $121.1 million at a 7% discount rate** in the monetized value of reduction of fatalities and injuries and other safety benefits	Chapter 8 **Safety** Pages 58-69
High costs of repairing aging assets in the corridor	Improved overhead wire system, installation of new traffic and pedestrian signals, replace aging support poles, improved storm water infrastructure, street paving and striping	Reduced maintenance costs. Assets in operation for extended timeframe	Pedestrians and transit passengers travelling along the 37 blocks of the corridor	*State of Good Repair:* the implementation of the project will reduce maintenance costs as new assets replace aging infrastructure; otherwise maintenance would be done on an as-needed basis and costs for the elements vary	**$22.4 million at a 3% discount rate or $13.7 million at a 7% discount rate** in reduced maintenance costs of the corridor	Chapter 9 **Maintenance & Repair Savings** Pages 70-76
Motor coach transit service along a dense and congested corridor; air pollution is an important issue in urban areas	Overhead wire system will be implemented for trolley coaches along 16th Street	Overall Bus fleet will not emit any more CO2 and other pollutants' emissions are decreasing simultaneously	All people using transit throughout 16th Street Corridor; all residents affected by the emissions from approximately 275,000 to 370,000 miles of motor coach service and approximately 1.5 to 2.5 million miles of auto travel a day	*Environmental Sustainability:* Bus fleet of SFMTA along 16th Street will not emit any CO2 as soon as the project is finished; other pollutants' emissions will decrease as well, quantified using the federal emissions cost factors	**$2.3 million at a 3% discount rate or $2.0 million at a 7% discount rate** in saved societal cost for each pollutant	Chapter 10 **Emissions Benefits** Pages 77-84

Results of the BCA

A Benefit-Cost Analysis (BCA) quantifies the benefits and costs of a particular project to determine whether an investment is justifiable. In order to be meaningful, a BCA must not only express all benefits and costs in monetary terms, it must also account for the change in value of the dollar over time. The value of a dollar changes not only with inflation, but also because today's dollar is worth more than a dollar available years from now. For this study, the analysis assumes a 30-year benefit horizon starting after project completion in 2020. These types of projects typically provide a stream of benefits that last a minimum of 20 years. The timeframe for analysis of the benefits and costs must therefore extend well into the future to measure project benefits accurately.

Exhibit ES-5 summarizes the cost and the benefits of each of the seven benefit categories in discounted present value dollars using both a 3 and 7 percent discount rate. The benefit cost analysis calculates that the project delivers benefits well in excess of costs. According to present-value-discounted SFMTA estimates, the project will cost $68.3 million and $57.3 million over 30 years at 3 and 7 percent discount rates, respectively. The largest category of benefits is the prevention of collisions at $227.4 million and 121.1 million at 3 and 7 percent discount rates, respectively. The analysis estimates that travel time savings are the second largest category of benefits at $139.6 million and $74.8 at 3 and 7 percent discount rates, respectively.

Exhibit ES-5: Costs and Benefits by Category Using 3 and 7 Percent Discount Rates

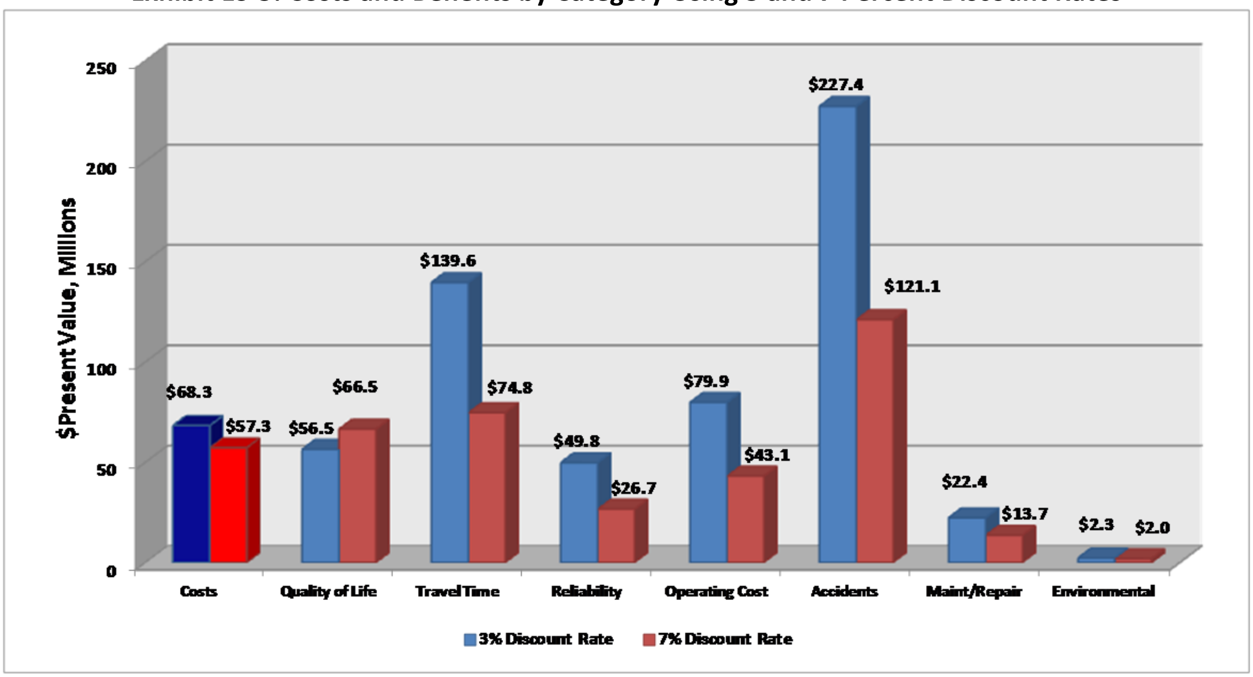
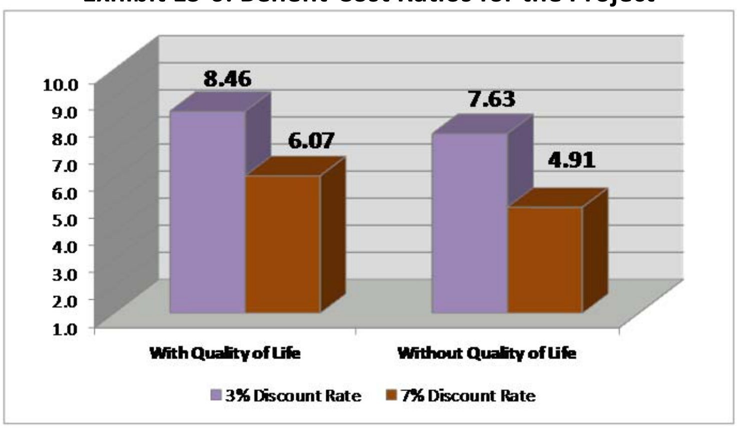


Exhibit ES-6 compares the benefits and costs using benefit-cost ratios. The benefit-cost ratio is the net present value of the benefits divided by the net present value of costs. A benefit to cost ratio of over one indicates that benefits probably exceed costs and that the investment is promising. A ratio under one indicates that benefits are probably less than costs and that the project sponsor should use further study or innovative strategies to justify the project. As Exhibit ES-6 shows, the benefit-cost ratios are far greater than one, indicating that this project presents a desirable investment. This exhibit presents the Benefit Cost Ratio with and without net Quality of Life Benefits due to the difficult nature of their estimation as the TIGER Guidance discusses. Travel related benefits have been subtracted from Quality of Life Benefits which are still positive. See Chapter 4 for a more detailed discussion of the estimation and adjustment of Quality of Life benefits in accordance with the TIGER Guidance. The benefits including quality of life outweigh costs by a ratio of 8.46 at a 3 percent discount rate and by a ratio of 6.07 at a 7 percent discount rate. The benefits without quality of life outweigh costs by a ratio of 7.63 at a 3 percent discount rate and by a ratio of 4.91 at a 7 percent discount rate. **It is the conclusion of this study that the benefits of the Project outweigh the costs and that the project provides a promising investment of public funds.**

Exhibit ES-6: Benefit-Cost Ratios for the Project



This report is accompanied by a Master Spreadsheet of all cost and benefit estimates calculated for this Benefit Cost Analysis. The spreadsheet tabs are color coded with each colored tab referring to a specific Chapter of the report. The summary tab for each chapter is labeled in capital letters with supporting tads in the same color in lower case letters. All tabs are linked to the Chapter 11 BCA tab and Summary tab which are gray. Exhibit ES-7 is the Summary tab in the project spreadsheet.

Exhibit ES-7: Summary Tab in the Project Spreadsheet

Year	Project Year	Project Cost (Chapter 3)	Net Present Dollar Costs 3%	Net Present Dollar Costs 7%	Quality of Life (Chapter 4)	Travel Time Savings (Chapter 5)	Reliability (Chapter 6)	Operating Cost Savings (Chapter 7)	Safety (Chapter 8)	State of Good Repair (Chapter 9)	Environmental Sustainability (Chapter 10) Without CO2	Environmental Sustainability (Chapter 10) Only CO2 @3%	Net Benefits Without CO2	Present Dollar Benefits 3% Without CO2	Present Dollar Benefits 7% Without CO2	Present Dollar Benefits 3% With CO2	Present Dollar Benefits 7% With CO2	Net Present Dollar Benefits 3% With CO2 @3%	Net Present Dollar Benefits 7% With CO2 @3%
2015	1	3,113,057	3,113,057	3,113,057						3,901,000			3,901,000	3,901,000	3,901,000	3,901,000	3,901,000	787,943	787,943
2016	2	4,058,092	3,939,895	3,792,609						940,000			940,000	912,621	878,505	912,621	878,505	(3,027,273)	(2,914,104)
2017	3	2,501,563	2,357,963	2,184,962						465,000			465,000	438,307	406,149	438,307	406,149	(1,919,656)	(1,778,813)
2018	4	28,709,609	26,273,359	23,435,593						115,000			115,000	105,241	93,874	105,241	93,874	(26,168,118)	(23,341,718)
2019	5	28,709,609	25,508,115	21,902,423						465,000			465,000	413,146	354,746	413,146	354,746	(25,094,969)	(21,547,677)
2020	6	-	-	-	(10,106,444)	7,448,152	2,658,292	4,449,752	11,874,628	759,000	49,064	60,545	17,132,445	14,778,598	12,215,196	14,839,142	12,275,741	14,839,142	12,275,741
2021	7	-	-	-	(10,169,271)	7,494,454	2,674,817	4,460,858	11,964,040	465,000	48,484	60,604	16,938,381	14,185,628	11,286,759	14,246,232	11,347,363	14,246,232	11,347,363
2022	8	15,000	12,196	9,341	(10,232,098)	7,540,756	2,691,343	4,471,963	12,053,451	806,200	47,876	60,633	17,379,491	14,131,116	10,823,073	14,191,749	10,883,706	14,179,553	10,874,365
2023	9	-	-	-	(10,294,925)	7,587,057	2,707,868	4,483,069	12,142,863	465,000	47,242	60,633	17,138,173	13,529,032	9,974,573	13,589,665	10,035,205	13,589,665	10,035,205
2024	10	-	-	-	(10,357,752)	7,633,359	2,724,393	4,494,174	12,232,274	115,000	46,580	60,604	16,888,028	12,943,267	9,185,968	13,003,871	9,246,572	13,003,871	9,246,572
2025	11	15,000	11,161	7,625	320,096,000	7,679,660	2,740,919	4,505,279	12,321,685	465,000	45,892	60,548	347,854,436	258,836,369	176,831,556	258,896,917	176,892,104	258,885,755	176,884,479
2026	12	-	-	-	(10,483,406)	7,725,962	2,757,444	4,516,385	12,411,097	223,000	45,176	60,718	17,195,657	12,422,508	8,169,533	12,483,226	8,230,251	12,483,226	8,230,251
2027	13	-	-	-	(10,546,233)	7,772,264	2,773,970	4,527,490	12,500,508	465,000	44,433	60,853	17,537,431	12,300,401	7,786,829	12,361,254	7,847,682	12,361,254	7,847,682
2028	14	15,000	10,214	6,224	(10,609,060)	7,818,565	2,790,495	4,538,596	12,589,919	115,000	43,663	60,955	17,287,177	11,771,727	7,173,564	11,832,681	7,234,519	11,822,467	7,228,294
2029	15	-	-	-	(10,671,887)	7,864,867	2,807,020	4,549,701	12,679,331	465,000	42,865	61,023	17,736,897	11,726,178	6,878,674	11,787,202	6,939,698	11,787,202	6,939,698
2030	16	2,918,200	1,873,082	1,057,690	(10,734,714)	7,911,169	2,823,546	4,560,806	12,768,742	759,000	42,041	61,060	18,130,590	11,637,335	6,571,360	11,698,396	6,632,420	9,825,314	5,574,730
2031	17	15,000	9,348	5,081	(10,797,541)	7,957,470	2,840,071	4,571,912	12,858,153	465,000	41,190	60,836	17,936,255	11,177,281	6,075,630	11,238,117	6,136,466	11,228,770	6,131,385
2032	18	-	-	-	(10,860,368)	8,003,772	2,856,596	4,583,017	12,947,565	2,030,200	40,312	60,591	19,601,094	11,858,984	6,205,204	11,919,575	6,265,795	11,919,575	6,265,795
2033	19	-	-	-	(10,923,195)	8,050,074	2,873,122	4,594,123	13,036,976	465,000	39,407	60,325	18,135,505	10,652,698	5,365,642	10,713,023	5,425,967	10,713,023	5,425,967
2034	20	15,000	8,554	4,148	(10,986,022)	8,096,375	2,889,647	4,605,228	13,126,387	115,000	38,475	60,040	17,885,090	10,199,617	4,945,376	10,259,657	5,005,417	10,251,103	5,001,269
2035	21	-	-	-	(11,048,849)	8,142,677	2,906,172	4,616,334	13,215,799	2,785,000	37,515	59,737	20,654,647	11,435,977	5,337,553	11,495,714	5,397,290	11,495,714	5,397,290
2036	22	-	-	-	(11,111,676)	8,188,979	2,922,698	4,627,439	13,305,210	115,000	35,541	58,297	18,083,190	9,720,606	4,367,327	9,778,903	4,425,625	9,778,903	4,425,625
2037	23	15,000	7,828	3,386	(11,174,503)	8,235,280	2,939,223	4,638,544	13,394,621	465,000	33,520	56,832	18,531,686	9,671,548	4,182,845	9,728,380	4,239,677	9,720,551	4,236,292
2038	24	-	-	-	(11,237,330)	8,281,582	2,955,748	4,649,650	13,484,033	115,000	31,453	55,343	18,280,135	9,262,394	3,856,138	9,317,736	3,911,480	9,317,736	3,911,480
2039	25	-	-	-	(11,300,157)	8,327,884	2,972,274	4,660,755	13,573,444	14,625,000	29,338	53,833	32,888,537	16,178,981	6,483,864	16,232,814	6,537,697	16,232,814	6,537,697
2040	26	5,353,200	2,556,718	986,323	(11,362,984)	8,374,185	2,988,799	4,671,861	13,931,089	759,000	27,175	52,305	19,389,125	9,260,354	3,572,430	9,312,659	3,624,735	6,755,941	2,638,412
2041	27	100,000	46,369	17,220	(11,425,811)	8,420,487	3,005,324	4,682,966	14,036,279	465,000	24,967	50,761	19,209,213	8,907,211	3,307,740	8,957,971	3,358,501	8,911,602	3,341,281
2042	28	100,000	45,019	16,093	(11,488,638)	8,466,789	3,021,850	4,694,072	14,141,469	115,000	22,713	49,204	18,973,253	8,541,551	3,053,373	8,590,755	3,102,576	8,545,736	3,086,483
2043	29	115,000	50,264	17,296	(11,551,465)	8,513,090	3,038,375	4,705,177	14,246,659	465,000	20,412	47,635	19,437,247	8,495,569	2,923,405	8,543,204	2,971,040	8,492,941	2,953,744
2044	30	100,000	42,435	14,056	(11,614,292)	8,559,392	3,054,900	4,716,282	14,351,849	115,000	18,064	46,059	19,201,195	8,147,957	2,698,974	8,194,016	2,745,033	8,151,581	2,730,976
2045	31	100,000	41,199	13,137	(11,677,119)	8,605,694	3,071,426	4,727,388	14,457,038	465,000	15,669	44,475	19,665,095	8,101,759	2,583,347	8,146,234	2,627,822	8,105,035	2,614,685
2046	32	115,000	45,999	14,119	(11,739,946)	8,651,995	3,087,951	4,738,493	14,562,228	115,000	13,227	42,887	19,428,949	7,771,330	2,385,350	7,814,217	2,428,237	7,768,218	2,414,119
2047	33	5,835,000	2,265,947	669,514	(11,802,773)	8,698,297	3,104,477	4,749,599	14,667,418	465,000	10,739	41,296	19,892,756	7,725,094	2,282,517	7,766,390	2,323,814	5,500,443	1,654,299
2048	34	100,000	37,703	10,723	(11,865,601)	8,744,599	3,121,002	4,760,704	14,772,608	115,000	8,204	39,705	19,656,516	7,411,022	2,107,861	7,450,727	2,147,565	7,413,025	2,136,842
2049	35	115,000	42,095	11,525	(11,928,428)	8,790,900	3,137,527	4,771,809	14,920,334	1,264,200	5,622	38,115	20,961,966	7,673,021	2,100,794	7,711,135	2,138,909	7,669,040	2,127,384
Total		**82,133,329**	**68,298,520**	**57,292,145**	**(6,497)**	**243,585,787**	**86,937,290**	**138,323,426**	**398,567,696**	**36,511,600**	**996,858**	**1,646,449**	**904,916,160**	**576,225,430**	**346,366,732**	**577,871,879**	**348,013,181**	**509,573,359**	**290,721,035**

CHAPTER 1: INTRODUCTION AND OVERVIEW OF THE PROJECT

Benefit-Cost Analysis (BCA) is essential for public infrastructure investment decision making. A BCA must consider benefits and costs to all parties to ensure transportation planners and others make fully informed decisions when developing, expanding or maintaining transportation infrastructure. In this research study, the project team conducted a BCA for the 22 Fillmore Transit Priority Project. The SFMTA will use this analysis to complete the BCA required by the United States Department of Transportation (USDOT) as part of the Transportation Investment Generating Economic Recovery (TIGER) Grant Application, including but not limited to the monetization of the long-term outcomes of the project and its alternatives.

The BCA identifies the different impacts and societal benefits the project and its alternatives will have on the city including the societal benefits as defined in the FY2015 TIGER Grant Notice of Funding Availability. These include, but are not limited to, the following: travel time savings; operating and maintenance cost savings; environmental benefits: reduction of long-term maintenance and repair costs; safety; property value increases; improved transportation options; and mode shift. The BCA also matches the types of impacts to the corresponding affected population. A discussion of the key limitations and sources of uncertainty is included in the analysis.

1.1 Overview of the Project

The SFMTA operates Muni, the oldest and largest transit system in the San Francisco Bay Area, providing over 40 percent of all transit trips in the region. In addition, it is the eighth largest transit system in the nation based on boardings, carrying more than 225 million passengers annually. Through the Muni Forward initiative, the SFMTA is modernizing the Muni network to make it safer and more reliable. This includes service enhancements like updating routes to provide more direct connections to other regional transit systems, changing service to increase frequency and ease crowding on popular routes, creating a Rapid Network that will make it more efficient to travel on our most heavily used routes. In addition to service changes, the SFMTA is implementing capital Transit Priority Projects to address transit delay, improve reliability, and increase safety and comfort.

The 22 Fillmore Transit Priority Project includes both service changes and capital investments on 16th Street, from Church Street to Third Street. The transit priority and pedestrian safety improvements include: transit-only lanes, transit bulbs, new traffic and pedestrian signals, and new streetscape amenities. The project will also include extending the overhead contact system (OCS) on 16th Street from Kansas Street to Third Street to allow for zero-emission transit service into Mission Bay.

The 22 Fillmore is a key east-west connection and as one of the first Transit Priority Projects to be completed, is critical in demonstrating the viability and benefits of the larger network both in San Francisco and other cities around the U.S.

No Build Project Baseline

This alternative assumes the existing 22 Fillmore trolley bus route remains with no physical street improvements or rerouting of the service. Basic maintenance will continue to enable use of the corridor but will not change the nature of the street, pedestrian or transit facilities.

To connect to the growing Mission Bay neighborhood and to provide continuous service along 16th Street, SFMTA launched a new, temporary bus route called the 55 16th Street line between 16th Street BART and Mission Bay. The BCA assumes that SFMTA will continue to provide this service in absence of the improvements.

22 Fillmore Transit Priority Project ("The Build Scenario")

The 22 Fillmore Transit Priority Project includes transit priority and pedestrian improvements along the 16th Street corridor. These features are designed to address transit delay, traffic congestion, too-closely spaced transit stops, narrow traffic lanes and slow transit boarding. The project includes capital improvements including transit-only lanes, sidewalk extensions or bus bulb-outs, pedestrian bulb-outs, new and upgraded signals, pedestrian countdown signals, high visibility crosswalks, landscaping and innovative storm-water management infrastructure. This project will also extend the overhead wire system from Kansas Street to Third Street, enabling electric-powered trolley bus service to replace the current motor coach system and providing cleaner more efficient transit travel.

These and other improvements should reduce travel time, increase transit service and improve safety along the corridor. They include enhancements to modernize the aging overhead wire system and the relocation of the bicycle route to 17th Street for safer and attractive parallel bike travel.

1.2 Organization of the Report

Chapter 2, Literature and Model Review, presents a review of the literature and models used in the project to ensure the BCA met the USDOT requirements. The project team reviewed the following TIGER guidance materials:

- Notice of Funding Availability
- 2015 Benefit-Cost Analysis Guidance for TIGER Grants Applicants
- TIGER Benefit-Costs Analysis (BCA) Resource Guide
- TIGER Benefit-Cost Analysis (BCA) Examples
- TIGER Webinars

Selected National Cooperative Highway Research Program (NCHRP) Benefit/Cost reports describing converting a lane for bus rapid transit (BRT) were also reviewed along with studies and guidance documents from previous BRT projects. The two models used in the study are also described in this chapter. They were the SF-CHAMP official forecasting tool for San Francisco and the SFMTA Transit Preferential Toolkit.

Chapter 3, Project Costs and Alternatives, presents the analytical assumptions for one-time capital and on-going maintenance costs associated with the project. The first subsection describes the baseline and the alternatives. The next subsection details the one-time construction, planning, engineering and design costs. The following section describes the maintenance costs. The fourth and final section of the chapter presents the discounted value of the costs.

The next seven chapters are organized around the eight benefits shown in the table below. The table is adapted from the TIGER Guidance. Each chapter of the report corresponds to a benefit as shown in the table. The "Travel Time Savings – Reliability" benefit was added by the project team. Chapter numbers are shown in the column at the right.

Long-Term Outcome	Types of Societal Benefits	Location
Quality of Life	Land Use Changes that Reduce VMT Increased Accessibility/Property Value Increases	Not Applicable Chapter 4
Economic Competitiveness	Travel Time Savings Travel Time Savings – Reliability[1] Operating Cost Savings	Chapter 5 Chapter 6 Chapter 7
Safety	Prevented Accidents	Chapter 8
State of Good Repair	Deferral of Complete Replacement Maintenance & Repair Savings Reduced VMT from Not Closing Bridges	Not Applicable Chapter 9 Not Applicable
Environmental Sustainability	Environmental Benefits from Reduced Emissions	Chapter 10

[1] Added by the Project Team

The final chapter, Results of the Benefit-Cost Analysis, takes the results of the benefits and costs, and combines them to evaluate whether the project investment is justifiable. The analysis accounts for the change in value of the dollar over time.

CHAPTER 2: LITERATURE AND MODEL REVIEW

The research team reviewed a number of resources to conceptualize and design the methodology for conducting the benefit-cost analysis of this project. They included guidance on conducting Transportation Investment Generating Economic Recovery (TIGER) benefit-cost analyses from U.S. Department of Transportation (USDOT) and the National Cooperative Highway Research Program (NCHRP), along with a wide range of research studies, government resources, benefit-cost analyses, and alternative transportation models.
In addition, two transportation models used to develop the benefit-cost analysis are also described below. The outputs were used to estimate time savings, traffic, passenger hours, transit trips and other factors.

2.1 TIGER Guidance Materials

The team looked at the following Transportation Investment Generating Economic Recovery (TIGER) materials to insure it was incorporating the standards and methods the Federal Highway Administration required.

Notice of Funding Availability[1]
The Notice of Funding Availability (NOFA) described the procedures for submitting and evaluation criteria for funding of USDOT's National Infrastructure Investments, similar but not identical to those under the "Recovery Act" of 2009, known as "TIGER Discretionary Grants." It details differences to the final notice published in the Federal Register on March 3, 2014. This review ensured the project conforms to the background and outlook enumerated by USDOT, and that it meets all requirements and guidance in terms of application of selection criteria. The application addresses the primary criteria of State of Good Repair, Economic Competitiveness, Quality of Life, Environmental Sustainability and Safety, and will be ready to obligate the grant funds by the September 30, 2017 deadline.

Benefit-Cost Analysis Analyses Guidance[2]
This document describes the basic components required for a TIGER Grant proposal. It describes how evidence of expected benefits should be justified and the importance of showing how residents would be positively impacted by the project. This project follows the guidance, estimating benefits and costs for at least 30 years into the future (2020 to 2050), plus any residual value of the project at the end of the analysis period. Costs and benefits were measured against a baseline of "no build," the scenario where the project is not TIGER funded. The requested alternatives to components of the programs are presented, and program impacts were clearly and carefully identified. The five specified long-term USDOT outcomes were enumerated and monetized according to guidance. Future benefits and costs were discounted to present values using the two specified discount rates. Forecasts of projected usage were presented. All methods, analyses and results were detailed to provide as much transparency as possible.

TIGER Benefit-Costs Analysis (BCA) Resource Guide[3]

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[1] Notice of Funding Availability for the Department of Transportation's National Infrastructure Investments under the Consolidated and Further Continuing Appropriations Act, United States Department of Transportation, 2015
[2] 2015 Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants, United States Department of Transportation April 6, 2015

This Resource Guide is a supplement to the 2015 Guidance described above. It provides additional guidance on methodology and technical information for monetizing benefits and costs in Benefit-Cost Analyses. This supplement also contains selected questions from past TIGER grant applicants. The Resource Guide was used to update the 2015 Value of Statistical Life (VSL) to $9.74 million and determine corresponding Abbreviated Injury Scale (AIS) levels of unit values accordingly. Values of Travel Time guidance were monetized as required as were Value of Emissions and Social Costs of Carbon.

TIGER Benefit-Cost Analysis (BCA) Examples[4]

This document provided examples of seven successful Applicants of TIGER BCA projects, across project types and geographies. They were reviewed by the project leaders for examples of assumptions, calculations, and document transparency.

Webinars: United States Department of Transportation

Benefit/Cost Analysis for Transportation Infrastructure: A Practitioners' Workshop

The project team is familiar with the contents of webinars sponsored by various government agencies such as the USDOT. One such presentation was held on May 5, 2010 at USDOT entitled: Benefit/Cost Analysis for Transportation Infrastructure: A Practitioners' Workshop. It was part of the outreach explaining what was required of TIGER proposals in terms of Benefit-Cost Analyses. The White House insisted BCAs be part of the application process evaluation and this webinar detailed and clarified the requirements and standards of BCA in TIGER grant applications. It helps assure that projects are based on best quality analysis available to spend limited federal funds. An important part of the webinar was a section on how to measure the benefits contained in USDOT's Strategic Goals, all of which are addressed in this project:

- Safety
- Livability
- Economic Competitiveness
- Environmental Sustainability
- State of Good Repair

TIGER 2015 Application Preparation Webinar

The project is familiar with the BCA's guidance on how to identify, quantify and compare expected benefits and costs presented in this Webinar. The overview webinar was presented by Robert Mariner, Deputy Director of the Office of Infrastructure Finance and Innovation, Office of the Secretary Office of Policy, USDOT.

2014 Webinar Series

The team used the information in this series to conform to TIGER requirements.

- **March 12th – How to Compete for TIGER Discretionary Grants**

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[3] TIGER Benefit-Costs Analysis (BCA) Resource Guide, United States Department of Transportation, March, 27, 2015

[4] TIGER Benefit-Cost Analysis (BCA) Examples, Update, United States Department of Transportation, March 6, 2012

- **March 19th – Preparing a TIGER Planning Grant Application**
- **March 21st – How to Compete for TIGER Discretionary Grants**
- **March 25th – Ports and TIGER: Strengths and Weakness for Capital and Planning Applications**
- **March 26th – Preparing a Benefit Cost Analysis (BCA) for a TIGER Discretionary Grant**
- **March 28th – Preparing a TIGER Planning Grant Application**
- **April 4th – Preparing a Benefit Cost Analysis (BCA) for a TIGER Discretionary Grant**

2.2 Bus Rapid Transit (BRT) Guidance and Previous Studies

The project team reviewed a number of previously conducted studies that incorporated benefit-cost analyses for guidance, applicability and methodologies in conducting this study. Previous Bus Rapid Transit (BRT) studies were also reviewed.

Cost/Benefit Analysis of Converting A Lane for Bus Rapid Transit – Phase II Evaluation and Methodology[5]

This NCHRP study examined the trade-offs of converting traffic lanes to exclusive BRT usage by performing a cost/benefit analysis of a hypothetical lane conversion to BRT. It concludes that under certain conditions positive net benefits can be realized from converting an arterial traffic lane to BRT.

Benefit/Cost Analysis of Converting a Lane for Bus Rapid Transit[6]

This two-phase effort investigated documented information on best practices of analysis for converting an existing lane to BRT (Phase I) and developed a benefit/cost tool to use in analyzing conversion of an existing lane to BRT, including the evaluation requirements and methodology.

TCRP Report 78[7]

This report presents a guidebook designed for individuals who plan and evaluate the benefits and costs of new investments in public transportation. It examines the theory and methods of BCA in transportation projects including how to asses the impacts on travel, secondary impacts on the environment and safety, and the direct costs and revenues of transit projects.

Bus Rapid Transit (BRT): An Efficient and Competitive Mode of Public Transport[8]

This report examines the global experiences of developing BRT systems worldwide. It presents global trends with emphasis on cities and regions with the most extensive and modern systems. The cost benefits of heavy-rail, light-rail and BRT systems relative to urban densities are compared. The future of BRT is discussed.

Geary Corridor Bus Rapid Transit (BRT) Study[9]

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[5] Research Results Digest 352, Cost/Benefit Analysis of Converting A Lane for Bus Rapid Transit – Phase II Evaluation and Methodology, National Cooperative Highway Research Program, Transportation Research Board of the National Academies, April, 2011

[6] Research Results Digest 336, Benefit/Cost Analysis of Converting a Lane for Bus Rapid Transit (336), National Cooperative Highway Research Program, Transportation Research Board of the National Academies, June, 2009

[7] TCRP Report 78: Estimating the Benefits and Costs of Public Transit Projects: A Guide for Practitioners – Transportation Research Board, NRC, 2002

[8] Cervero, Robert. Bus Rapid Transit (BRT): An Efficient and Competitive Mode of Public Transport, Berkeley Institute of Urban and Regional Development, University of California, August 2013

[9] Geary Corridor Bus Rapid Transit (BRT) Study, San Francisco County Transportation Authority, June 18, 2007

The study presents conceptual design and evaluates a set of BRT alternatives along Geary Boulevard in San Francisco. It examines a 2015 baseline no-project scenario, a peak hour bus lane alternative and three full-featured BRT alternatives: a curb-running BRT design and two center-running BRT designs. A three-step modeling transportation process, analysis of conceptual engineering designs of each alternative, and design charrettes focused on key station attributes were used to conduct the evaluation.

The study team also reviewed various articles from the Public Journal of Transportation, including:

- Levinson, et al., Bus Rapid Transit: An Overview. Public Journal of Transportation, Volume 5, No. 2, 2002
- Jarzab, et al., Characteristics of Bus Rapid Transit Projects: An Overview. ibid
- Polzin, SE and Baltes, MR. Bus Rapid Transit: A Viable Alternative?, ibid.
- Vuchic, VR. Bus Semirapid Transit Mode Development and Evaluation, ibid.
- Carey, GN. Applicability of BRT to Corridors. Ibid
- Koonce, P., et al., Detection Range Setting Methodology for Signal Priority. ibid
- Pahs, M., et al., Door-to-Door Mobility: Evaluating a BRT Community Transport Concept. ibid
- Rathwell, S. and Schijns, S. Ottawa and Brisbane: Comparing a Mature Busway System. ibid.

2.3 Transportation Models Used in the Study

The project incorporated the findings of two transportation models in the benefit-cost analysis to estimate trips, mileages, time savings, passenger hours, etc.

SF-CHAMP

SF-CHAMP is the official travel forecasting tool for San Francisco, housed in San Francisco County Transportation Authority (SFCTA). It is a state of the art activity-based model that predicts future travel in the city.[10] Impacts of land use, socioeconomic and transportation changes are assessed to determine regional travel demand. SF-CHAMP uses the following inputs in the model to produce measures relevant to transportation and land use planning:

- Residents' observed travel patterns
- Socioeconomic characteristics
- Land use factors
- Representations of the city's transportation system
- Population and employment characteristics
- Transit line boardings
- Roadway volumes
- Number of vehicles per household

The project used the SF-CHAMP model runs to compare the 2040 Scenario A: Baseline Corridor (no build) to the 2040 Scenario B: Full Build-out forecast.

Travel Time Reduction Proposals: Transit Preferential Toolkit[11]

The toolkit describes common measures to reduce transit travel time. It includes planning-level cost estimates and estimated travel time savings. The following sources of delay are reviewed; transit stop

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[10] Modeling and Travel Forecasting, San Francisco County Transportation Authority, Moving the City, 2015

[11] Travel Time Reduction Proposals: Transit Preferential Toolkit, SFMTA Transportation Engineering, Draft, December 6, 2012

delay; dwell delay; merge delay; congestion delay; traffic signal delay; STOP sign delay and parking delay. For each time savings measure the scenario, estimated time savings and costs were analyzed.

CHAPTER 3: PROJECT SCHEDULE AND COSTS

This section describes the analytical assumptions for both one-time capital and on-going maintenance costs associated with the 22 Fillmore Multimodal project. The first subsection describes the baseline and the alternatives. The next subsection details the one-time construction, planning, engineering and design costs. The third section describes the maintenance costs. The fourth and final section of this chapter presents the discounted value of the costs.

3.1 Baseline and Alternatives

This BCA measures costs and benefits of the proposed project against a baseline (also called the "base case" or a "no build" case). The baseline represents an assessment of the way the world would look if this project does not receive the requested TIGER Discretionary Grant funding. For the most part, in the baseline, the 16th street corridor will resemble the present state. However, the BCA analysis factors in projected changes (e.g., baseline economic growth, increased traffic volumes, or completion of already planned and funded projects) that would occur even in the absence of the requested project. In addition, the baseline assumes the continuation of reasonable and sound management practices. For example, the baseline scenario assumes the city and SFMTA continue routine maintenance on the corridor and trolley infrastructure systems. In addition, the baseline assumes that the SFMTA continues to operate and increase frequency of the Route #55 diesel bus shuttle to meet anticipated growth in transit demand in the corridor.

The baseline is also realistic in terms of transportation assumptions. In the absence of the project, most transit riders will continue to follow the same route, although more riders will utilize the Route #55 diesel bus shuttle and fewer travelers will mode shift from auto to transit. This analysis uses the SF-CHAMP model to develop all of the travel patterns.

The proposed project has independent utility. It is part of a larger planned BRT network, which is just in the planning stages. However, it has transportation value in the absence of the other components. All of the costs and impacts of the project form the basis of the estimates of benefits and costs, as it would be incorrect to claim benefits for the entire project but only count the costs associated with the project to be funded by the TIGER Discretionary Grant.

SFMTA may eventually build this project absent TIGER funding. However, the length or probability of delay is unknown. In addition, such a delay would only postpone both benefits and costs, resulting in a similar benefit-cost ratio and fewer net benefits. The lost benefits in terms of added emissions, lost-time and accident costs will never be recovered. Moreover, as this project will aid in demonstrating the compelling benefits of this innovative urban BRT network, delaying the project could potentially delay the implementation of the entire BRT network. Therefore, this BCA does not include a "now versus later" comparison.

This benefit-cost analysis does not evaluate smaller-scale and more focused projects for comparison purposes. The BCA guidance notes, "If an applicant seeks funds to establish a relatively large streetcar project, it should also evaluate a more focused project serving only the more densely populated corridors of an area." This project is limited to a 2.17-mile portion of the planned BRT network, and constructing an even shorter section would serve little purpose as SFMTA has already constructed a short test section of BRT "red lanes" in the Church Street Project.

3.2 Capital Costs

The SFMTA engineering staff developed capital costs for the project. Exhibit 3-1 summarizes the project schedule including the major project phases and the duration of each.

Exhibit 3-1: Project Schedule

Milestone	Duration
Outreach & Legislation	Jan 2015 to Sept 2015
Conceptual Engineering	Sept 2015 to June 2016
Detailed Design	July 2016 to June 2017
Advertise & Award	July 2017 to Jan 2018
Construction	April 2018 to Oct 2019

Exhibit 3-2 provides the costs for each of the phases and elements of the project features including the number of units and the unit costs for each feature. Total cost of the project is $67.1 million.

Exhibit 3-2: Project Phases and Elements – Units, Unit Costs and Extensions

Phase	Features	Units	Unit Cost	Extension
Construction Only	Tranist Bulbs	25	200,000	5,000,000
	Streetscape elements on bulbs	25	75,000	1,875,000
	Pedestrian bulbs	25	70,000	1,750,000
	Curb Ramps	5	5,000	25,000
	Relocate Hydrants	7	50,000	350,000
	Catch Basins	50	7,260	363,000
	Signal upgrade	5	200,000	1,000,000
	New signal	8	400,000	3,200,000
	Streetscape	1	2,000,000	2,000,000
	OCS duckbank underground	1	3,150,000	3,150,000
	OCS -foundation and poles	1	1,367,300	1,367,300
	OCS - overground	1	-	3,149,420
	Repave Church to 7th		-	5,000,000
	Final Striping	500,000	1	500,000
	Bike Share Stations		-	100,000
	17 th street bike lanes		-	200,000
	Others- Allowance, mob/demob, hazard material management, traffic control, permits (15%)		-	4,324,458
	Total Core Project		**-**	**33,354,178**
Soft Costs	Environmental and Planning Out reach 5%		-	1,667,709
	Predevelopment 2%		-	667,084
	CER 7%		-	2,334,792
	Detail Design 15%		-	5,003,127
	Construction Support 20%		-	6,670,836
	Project Contengincy 35%		-	17,394,204
Total	**Total**			**67,091,929**

Exhibit 3-3 combines the project schedule and project elements assigning each of the costs to the appropriate year. For example, SFMTA has scheduled conceptual engineering to occur from September 2015 to June 2016. As a result, this feature of the project takes place for 3 months in 2015 and six months in 2016. The analysis, therefore, places one-third of the cost of conceptual engineering (CER) in 2015 and two-thirds in 2016. The analysis assumes that the project contingency will occur in the same time-period as construction. The bottom row of the exhibit contains the project spending by year.

Exhibit 3-3: Project Elements and Project Costs by Year

		Percent of Activity in Each Year					Project Spending in Each Year				
Features	Extension	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Construction	33,354,178	0%	0%	0%	50%	50%	-	-	-	16,677,089	16,677,089
Environmental & Planning Outreach	1,667,709	100%	0%	0%	0%	0%	1,667,709	-	-	-	-
Predevelopment	667,084	100%	0%	0%	0%	0%	667,084	-	-	-	-
CER	2,334,792	33%	67%	0%	0%	0%	778,264	1,556,528	-	-	-
Detail Design	5,003,127	0%	50%	50%	0%	0%	-	2,501,563	2,501,563	-	-
Construction Support	6,670,836	0%	0%	0%	50%	50%	-	-	-	3,335,418	3,335,418
Project Contingency	17,394,204	0%	0%	0%	50%	50%	-	-	-	8,697,102	8,697,102
Total	67,091,929						3,113,057	4,058,092	2,501,563	28,709,609	28,709,609

3.3 Maintenance Costs

The SFMTA engineering personnel also developed maintenance costs for the project. Exhibit 3-4 lists each maintenance item along with the unit cost, units, number of units, year of implementation assumptions, and scheduling rationale. Note that there are no quantities for some of the maintenance items. The no-build scenario does not require these items. However, the exhibit includes these items as the build alternative does require them.

Exhibit 3-4: Maintenance Costs by Item – Unit Costs, Units, and Quantities

Item	Unit Cost	Units	Quantity	Years of Implementation	Total Cost	Maintenance Schedule
Traffic Signal Conduits	$ 100,000	intersection	11	2040	$ 1,100,000	Replace every 20 years; new with project, 19 original signals + 6 new with project
Full Signal Upgrade	$ 350,000	intersection	0	n/a	$ -	Replace every 40 years; all signals upgrades as part of project and not upgraded during this study period
Transit Signal Priority	$ 30,000	intersection	75	25 intersections in 2030, 2040	$ 2,250,000	One upgrade implemented in project; update every 10 years; 25 intersections x 3 cycles = 75
Signage	$ 2,000	block	111	37 blocks in 2030, 2040	$ 222,000	As needed - signs typically last 10 years; $200 per sign (inclusive of labor, etc.); consider average of 10 signs per block
Lighting						Replace Bulbs 3-5 years and fixture life cycle 15 year, poles 50 years
Curb Return	$ 60,000	intersection	0	n/a	$ -	Part of project
Sewer	$ 3,750,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 100 years
Potable Water	$ 1,250,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 50 years
AWSS (fire hydrant water)	$ 2,500,000	mile	0	n/a	$ -	Ancillary project; would be complete prior to this project and infrastructure lifespan lasts 50 years
Red Transit only Lane Paint	$ 35,000	blocks	111	Painted in 2030, 2040, 2047	$ 3,885,000	Would be repainted when paving treated (cycle below); $5/sq ft for paint installation; lane approx. 12 ft. x 600 ft. per block
OCS Pole and Duct Bank Replacement	$ 18,600	pole, foundation and grounding	0	n/a	$ -	New poles have a 50 year life cycle and all poles needing upgrades would be included in the project for the Church to Valencia and Kansas/17th Street segments
OCS Wire Replacement	$ 50	linear foot	46400	2040	$ 2,320,000	Every 20 years, start 2040 as new wire installed as part of project; corridor is 11,600 feet long, need 2 lengths in each direction; 11600 x 4 = 46,400
OCS Wire Retensioning	$ 6,000	year	10	Every three years	$ 60,000	Every 10-15 years for the Church to Valencia and Kansas/17th Street segments, start 2020; inspection and retensioning the wires every 3 years; 35 years/3 = 12
OCS Inspection and Debris Removal	$ 3,000	year	10	Every three years	$ 30,000	Every 10-15 years for the segment on Kansas and 17th Street (OCS Overhead Feeder System*), start 2020; inspection and retensioning the wires every 3 years
OCS Special Work	$ 6,000	year	10	Every three years	$ 60,000	Every 2 years; adjusts the switches and enables turns for the buses (7 intersections with turns plus 3 more where the 22 Fillmore intersects with other trolley lines), start 2015; assume same level of effort as wire retensioning
Paving and Striping	$ 21,600	blocks	37	2030	$ 799,200	Project area first preservation in 2030
	$ 21,600	blocks	37	2040	$ 799,200	Project area second preservation in 2040
	$ 120,000	blocks	37	2047	$ 4,440,000	Project area repaved in 2047
TOTAL:					**$ 15,965,400**	

Exhibit 3-5 provides additional detail on the paving maintenance item. San Francisco Public Works has a goal to maintain a "good" PCI score of 70 citywide and this analysis uses this goal as a street-level goal as well. San Francisco Public Works also suggests the following improvement schedules:

- A first preservation treatment is required in approximately 10 years to maintain a “good” rating
- After the second preservation treatment the pavement will move to at "at risk" in approximately 7 years
- Repaving needed after two preservation treatments in approximately 27 years

The base case followed these rules. After the initial construction in 2020, the schedule calls for preservation in 2030 and 2040 with a repaving in 2047. The analysis assumes that all 37 blocks will receive preservation or repaving at the same time.

Exhibit 3-5: Pavement Conditions, Improvements Required and Costs

Pavement Condition Index (PCI)	Improvement Required	Cost
85 – 100 “excellent”	No improvement needed	$0
70 – 84 “good”	Pavement preservation – specialized sealing treatments to extend life of street	$21,600
50 – 69 “at-risk”	Repave - grind off and replace the top two inches of asphalt	$120,000
25 – 49 “poor”	Resurface with base repair - grind off and replace the top two inches of asphalt and repair the concrete base	$165,000
0 – 24 “very poor”	Reconstruction - reconstruct the street including concrete base and top layer of asphalt	$520,000

Exhibit 3-6 summarizes the maintenance costs for the “build” case. The total undiscounted costs are approximately $15 million. The largest cost is for paving followed by repainting the lanes red.

Exhibit 3-6: Maintenance Costs by Year

Year	Traffic Signal Conduits	Transit Signal Priority	Signage	OCS Wire	OCS Maintenance	Red Transit Only Lane Paint	Paving Maintenance	Total
2015								-
2016								-
2017								-
2018								-
2019								-
2020								-
2021								-
2022					15,000			15,000
2023								-
2024								-
2025					15,000			15,000
2026								-
2027								-
2028					15,000			15,000
2029								-
2030		750,000	74,000			1,295,000	799,200	2,918,200
2031					15,000			15,000
2032								-
2033								-
2034					15,000			15,000
2035								-
2036								-
2037					15,000			15,000
2038								-
2039								-
2040	100,000	750,000	74,000	2,320,000	15,000	1,295,000	799,200	5,353,200
2041	100,000							100,000
2042	100,000							100,000
2043	100,000				15,000			115,000
2044	100,000							100,000
2045	100,000							100,000
2046	100,000				15,000			115,000
2047	100,000					1,295,000	4,440,000	5,835,000
2048	100,000							100,000
2049	100,000				15,000			115,000
Total	**1,000,000**	**1,500,000**	**148,000**	**2,320,000**	**150,000**	**3,885,000**	**6,038,400**	**15,041,400**

3.4 Discounted Value of Capital and Maintenance Costs

Exhibit 3-7 sums the capital and maintenance costs and discounts the costs in each year to present values using both a 3 percent and a 7 percent real discount rate. The total undiscounted costs of the project are approximately $82.1 million. The total discounted costs are approximately $68.3 million using a 3 percent and approximately $57.3 million using a 7 percent real discount rate.

Exhibit 3-7: Summary of Discounted Project Costs

Year	Maintenance Costs (Dollars)	Construction Costs (Dollars)	Total Construction and Maintenance Costs (Dollars)	Present Dollar Value of Project Costs at 3%	Present Dollar Value of Project Costs at 7%
2015	-	3,113,056.61	3,113,057	3,113,057	3,113,057
2016	-	4,058,092	4,058,092	3,939,895	3,792,609
2017	-	2,501,563	2,501,563	2,357,963	2,184,962
2018	-	28,709,609	28,709,609	26,273,359	23,435,593
2019	-	28,709,609	28,709,609	25,508,115	21,902,423
2020	-	-	-	-	-
2021	-	-	-	-	-
2022	15,000	-	15,000	12,196	9,341
2023	-	-	-	-	-
2024	-	-	-	-	-
2025	15,000	-	15,000	11,161	7,625
2026	-	-	-	-	-
2027	-	-	-	-	-
2028	15,000	-	15,000	10,214	6,224
2029	-	-	-	-	-
2030	2,918,200	-	2,918,200	1,873,082	1,057,690
2031	15,000	-	15,000	9,348	5,081
2032	-	-	-	-	-
2033	-	-	-	-	-
2034	15,000	-	15,000	8,554	4,148
2035	-	-	-	-	-
2036	-	-	-	-	-
2037	15,000	-	15,000	7,828	3,386
2038	-	-	-	-	-
2039	-	-	-	-	-
2040	5,353,200	-	5,353,200	2,556,718	986,323
2041	100,000	-	100,000	46,369	17,220
2042	100,000	-	100,000	45,019	16,093
2043	115,000	-	115,000	50,264	17,296
2044	100,000	-	100,000	42,435	14,056
2045	100,000	-	100,000	41,199	13,137
2046	115,000	-	115,000	45,999	14,119
2047	5,835,000	-	5,835,000	2,265,947	669,514
2048	100,000	-	100,000	37,703	10,723
2049	115,000	-	115,000	42,095	11,525
Total	**15,041,400**	**67,091,929**	**82,133,329**	**68,298,520**	**57,292,145**

CHAPTER 4: QUALITY OF LIFE BENEFITS - ACCESSIBILITY & PROPERTY VALUE

This chapter describes Quality of Life benefits and it components as defined by the United States Department of Transportation (USDOT) for the Transportation Investment Generating Economic Recovery (TIGER) Grant application. This chapter also describes the quantification of benefits and how they align with the requirements of USDOT regarding a TIGER grant. A short compilation of measures that are included in the 22 Fillmore Transit Priority Project depicts how this project will improve Quality of Life for the community and how these benefits are a measureable and legitimate part of this BCA. Section 5 cites a variety of literary sources regarding Quality of Life improvements which are divided between discussing *Accessibility* and *Property Value Increases.* Finally, the last part of this chapter sums up a methodology of how Quality of Life benefits have been calculated for this project, including the elimination of double counting, and includes a table showing these results.

4.1 Description of the Quality of Life Benefit

The USDOT TIGER Resource Guide suggests three types of societal benefits that relate to the long-term outcome of improving the quality of life for the community: *Land Use Changes that Reduced VMT, Accessibility* and *Property Value Increases,* as shown in Exhibit 2-1. Accessibility and Property Value factors are discussed as a benefit to the long term outcome *Quality of Life*[12] within this BCA.

Exhibit 4-1: Accessibility and Property Value Increases are parts of Quality of Life

Long-Term Outcome	Types of Societal Benefits
Quality of Life	Land Use Changes that Reduce VMT Increased Accessibility Property Value Increases

The implementation of the 22 Fillmore Transit Priority Project will not include land use changes as part of this project. However, the improved transit service is essential to mitigate the increases in vehicle miles traveled (VMT) that may occur as a result of the substantial brownfield redevelopment activities planned for Mission Bay.

The term *Accessibility* describes how well-connected neighborhoods, and thus its residents, are to the local transport system. Quick access to transit options is important for every resident of an urban district, because it provides a valuable connection to retail, recreational or cultural facilities in other parts of the city. Accessibility consists of different factors that need to be taken into account including: livability, walkability, safety of walkways to transit stops, and the development of adjacent property values. In this BCA, the focus is on accessibility as a whole and the impact of improved access on property value trends.

Property Value Increases due to improvements in transit functionality are considered to be the cumulative value of an infrastructure investment, meaning they quantify the increase in *Quality of Life* of an area. They are most often not included in a BCA, in order to avoid double counting. This approach will nevertheless discuss property value increases as a factor and compile a benefit estimation that subtracts travel time savings and other estimated benefits from property value increases which are based on the 16th Street project.

[12] US Department of Transportation (2015): Benefit-Cost Analysis Guidance for TIGER Applicants

4.2 Justification as a TIGER Benefit

In the framework of the TIGER Grant program, the USDOT gives consideration to projects that seek to improve access to reliable, safe, and affordable transportation in context of projects that promote *Ladders of Opportunity*. Ladders of Opportunity are supported by an increase in connectivity to employment, education, services and other opportunities, particularly for disadvantaged groups: low-income groups and minority persons or populations. With a 51% minority and a 25% low-income rate within a quarter-mile of the 16th Street corridor, the 22 Fillmore project develops better access to public transportation for adjacent residents falling into these categories, and thus significantly impacts these groups. Moreover DOT states in the NOFA that the extent to which a project will anchor positive and long-lasting quality of life changes can be a deciding factor.[13] The goal of this analysis is to demonstrate and illustrate the improvements in *Quality of Life* in the corridor that this project will support. It is crucial to also evaluate the property value changes as they pose a valid measurement of such developments.

4.3 Quality of Life Benefits of This Project

22 Fillmore Transit Priority Project will implement transit-only lanes on a busy corridor which will significantly increase speeds of these buses and decrease travel time. Some existing bus stops will be renewed, others will be removed, and new bus bulb-outs will be constructed for over half the corridor in the middle of 16th Street. Several new bus bulbs will further decrease bus travel and dwelling time, provide a safer environment for passengers and space for landscaping. Overall, the number of entry and exit points will decrease compared to the base line of the project, yet shorter transit and dwell times make up for this decrease. This higher efficiency is going to attract more residents to use transit and will also cause previous auto users to shift modes to transit. Furthermore, new pedestrian signals and wider, safer refuges throughout the corridor will increase safety, walkability, and accessibility. These greatly improved conditions in quality of transit service and other factors will impact property values along 16th Street in the long run. All of the above are part of the *Quality of Life* benefits for the corridor, the calculation of which will show that this project has additional benefits beyond travel time savings and more efficient transportation. The time related benefits estimated in other BCA report sections are part of the reason property values in the corridor will increase, so they are removed from the Quality of Life benefits estimated in this section to eliminate double counting.

4.4 Review of Quality of Life Benefit Literature

This section will review the recent literature on the two Quality of Life benefits that will be generated by the improvements planned for this corridor: Accessibility and Increased Property Value.

Accessibility

There are numerous studies and reports that address how increased accessibility can have a positive long-term outcome for a particular area. The main cause of improved accessibility and an increased use of transit options is a reduction in transit travel times. Reduced travel time is the most significant factor in the decision to use transit. Pedestrians considering the use of transit are not only influenced by travel time but furthermore by the character and quality of the environment through which they walk[14]. This means that accessibility as a whole relies on multiple factors: number of access points, travel time and

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[13] US Department of Transportation (2015): *Notification of Funding Availability*

[14] Susan L. Handy, Kelly J. Clifton (2001): Evaluating Neighborhood Accessibility: Possibilities and Practicalities

safety as well as width of sidewalks, intensity of auto traffic along the walkways, appeal of landscaping efforts, lighting, benches, and traffic signals from and to transit stops. It can thus be concluded that it is difficult to measure or estimate accessibility, because it not only relies on factual information, but also on a subjective perception of the individual.

Measurable factors such as travel time are useful tools for monetizing benefits related to accessibility. Improvements in transit travel time translate into improved access to jobs. This is a key economic benefit to people who choose not to drive a car and/or cannot afford to own a car.[15] As 58% of people living in a quarter-mile range of 16th Street do not own a car, they will be able to seize a wider range of opportunities for the same travel time investment in their personal and professional life after the 16th Street project has been completed, underlining the fulfillment of USDOT's requirement to provide Ladders of Opportunity to close-by community members.

There are few studies that have been conducted on the term *livability.* Livability includes the factors mentioned above and is the approach to sum up the connectivity and neighborhood appeal or rather attractiveness of a district as a whole in one word. Unlike property values, which illustrate the monetized worth that demand and supply determine through a free market, livability is an attempt to combine this variety of traits on a qualitative basis. One of the principles expressed by USDOT is to enhance the unique characteristics of all communities by investing in healthy, safe and walkable neighborhoods, whether, rural, urban or suburban.[16] It has been reported that investment in improved pedestrian facilities would generate $128 per year in health benefits for each pedestrian, who did not formerly engage in physical activity.[17] Such statistics show that walkability, as a part of accessibility, has a broader spectrum of benefits than just travel time savings. This is a small numerical benefit, the value of which is controversial and requires current and future health information on the local population. As such it is not monetized and included in the current BCA calculation.

Further, the San Francisco Municipal Transportation Agency (SFMTA) in coordination with the San Francisco County Transportation Authority (SFCTA) is studying a proposed Bus Rapid Transit (BRT) connection on Geary Boulevard, just a few miles north-west of 16th Street. This study noted that BRT improvements similar to those planned for 16th Street are also expected to make corridors more accessible, improving the livability for neighbors, as well as appeal for visitors.[18] The proximity of Geary Boulevard and 16th Street, the similarities of both projects, and an increased importance of 16th Street within the San Francisco's infrastructure implies that the 22 Fillmore project will have similar effects on livability along the 16th corridor.

Property Value Increases

As in most urban environments, San Francisco has already been divided into a finite number of parcels. The 22 Fillmore project will improve the safety of the corridor and reliability of the transit service along the corridor, making it more desirable and therefore in greater demand. This often leads to higher property values for those parcels with easy access to the corridor. Moreover it is desirable for residents

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[15] San Francisco County Transportation Authority (2007): *Geary Corridor Bus Rapid Transit Study*
[16] US Department of Transportation (2015): Livability 101: Six Principles of Livability
[17] National Cooperative Highway Research Program (2006): Guidelines For Analysis of Investments in Bicycle Facilities
[18] San Francisco County Transportation Authority (2007): *Geary Corridor Bus Rapid Transit Study*

to live closer to transit stops because they are able to travel to their desired destination in a shorter amount of time.[19]

Numerous academic and government research projects have shown that improved transit systems influence property values and various empirical studies have validated the positive influence of transportation improvements on property values as well. For example, rail transit stations constructed in residential areas have been shown to result in an average increase in single-family home sales prices of 3%.[20] Considering such studies focus on rail transit transportation systems, it is uncertain whether these conclusions could be applied to BRT systems as well and the amount of available literature regarding economic impacts of BRT is small. Nevertheless, the available studies on this topic state that the positive impacts of rail transit can be transferred to bus transit. If the land-use of areas surrounding BRT stations is integrated in the planning process early on, land-use benefits similar to those produced by rail transit are likely to occur. Ottawa, Pittsburgh, Brisbane and Curitiba have performed such integration at an early state of BRT construction and thus realization of these benefits could be achieved.[21]

In addition, it is also important to consider walkability and overall quality of life of a neighborhood while estimating future property value developments. Walkable neighborhoods, parks and open spaces are believed to generate economic benefits to local home owners through higher property values. In fact, an increase in the percentage of open space land surrounding a property can raise average house prices by up to 1% of total property value.[22] It is expected that the 16th Street project including projects like sidewalk widening, landscaping and new pedestrian safety refuges will positively influence the property values along 16th Street. This redevelopment of the corridor will make the neighborhood more walkable, appealing and attractive, and provide other social benefits and quality of life benefits, independent from travel time savings. There is evidence that creation of such pedestrian-friendly environments near BRT stops can further increase land- and property-value benefits.[23]

4.5 Quality of Life Benefit Estimation Methodology

Basic Assumptions

To prevent double counting of the benefits in this category with others in this analysis, the USDOT has distributed guidance and previous TIGER BCAs illustrating the error in asserting property value increases net of travel time savings. An applicant is obligated to provide rigorous justification of such benefits, as is presented above.[24]

In order to generate an estimation of long-term quality of life benefits focused on the two factors *Accessibility* and *Property Value Increases,* a thorough literature review and comparison of academic

[19] Robert Cervero, Chang Deok Kang (2009): Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea

[20] Robert Cervero, David Aschauer (1998): Economic Impact Analysis of Transit Investments: Guidebook for Practitioners

[21] Herbert S. Levinson et al. (2002): Journal of Public Transportation, Volume 5, No. 2, Bus Rapid Transit: An Overview

[22] Robert Wood Johnson Foundation (2010): The Economic Benefits of Open Space, Recreation Facilities and Walkable Community Design

[23] Nicolas Estupinan and Daniel A. Rodriguez (2008): The Relationship between Urban Form and Station Boardings for Bogota's BRT

[24] US Department of Transportation (2015): Benefit-Cost Analysis Guidance for TIGER Applicants

studies has been executed. This review showed that it is reasonable to assume that residents adjacent to newly-installed BRT/transit priority streets are not only going to benefit from faster transit, but they are likely to benefit from increased accessibility, livability, and walkability which improve overall Quality of Life. The 22 Fillmore project will also yield:

- Substantial travel opportunities for all residents of the San Francisco area in order to reach Mission Bay and its major economic redevelopment project;
- Improved access to entertainment and sports venues such as AT&T Park and the proposed Golden State Warriors' arena;
- Health benefits to society by encouraging more residents to mode shift to walking and transit; and,
- Ladders of Opportunity that provide improved access to this district with over fifty percent minority and twenty two percent poverty level residents.

In order to quantify such benefits the focus of this specific chapter has been shifted from more tangible benefits (e.g. travel time savings and safety benefits) to property value increases. These quantify the overall change in Quality of Life of a neighborhood and hence give valuable insight in future developments after transit priority projects have been introduced.

This analysis has been informed by a study that investigates influences of BRT introduction along a corridor in Seoul, Korea, and how this construction has influenced adjacent property and land-use values.[25] Since its subject includes BRT being established within a highly dense area with a large amount of commuters, this study shows some parallels to 16th Street project in San Francisco. The Korea study quantified the average land price premiums at 5-10 percent within 300 meters of BRT stops. Considering the fact that the 16th Street transit corridor is going to have an average of 5 stations over each mile of its length, this study's results suggest San Francisco's improved BRT line along 16th Street will also impact local property values.

Quality of Life Methodology

Quality of Life Benefits have been calculated by first estimating the overall value of properties adjacent to 16th Street.

Average land prices are estimated by gathering average property value from Census data of three different ZIP Codes along 16th Street. These property values were multiplied by the percentage of housing units in each ZIP Code compared to total units in all three ZIP Codes. Housing unit data was gathered from the Census, as well.[26] Details of this calculation are shown in Exhibit 4-1 below.

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[25] Robert Cervero, Chang Deok Kang (2009): Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea

[26] U.S. Census Bureau (2009-2013): *5-Year American Community Survey,* Selected Housing Characteristics

Exhibit 4-2: The 16th Street Corridor Property Values

Property values along 16th Street					
Neighborhood	ZIP Code	Occupied Housing Units	Median Value of owner-occupied units	Ratio to total units	Weighed unit value
Mission District	94110	27,668	$768,200	52.50%	$403,335
	94103	11,687	$628,000	22.18%	$139,276
Potrero Hill	94107	13,342	$719,000	25.32%	$182,039
Total		52,697		100.00%	$724,650

Census data provided an estimate of the average property value in the three zip code areas in the Mission region and the SFCHA provided the number of housing units within a quarter mile of 16th Street. The literature indicated that rail projects in the US and elsewhere had demonstrated that a 3% increase in property value could be expected. This was well below the 7.5% Total reported in the Korean BRT development.

For this analysis a relatively low percentage increase of 1.5% was chosen. The assumed low growth was all that was needed with the high property values to demonstrate that even after the time related benefits estimated in other chapters were subtracted from the Property Value increase, a substantial benefit beyond the time related benefits still remained.

This calculation results in Gross Dollar Value of Quality of Life Benefits. Gross values are assumed to occur in 2025 as there is a lag period over which the increase occurs. The property value benefit is a one-time increase realized by the property owner with tax appraisal modifications and sale of the property. No research on the timing distribution of these benefits was located, so it was assumed that all benefits occur in 2025. In actuality, the realization of these benefits will likely occur over a multi-year period.

The 2025 value has been discounted from 2025 to a 2015 Dollar value at both 3% and 7% discount rates. From discounted 2015 dollar values, 2015 Travel Time Savings Benefits and Reliability Benefits are subtracted, in order to prevent double counting of benefits. Exhibit 4-3 shows the calculation of property value increases and the reduction of benefits counted elsewhere.

Exhibit 4-3: Results of Quality of Life Benefit Calculations

		Data Sources and Calculation
Housing Units Within Quarter Mile of 16th	30,407	SFCHA Estimate
Average Value of 16th Street Housing Units	$ 724,650	Census data for three Mission Zip Codes
Total Value of Housing Units	$ 22,034,438,638	Number of Units times Average Value
Assumed Value Increase	1.5%	Assumed gross increase from Project
Gross Dollar Value Increase	$ 330,516,580	Reduction % times the Property Value
Discount from 2025 to 2015 Dollars, 3%	$ 245,935,376	Discount Benefit at 3%
Discount from 2025 to 2015 Dollars, 7%	$ 168,017,869	Discount Benefit at 7%
Travel Time Benefits (3%) NPR 2015	$ 139,636,844	
Travel Time Benefits (7%) NPR 2015	$ 74,783,279	
Reliability Benefits (3%) NPV 2015	$ 49,837,262	
Reliability Benefits (7%) NPV 2015	$ 26,690,620	
Net Present Dollar Value (3%)	$ 56,461,269	Subtract Time Benefits from Property Value at 3%
Net Present Dollar Value (7%)	$ 66,543,971	Subtract Time Benefits from Property Value at 7%

CHAPTER 5: ECONOMIC COMPETITIVENESS – TRAVEL TIME SAVINGS

The Benefit-Cost Analysis Analyses Guidance for TIGER Grant Applicants lists five Long-Term Outcomes on page 7, along with the types of social benefits realized for each.[27] This chapter discusses and quantifies the Economic Competitiveness long-term outcome, focusing on the Travel Time Savings societal benefit.

The chapter is divided into five sections, including:

1. Description of the benefit
2. Justification as a TIGER benefit
3. The benefit in this project
4. Related research
5. Estimation methodology

5.1 Description of the Time Savings Benefit

The *Value of Travel Time* (VTT) refers to the cost of time spent on transport. It includes waiting as well as actual time in travel. VTT covers costs to consumers of personal (unpaid) time spent on travel, and costs to businesses of paid employee time spent in travel. The *Value of Travel Time Savings* (VTTS) refers to the benefits from reduced travel time costs. [28]

Total travel time cost is the product of time spent traveling and unit costs. Unit costs can vary by travel conditions, type of travel and traveler preferences.[29] Travel time costs can differ by traveler preference or needs, and for different parts of a trip. Unreliability imposes additional costs.

Factors that affect travel time valuation include:

- Type of trip, traveler and pleasant/unpleasant conditions
- Objectively measured vs. perceived travel time
- Income levels of travelers
- The experience or perceived health benefits
- Variability and arrival uncertainty
- Type of travel (eg. Driving vs. transit)
- Improvements that reduce motorists' need to chauffeur non-drivers
- Drivers vs. non-drivers

5.2 Justification as a TIGER Benefit

Economic Competiveness is one of five long-term outcomes and primary selection criteria in the FHWA's TIGER grant program.[30] The box below, taken from the table on page 7 of the TIGER Guidance, shows the portion

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[27] 2015 Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants, United States Department of Transportation April 6, 2015

[28] Transportation Cost and Benefit Analysis II – Travel Time Costs. Victoria Transport Policy Institute, 2013, p. 5.2-2.

[29] Kenneth Small, Cliford Winston and J. Yan (2005), *Uncovering the Distribution of Motorists' Preferences for Travel Time and Reliability: Implications for Road Pricing*, University of Irvine (www.economics.uci.edu); at www.socsci.uci.edu/~ksmall/Value%20of%20time%20note.pdf.

containing the Travel Time Savings benefit. This section of the report addresses the estimation of travel time savings stemming from the 22 Fillmore Transit Priority Project.

Long-Term Outcome	Types of Societal Benefits
Economic Competitiveness	✓**Travel Time Savings** Operating Cost Savings

The USDOT recognizes the critical importance of travel time in evaluating the benefits of transportation infrastructure and rulemaking initiatives.[31] The agency acknowledges, however, that reduction of travel time, as a major purpose of investment, may conflict with other agency rules, such as safety, by actually slowing travel. It is difficult to assign a monetary value to the benefit of reduction of travel time in benefit/cost analyses and has been the subject of investigations across the globe for decades. USDOT recognizes the inexact nature of the variables and their relationships but acknowledges they provide a "useful framework" for subsequent government policies and research calculations.[32]

In general, travel time is conceived as a negative demand in that consumers are willing to pay to reduce it. Its value depends on the traveler and trip situation, along with transportation alternatives. The value of travel time reduction is based on:

- A monetary benefit resulting from time that could be spend on production,
- Recreation or other enjoyable or necessary activities for which individuals are willing to pay,
- Travel conditions during part of or the entire trip.

The Transportation Economics Committee of the Transportation Research Board (TRB) identifies additional issues to consider, such as:[33]

- Regional differences in wage rates
- Intercity vs. local trips
- Small travel time savings vs. large travel time savings
- Passenger vs. driver time
- Travel time as a benefit rather than a dis-benefit
- Types of transportation models used in the value of time

The USDOT maintains travel time savings as a typical benefit to carriers, passengers and shippers and the agency provides regularly updated guidance on the Value of Time benefit.[34] In its guidance, the USDOT cautions TIGER grant applicants to match travel time savings to the correct population group and correct time period.[35]

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30 Ibid.
31 Trottenberg, Polly. Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis, Memorandum, September 28, 2011.
32 The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations, Revision 2. USDOT.
33 Transportation Benefit-Cost Analysis; Issues to consider. http://bca.transportationeconomics.org/benefits/travel-time/issues-to-consider
34 http://www.dot.gov/administrations/office-policy/2015-value-travel-time-guidance
35 TIGER 2015: Preparing a Benefit-Cost Analysis, Webinar.

In 2013, USDOT recommended the following surface mode hourly values of local travel time savings:

- Personal $12.50
- Business $24.40
- All Purposes $13.00

5.3 Time Savings Benefit of this Project

Muni Forward which includes the 22 Fillmore Transit Priority Project on 16th Street incorporates engineering features designed specifically to address the root causes of transit delay, among its other benefits.[36] The project incorporates technology and infrastructure to speed travel along the corridor and support faster more reliable multimodal transportation. Improvements to transit and walking on 22 Fillmore should be reduced by about five minutes in each direction, a reduction of 25 percent.[37] Improvements designed to reduce travel time in the 16th Street corridor include:

- Replacement of traffic and pedestrian signals (depending on an upcoming assessment)
- Cameras to enforce transit-only lanes (pending approval of legislation)
- Service changes to increase the frequency of the transit route
- Modifications to address bottlenecks

For Pedestrians:

- Widened sidewalks
- New pedestrian countdown signals

For Transit:

- Dedicated red - painted transit lanes to reduce congestion
- Transit signal priority – to reduce wait times at red lights
- Fewer bus turns – to speed travel
- Reduced boarding and alighting times for passengers
- Fewer closely spaced transit stops
- Bus bulbs allowing bus to stay in its own traffic lane and ease boarding and alighting of the bus – to reduce dwell time

For Cyclists:

- Relocation of the bike lane to parallel street reducing conflicts with other vehicles

For Motorists:

- Upgraded or new countdown signals
- Restricted left turns
- Fewer conflicts with buses
- Reduced double parking
- Increased traffic flow

5.4 Measuring the Value of Time Saved

An hour of travel associated with a business trip or commerce is usually valued at the average traveler's wage plus overhead—representing the cost to the traveler's employer. Personal travel time (either for commuting or leisure) is usually valued as a percentage of average personal wage or through estimates

[36] Muni Forward Transit Priority Project Status, SFMTA.
[37] 22 Fillmore - 16th Street Transit Priority Project,

of what travelers would be willing to pay to reduce travel time. Recently researchers have identified another important benefit: travel time reliability. Due to uncertainty in travel time, travelers add “buffer time” to their trips to ensure they arrive at their destination on time. Some Transportation Systems Management Operations projects reduce travel time, some reduce buffer time, and some reduce both. Both are benefits.

The TIGER Resource Guide provides national average wage rates to be used in the valuation of time saved. These data are in 2013 dollars, so they would need to be price updated to 2015 dollars for this BCA. However, San Francisco is an urban area with one of the highest wage rates in the country. As such the local wage information from the US Census for the region is used as a basis for the local value of time. The Metropolitan Planning Commission (MTC) for the SF Bay region developed the value of time shown in Exhibit 5-1 for their regional plan. The MTC dollar values were price updated to 2015 dollars using the CPI.

Exhibit 5-1: Value of Time for San Francisco Bay Region, 2015 Dollars

Benefit	Valuation (2015,$)	Definition and Source
In-Vehicle Travel Time (Auto and Transit) per Person Hour of Travel	$16.28	This valuation is set equal to one-half of the mean regional wage rate ($32.56). The valuation represents the discomfort to travelers of enduring transportation related delay and the loss in regional productivity for on-the-clock travelers & commuters. Sources: Caltrans Cal B-C Model; Bureau of Labor Statistics National Compensation Survey, 2011
Out-of-Vehicle Travel Time (Transit) per Person Hour of Travel	$35.82	This valuation is set equal to 2.2 times the valuation of in-vehicle transit time. The valuation represents the additional discomfort to travelers of experiencing uncertainty of transit arrival time, exposure to inclement weather conditions, and exposure to safety risks. Source: FHWA Surface Transportation Economic Analysis Model (STEAM)
In-vehicle Travel Time (Freight/ Trucks) per Vehicle Hour of Travel	$26.65	The valuation is set equal to the average wage rate for a Bay Area employee in the Transportation – Truck Driver (average of heavy and light) occupation sector ($23.83/hour), plus the average hourly carrying value of cargo ($2.41/hour). Sources: FHWA Highway Economic Requirements System; Bureau of Labor Statistics National Compensation Survey, 2011
Travel Time Reliability (Auto) per Person Hour of Non-recurring Delay	$16.28	The valuation represents the additional traveler frustration of experiencing non-expected incident related travel delays. The value is set equal to the value of in-vehicle travel time for autos. Source: SHRP2 L05 Project – "Incorporating Reliability performance Measures into the Transportation Planning and Programming Processes"
Travel Time Reliability (Freight/Truck) per Vehicle Hour of Non-recurring Delay	$26.65	The valuation represents the additional loss of regional productivity of experiencing non-expected incident related travel delays. The value is set equal to the value of in-vehicle travel time for trucks. Source: SHRP2 L05 Project – "Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes"

Source: PLAN BAY AREA - Performance Assessment Report, Prepared by MTC Staff, July 8, 2013. Values updated to 2015 using the CPI, http://data.bls.gov/cgi- bin/cpicalc.pl?cost1=26.24&year1=2013&year2=2015

All calculations are carried out in 2015 dollars and estimated for current and future years, 2015 to 2050. Annual benefits in 2015 dollars are discounted to 2015 using 3 and 7 percent discount rates.

5.5 Estimating the Value of Time Benefits

The 22 Fillmore Transit Priority Project will transform the transit service provided along this highly congested corridor. Travelers will experience a shorter, more reliable trip. This time savings is valued by travelers at the rates suggested in the previous section. In order to estimate the net present value of these benefits, the following assumptions we made. All calculations are provided in the BCA spreadsheet submitted with this application.

1. ***Estimate the number of travelers receiving this benefit.*** The number of transit riders will increase as a result of the improved service. We use the SF-CHAMP model to estimate transit riders in the corridor with and without the project in 2040. Time will be saved by the transit riders who would have ridden the bus/trolley service on 16th Street in the No-Build Scenario. Additional riders shifting modes will also enjoy the fast trip, but their change in travel time depends on their old trip which may have been shorter than the transit trip chosen in the build scenario. No adjustment in the estimated benefit is calculated for these riders as it is assumed that their decision to shift modes is rational and was responsive to other benefits realized, but not estimated here.
2. ***Interpolate ridership.*** The SF-CHAMP model provides ridership estimates (boardings) for 2040 with and without the project. SF-CHAMP also provides a 2012 baseline ridership estimate. We trend ridership between 2012 and 2040 and continue that trend to 2050 to produce annual ridership estimates.
3. ***Estimate travel time savings for 16th Street service***. This is a multi-step process involving the speed impacts on bus service from each corridor modification.
    a. Exhibit 5-2 provides a breakdown of each corridor modification for each bus stop and cross street section of the route.
    b. Assumptions about the time savings realized for each modification are made for each of the three unique sections of the route.
    c. Current bus run time is developed from Automatic Passenger Count Systems.
    d. Exhibit 5-3 presents the time savings for each section of and the total corridor, summed from the individual modification estimates.
    e. Exhibit 5-4 aggregates these time savings for both inbound and outbound directions and for the AM and PM peak periods.
    f. Exhibit 5-4 provides the overall average travel time savings by weighting the direction and peak values with 2040 boarding estimates for the No-Build.
    g. The weighted average travel time savings for the full 16th Street corridor in 6.4 minutes per trip. Time saved ranged from 5.9 to 7.3 minutes depending on direction and peak period.
4. ***Estimate the length an average traveler's trip***. Since all travelers will not be on the corridor for the full length, they will not enjoy the full travel time savings. The CHAMP model suggested that riders may average about 60 percent of the corridor distance. To be conservative, this analysis assumed the on average traveler's would be on the corridor for half its length and realize half of the total time savings.

5. ***Estimate Annual Travel Time Savings***. The number of weekday boardings in each year in the peak periods, times the minutes saved per trip, times fifty percent, divided by sixty, provided the annual hours saved as shown in Exhibit 5-5.

Exhibit 5-2: Estimated Bus Time Savings, 16th Street Corridor by Time-of-Day, Cross Street, and Improvement Type

Side Riding Transit Lane (WB aka IB only) & 2 stop removals

		APC Data			
		(IB) AM	(IB) PM	(OB) AM	(OB) PM
Existing Time		531	626	642	639
TSP Savings	10.00%	53	63	64	64
Transit Only Lane Savings	5.0	70	70	0	0
Converting Stops to Bulb Outs/Islands	5.0	30	30	30	30
Moving Stop from NS to FS	5.0	10	10	10	10
Ped Bulb Influences	2.0	8	8	8	8
New Signals	0.0				
Stop Removal	30.0	30	30	30	30
Stop Addition	-30.0	0	0	0	0
		330	415	500	497

Stops	Transit Only	Convert Stop	Move Stop	Ped Bulb	New Signals	Stop Removal	Stop Addition
Church	1	1					
Dolores	1	1	1				
Guerrero	1			1		1	
Albion	1						
Valencia	1	1	1				
Hoff/Julian	1						
Mission	1	1					
Capp	1			1			
South Van Ness	1						
Shotwell/Folsom	1	1		1	1		
Harrison	1			1			
Alabama	1						
Florida	1						
Bryant	1	1					
	14	6	2	4	1	1	0

Center Running Transit Lanes (both directions) & 1 stop removal

		APC Data			
		(IB) AM	(IB) PM	(OB) AM	(OB) PM
Existing Time		273	391	328	309
TSP Savings	10.00%	27	39	33	31
Transit Only Lane Savings	5.0	60	60	60	60
Converting Stops to Bulb Outs/Islands	5.0	20	20	20	20
Moving Stop from NS to FS	5.0	0	0	0	0
Ped Bulb Influences	2.0	10	10	10	10
New Signals	0.0				
Stop Removal	30.0	30	30	30	30
Stop Addition	-30.0	0	0	0	0
		126	232	175	158

Stops	Transit Only	Convert Stop	Move Stop	Ped Bulb	New Signals	Stop Removal	Stop Addition
Potrero	1	1					
Utah	1				1		
San Bruno/Vermont	1			1	1	1	
Kansas	1			1			
Rhode Island	1	1		1			
DeHaro	1			1			
Carolina	1						
Wisconsin	1	1			1		
Arkansas	1						
Connecticut	1			1	1		
Missouri	1	1			1		
Mississippi/7th	1						
	12	4	0	5	5	1	0

Side Running Transit Lanes (both directions) & 1 stop addition

		APC Data			
		(IB) AM	(IB) PM	(OB) AM	(OB) PM
Existing Time		221	256	243	237
TSP Savings	10.00%	22	26	24	24
Transit Only Lane Savings	5.0	10	10	10	10
Converting Stops to Bulb Outs/Islands	5.0	0	0	0	0
Moving Stop from NS to FS	5.0	0	0	0	0
Ped Bulb Influences	2.0	0	0	0	0
New Signals	0.0				
Stop Removal	30.0	0	0	0	0
Stop Addition	-30.0	-30	-30	-30	-30
		219	250	239	233

Stops	Transit Only	Convert Stop	Move Stop	Ped Bulb	New Signals	Stop Removal	Stop Addition
Owens	1						1
4th Street	1						

Exhibit 5-3: Estimated Transit Travel Time Savings 16th Street Corridor – With Project

Travel Times (minutes)

		APC Data **Existing (IB)**	APC Data **Existing (OB)**
Church <--> Bryant (1.0 miles) 8 existing stops	AM Peak	8.85	10.70
	PM Peak	10.43	10.65
	Proposed: Side Riding Transit Lane (WB aka IB only) & 2 stop removals		
		Proposed (IB)	**Proposed (OB)**
	AM Peak	5.00	7.83
	PM Peak	6.42	7.79

STOPS: Church, Dolores, Guerrero (proposed for removal), Valencia, Mission, Shotwell/Folsom, Harrison (proposed for removal), Bryant

		APC Data **Existing (IB)**	APC Data **Existing (OB)**
Bryant <--> Missouri (0.8 miles) 6 existing stops	AM Peak	4.55	5.47
	PM Peak	6.52	5.15
	Proposed: Center Running Transit Lanes (both directions) & 1 stop removal		
		Proposed (IB)	**Proposed (OB)**
	AM Peak	1.78	2.48
	PM Peak	3.29	2.24

STOPS: Potrero, San Bruno/Vermont (proposed for removal), Rhode Island, Wisconsin, Missouri, Mississippi

		APC Data **Existing (IB)**	APC Data **Existing (OB)**
Missouri <--> 3rd & Gene Friend (0.3 miles) 1 existing stop	AM Peak	3.68	4.05
	PM Peak	4.27	3.95
	Proposed: Side Running Transit Lanes (both directions) & 1 stop addition		
		Proposed (IB)	**Proposed (OB)**
	AM Peak	3.65	3.98
	PM Peak	4.17	3.89

Exhibit 5-4: Weighted Average Travel Time Savings, with 16th Street Improvements

	Existing (IB) (Sec)	Existing (OB)(Sec)
AM Peak	1025	1213
PM Peak	1273	1185
	Proposed (IB)(Sec)	**Proposed (OB)(Sec)**
AM Peak	626	857
PM Peak	833	835
	Change (Sec)	**Change (Sec)**
AM Peak	399	356
PM Peak	440	350
	Change (Min)	**Change (Min)**
AM Peak	6.7	5.9
PM Peak	7.3	5.8
Weighed Average Savings	6.4	Minutes per Trip

6. ***Monetize the time savings***. Travel time savings are valued differently depending on the traveler and trip purpose. This analysis followed the TIGER Guidelines by assuming the 95.4% of the travel was personal including commuters and 4.6% of the travel was on the clock business travel. Personal travel is valued at $16.28 in 2015 dollars and "on the clock" business travel is valued at $26.65 in 2015 dollars. These values reflect current San Francisco Bay Area wage rates.
7. ***Sum the values***. Add the dollar values for personal and business benefits, year by year in 2015 dollars.
8. ***Discount the Annual Benefits***. Apply 3 and 7 present discount factors to the annual 2015 benefits and sum to estimate the net present value of time saved as shown in Exhibit 5-5.

The substantial amount of time saved from 2020-2050 as a result of this project produces dollar benefits to travelers of $139.6 million and $74.8 million larger than project costs at both the 3 and 7 present discount rates. Key assumptions in this estimate include the time savings estimate per trip and the number of travelers expected to utilize this corridor in the future. With the project, higher congestion levels, additional crashes and more lost time will impact all travelers who travel in or close to this corridor.

The value of time saving benefits is only estimated here for the AM and PM peak periods. It should be noted that the six hour Mid-Day period is also highly congested and travelers in this period are also likely to enjoy substantial time savings. While the weekend days see fewer boarding, the corridor improvements will also offer time savings to these travelers, but estimate of this value is included in this analysis.

Exhibit 5-5: Value of Travel Time Saved (with the implementation of the project)

Calender Year	Boardings Baseline	Annual Travel Time Savings - Hours	Value of Time - Personal, 2015 Dollars	Value of Time - Business, 2015 Dollars	Total Value of Time	Present Dollar Value (3%)	Present Dollar Value (7%)
2015	8,333,991	444,480	$ 6,903,265	$ 544,887	$ 7,448,152	$ 7,448,152	$ 7,448,152
2016	8,385,800	447,243	$ 6,946,179	$ 548,275	$ 7,494,454	$ 7,276,169	$ 7,004,162
2017	8,437,608	450,006	$ 6,989,093	$ 551,662	$ 7,540,756	$ 7,107,885	$ 6,586,388
2018	8,489,417	452,769	$ 7,032,008	$ 555,049	$ 7,587,057	$ 6,943,232	$ 6,193,299
2019	8,541,225	455,532	$ 7,074,922	$ 558,437	$ 7,633,359	$ 6,782,140	$ 5,823,453
2020	8,333,991	444,480	$ 6,903,265	$ 544,887	$ 7,448,152	$ 6,424,842	$ 5,310,430
2021	8,385,800	447,243	$ 6,946,179	$ 548,275	$ 7,494,454	$ 6,276,487	$ 4,993,871
2022	8,437,608	450,006	$ 6,989,093	$ 551,662	$ 7,540,756	$ 6,131,324	$ 4,696,004
2023	8,489,417	452,769	$ 7,032,008	$ 555,049	$ 7,587,057	$ 5,989,293	$ 4,415,736
2024	8,541,225	455,532	$ 7,074,922	$ 558,437	$ 7,633,359	$ 5,850,334	$ 4,152,041
2025	8,593,034	458,295	$ 7,117,837	$ 561,824	$ 7,679,660	$ 5,714,389	$ 3,903,950
2026	8,644,842	461,058	$ 7,160,751	$ 565,211	$ 7,725,962	$ 5,581,399	$ 3,670,549
2027	8,696,651	463,821	$ 7,203,665	$ 568,599	$ 7,772,264	$ 5,451,309	$ 3,450,978
2028	8,748,459	466,584	$ 7,246,580	$ 571,986	$ 7,818,565	$ 5,324,063	$ 3,244,427
2029	8,800,268	469,348	$ 7,289,494	$ 575,373	$ 7,864,867	$ 5,199,604	$ 3,050,131
2030	8,852,076	472,111	$ 7,332,408	$ 578,761	$ 7,911,169	$ 5,077,878	$ 2,867,372
2031	8,903,885	474,874	$ 7,375,323	$ 582,148	$ 7,957,470	$ 4,958,832	$ 2,695,471
2032	8,955,693	477,637	$ 7,418,237	$ 585,535	$ 8,003,772	$ 4,842,414	$ 2,533,789
2033	9,007,502	480,400	$ 7,461,151	$ 588,922	$ 8,050,074	$ 4,728,570	$ 2,381,726
2034	9,059,310	483,163	$ 7,504,066	$ 592,310	$ 8,096,375	$ 4,617,250	$ 2,238,715
2035	9,111,119	485,926	$ 7,546,980	$ 595,697	$ 8,142,677	$ 4,508,403	$ 2,104,222
2036	9,162,927	488,689	$ 7,589,894	$ 599,084	$ 8,188,979	$ 4,401,980	$ 1,977,746
2037	9,214,736	491,453	$ 7,632,809	$ 602,472	$ 8,235,280	$ 4,297,931	$ 1,858,811
2038	9,266,544	494,216	$ 7,675,723	$ 605,859	$ 8,281,582	$ 4,196,209	$ 1,746,974
2039	9,318,353	496,979	$ 7,718,637	$ 609,246	$ 8,327,884	$ 4,096,767	$ 1,641,814
2040	9,370,161	499,742	$ 7,761,552	$ 612,634	$ 8,374,185	$ 3,999,558	$ 1,542,937
2041	9,421,970	502,505	$ 7,804,466	$ 616,021	$ 8,420,487	$ 3,904,535	$ 1,449,970
2042	9,473,778	505,268	$ 7,847,380	$ 619,408	$ 8,466,789	$ 3,811,656	$ 1,362,563
2043	9,525,587	508,031	$ 7,890,295	$ 622,796	$ 8,513,090	$ 3,720,874	$ 1,280,388
2044	9,577,395	510,794	$ 7,933,209	$ 626,183	$ 8,559,392	$ 3,632,147	$ 1,203,132
2045	9,629,204	513,558	$ 7,976,123	$ 629,570	$ 8,605,694	$ 3,545,432	$ 1,130,505
2046	9,681,012	516,321	$ 8,019,038	$ 632,957	$ 8,651,995	$ 3,460,687	$ 1,062,231
2047	9,732,821	519,084	$ 8,061,952	$ 636,345	$ 8,698,297	$ 3,377,871	$ 998,052
2048	9,784,629	521,847	$ 8,104,867	$ 639,732	$ 8,744,599	$ 3,296,943	$ 937,724
2049	9,836,438	524,610	$ 8,147,781	$ 643,119	$ 8,790,900	$ 3,217,864	$ 881,018
Total					**$243,585,787**	**$139,636,844**	**$ 74,783,279**

CHAPTER 6: ECONOMIC COMPETITIVENESS - RELIABILITY

6.1 Description of the Reliability Benefit

Congestion on America's roadways continues to cost travelers time by slowing the average trip time and increasing the variability of trip time. More than half of all congestion is due to unexpected or nonrecurring delays, caused by crashes, construction work zones, special events, or weather conditions. These effects are particularly acute on major urban arterials such as the 16th Street corridor which carries a heavy load of buses, autos, trucks, bikes and walkers from the start of the AM peak to the close of the PM peak traffic periods. Inconsistent travel conditions are frustrating, cost travelers time and money, and put motorists and traffic incident responders at greater risk. Reliability promotes the quality and consistency of travel times encountered by people as they go about their daily lives.

Reliability of travel time has been deemed to be so important and pressing a need that an entire section of the Strategic Highway Research Program SHRP 2 program was dedicated to Reliability. These studies seek to improve travel-time reliability by providing transportation agencies data monitoring, analysis, and planning tools to understand how fluctuations in traffic and road conditions affect traffic operations. These studies also identify effective strategies to reduce the variable and uncertain travel times caused by recurring and nonrecurring congestion. The proposed improvements to the 16th Street corridor will greatly strengthen the reliability of transportation in this vital and rapidly redeveloping area of San Francisco.

6.2 Justification as a TIGER Benefit

Improving transportation reliability is a top strategic goal adopted by the U.S. Department of Transportation (USDOT). Travel time reliability measures the extent of unexpected delay. A formal definition for travel time reliability is: the consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day.

Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, freight shippers, or even pedestrians. Personal and business travelers value reliability because it allows them to make better use of their own time. Shippers and freight carriers require predictable travel times to remain competitive. Reliability is a valuable service that can be provided on the 16th Street corridor by improving trolley service, dedicating bus only lanes, improving operations with restricted left turns, international pedestrian crossing and other modifications. Because reliability is so important for transportation system users, transportation planners and decision-makers, this BCA includes an estimate of the value of travel time reliability based on the reports from the Reliability Section of SHRP2.

Transportation Investment Generating Economic Recovery or TIGER grants allow the USDOT to invest in road, rail, transit and port projects that benefit critical national objectives. The grants specify "economic competitiveness" as one of five long-term outcome benefits that must be detailed as part of the benefit cost analysis.[38] Travel Time Reliability (TTR) is regularly identified by travelers as the most valuable improvement that transportation planning, infrastructure investment, and system operations can offer them.

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[38] About TIGER Grants. U.S. DOT. April 16, 2015.

6.3 Reliability Benefits of this Project

SFMTA has identified reliability as a high priority in the design of these16th Street Corridor improvements. Some of the key project components will include

- Reducing crash delays by adding international pedestrian crossings, pedestrian bulbs, eliminating mixed bus auto traffic flow and other features. It is estimated that crashes will be reduced by 26% as a result of these improvements.
- More frequent bus service in the corridor by restructuring the Route 22 and 33 buses and increasing bus operating speed.
- Dedicated bus only lanes will allow buses to operate on schedule through the 16th Street corridor.

These and other corridor investments will allow users of the 16th Street corridor to reduce their average travel time as well as experience lower variability of travel time. This reduction in variability will allow travelers to reduce their buffer time. The SFMTA's working definition of Buffer time is the amount of additional time beyond the median travel-time that travelers need to allow to assure that they arrive at their destination on time at least 85 percent[39] of the time.

6.4 Review of Reliability Benefit Literature

Understanding the importance of reliability to travelers has led to numerous research projects designed to define and measure reliability as well as to understand how reliability considerations can be incorporated in planning and design. Many studies have identified a number of reliability performance measures and provided recommendations on their suitability for different purposes. Lomax et al. (2003) defined three broad categories of reliability performance indicators and discussed a variety of measures based on these concepts: (1) statistical range, (2) buffer time measures, and (3) tardy trip indicators. The authors suggested three specific indicators— percent variation, Misery Index, and Buffer Time Index—as promising measures that provide consistent analytical conclusions.

The National Cooperative Highway Research Program (NCHRP) Report 618 (Cambridge Systematics, Inc. et al. 2008) provides guidance on selecting measures for different purposes and types of analyses. The reliability measures recommended by that study include Buffer Index, percent on-time arrival, Planning Time Index, percent variation, and 95th percentile. The SHRP 2 Project L03 (Cambridge Systematics, Inc., et al. 2013) conducted an extensive empirical study and pointed out some shortcomings of the performance metrics recommended by previous studies. For example, the 95th percentile travel time may be too extreme to reflect certain improvements introduced by traffic operations strategies, but the 80th percentile would be useful in such cases. Also, for performance indicators that measure the distance between central and extreme values (e.g., Buffer Index), the median would be a more robust central tendency statistic than the mean because travel time distributions are by nature skewed. Based on such modifications, the study recommended six reliability metrics: Buffer Index, failure/on-time measures, Planning Time Index, 80th percentile Travel Time Index, skew statistic, and Misery Index.

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[39] Several studies initially suggested a Buffer Time Index measured at the 95% mark, but SHRP2 L03 suggested a more realistic observation point at about 80%. The SFMTA Visualizer used in this study to estimate Buffer Time reductions uses the 85% figure.

Many previous studies have focused on corridor- or link-level travel time reliability. SHRP2 project L04, ***Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools*** performs a full range of analysis addressing network level, origin–destination–level (O-D–level), path-level, and segment- or link-level travel time reliability using regional planning and operations models. SHRP 2 Reliability Project L17, ***Gap Filling Project 5: Guidebook: Placing a Value on Travel Time Reliability*** addresses ways for analysts to value reliability and include these values in project benefit cost analysis (BCA). Value of travel time (VOT) refers to the cost of time spent on transport, including both waiting time and actual travel time. VOT includes costs to consumers of personal (unpaid) time spent on travel and costs to businesses of paid employee time spent in travel (Victoria Transport Policy Institute 2011). The U.S. Department of Transportation's (USDOT) recommended values of travel time in its TIGER Resource Guide. The value of travel time as a percentage of the wage rate is converted to a dollar value using wage data from the Bureau of Labor Statistics for business travel and truck driver wage rates. The value of reliability (VOR) represents the cost of (un)reliability in monetary terms and is calculated as the ratio of travel reliability and travel cost (Carrion and Levinson 2010). The reliability ratio (RR) is the ratio of the value of 1 minute of standard deviation (i.e., VOR) to the value of 1 minute of average travel time (VOT). Thus, RR = VOR/VOT. (Bhouri and Kauppila 2011). Previous studies have suggested that the reliability ratio can produce a broad range of values and L07 recommends a RR of between .8 and 1.2, see, Carrion and Levinson (2012).

The assumed VOR for the San Francisco Bay Area in 2015 is shown on Exhibit 5-1 in the Value of Time Savings Chapter along with other time related values applied in this BCA.

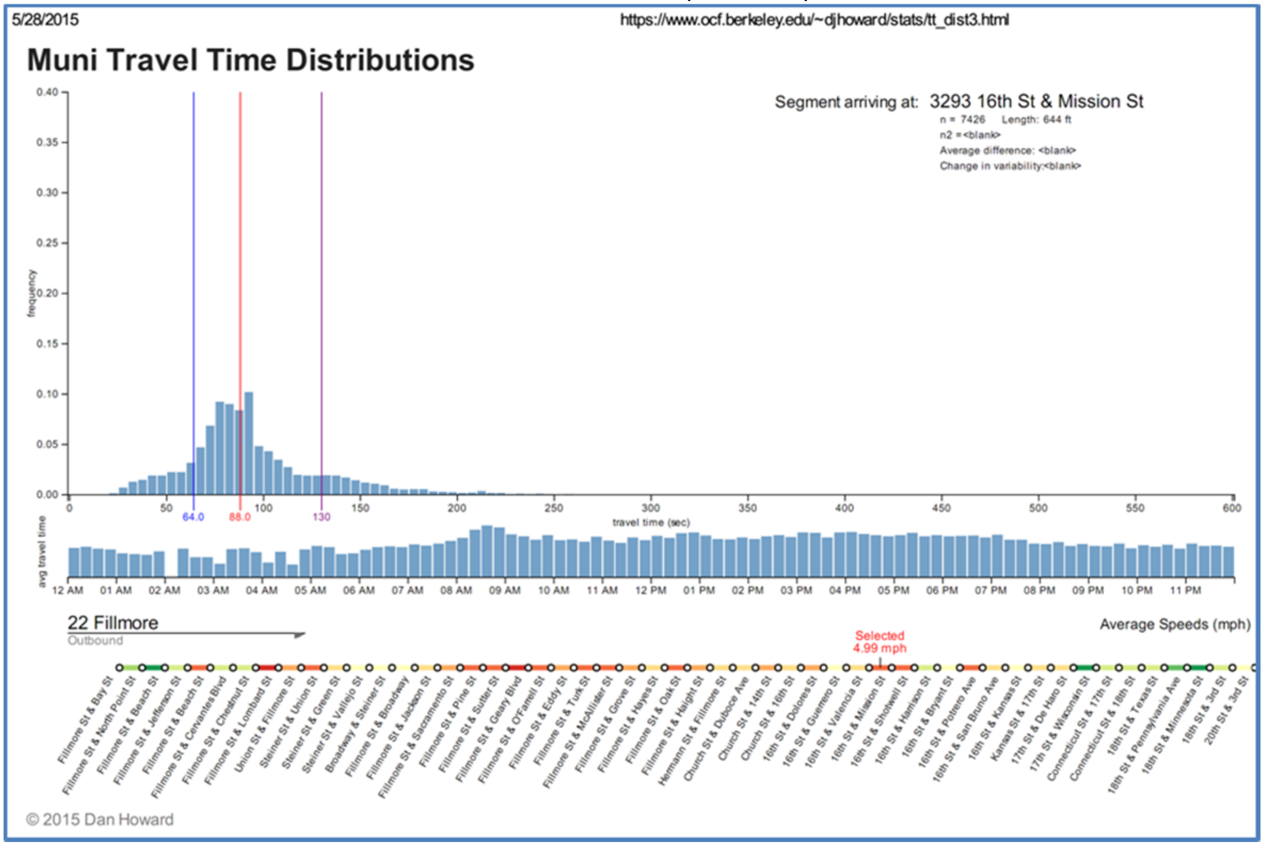
6.5 Reliability Benefit Estimation Methodology

This section describes the data and methodologies used in the project to calculate the benefits of reducing the variability of travel time. This analysis applies an SFMTA model called Travel Time Visualizer. Visualizer utilizes data from the SFMTA system operations to record the variation in travel time between bus stops. By collecting these operating statistics for all buses operating in the 16th Street Corridor we are able to estimate travel time and variability and develop a value of travel time variability improvement.

There are many measures of travel time variability that can be used for specific purposes, but not all such statistics are useful for BCA. The key for a BCA is that any measure of effectiveness be convertible into dollars so that reliability benefits can be combined with other benefits (safety, emissions, travel time, etc.) so that the total benefits of the project can be compared with the total cost of the project.

Buffer time is the amount of time a traveler must add to the median travel time to ensure arriving at their destination on time. Buffer time is valued in the same way that travel time is valued. If a project improved the certainty of travel time (reduced variation in travel time), travelers will be able to plan for a lower buffer time thus saving time that can be applied for other purposes. The SFMTA Visualization tool allows for the estimation of current buffer time on the corridor. Exhibit 6-1 provides a screen capture from the Visualizer tool for the Muni 22 Fillmore route.

Exhibit 6-1: Screen Shot of Visualized Output for Sept on Muni 22 Routes



The Visualization model provides the ability to process the bus operations data to calculate the median and 85% confidence value for weekday bus travel on the 16th Street corridor. This is accomplished by accumulating the distribution data for each stop, Church & 16th to 3rd Street, and estimating the trip time distributions for the project segment of the 22 Fillmore route. The difference between the median trip time and the 85th percentile of travel time is the estimate of current buffer time. Improvements to the corridor will reduce the variance in trip times allowing travelers to reduce their buffer time and apply that time to other activities.

Exhibit 6-2 is the result of the accumulation of the stop to stop times on the 22 Fillmore in the 16th Street corridor. By subtracting the 85th percentile bus trip time from the median bus trip time the buffer time for this corridor is revealed as 8.46 minutes. The median trip time is for the corridor is just over 19 minutes.

Exhibit 6-2: MUNI 22 FILLMORE TRAVEL SPEEDS - ALL DAY, 2015 YTD

ALL DAY	
OUTBOUND	total
Transit travel speed of the 22 Fillmore from 16th/Church to 20th/3rd (MPH)	9.52
Median Transit Travel Time (sec) (red line)	1159.00
85 Percentile Transit Travel Time (sec) (purple line)	1692.00
15 Percentile Transit Travel Time (sec) (blue line)	817.00
Travel Time Variability Ratio	
Difference between the 85 percentile and mean travel time (sec)	**533.00**
Conversion to Minutes	**8.88**
ALL DAY	
INBOUND	total
Transit travel speed of the 22 Fillmore from 16th/Church to 20th/3rd (MPH)	9.33
Median Transit Travel Time (sec) (red line)	1130.00
85 Percentile Transit Travel Time (sec) (purple line)	1612.70
15 Percentile Transit Travel Time (sec) (blue line)	786.00
Travel Time Variability Ratio	
Difference between the 85 percentile and mean travel time (sec)	**482.70**
Conversion to Minutes	**8.05**
Average Minutes of Buffer Time Required	**8.46**

Source: SF Travel Time Visualizer, 2015 data Year-to-Date

By comparing the impacts of a similar BRT pilot on the 22 Fillmore route, but not in the 16th Street corridor, the expected change in buffer time for the 16th Street operations can be estimated. SFMTA launched the Church Street Transit Lanes Pilot on March 23, 2013 to evaluate the effectiveness of various service improvement strategies that will be introduced as part of the Agency's larger Transit Effectiveness Project (TEP). The pilot establishes center- running, dedicated transit-and-taxi-only lanes along three blocks of Church Street, in both directions, between 16th Street and Duboce Avenue. To protect the integrity of these lanes, the pilot also includes left turn restrictions, parking changes, and a red paint treatment that has proven effective at reducing transit lane violation rates in New York City and abroad, all modifications similar to the proposed modifications planned for the 16th Street corridor. A comprehensive data collection and analysis effort was undertaken to understand the Pilot's impact on transit service, local circulation, driver compliance, and finally, to assess the durability of the red paint treatment. The findings from this analysis suggest that:

1. The dedicated lanes have reduced transit travel times and improved reliability:
   a. The lanes have largely eliminated congestion-related delay through the corridor, resulting in average travel time savings of up to 14% (1 minute).
   b. The lanes have largely reduced congestion-related reliability issues through the corridor, resulting in average reductions in travel time variability of up to 27%. This

helps keep trains running on schedule, and reduces the bunching and gapping that can lead to overcrowding.

2. These benefits come at minimal additional cost to people in personal vehicles:
   a. The pilot has not significantly increased delay for drivers through the corridor (~800 drivers per peak hour), except at the northbound approach to Duboce Avenue, where multiple factors have combined to add up to a minute of additional delay.
   b. The pilot has not reduced parking supply, and has in fact expanded it by truncating commercial loading hours to better meet local merchants' needs.

The value of the savings in buffer time is estimated on Exhibit 6-3. The following steps were applied to arrive at the net present value of reliability benefits at 3 and 7 percent discount rates:

1. ***Estimate Annual Boardings.*** The SF-CHAMP model runs for the Build and No-Build for 2020 and 2040 provided the boardings estimates for the 16th Street corridor in these two years. Annual boardings were trended between 2020 and 2040 and at the same rate from 2040 to 2050.
2. ***Estimate Annual No-Build Buffer time.*** Estimated annual buffer time from the Travel Time Visualization tool was multiplied by each year's boardings.
3. ***Estimate Annual Buffer Time Savings.*** Multiply annual buffer time by ½ of the Church Street Pilot savings estimate of 27percent. The Church Street estimate is on a limited corridor. Modifications applied on Church Street and traffic conditions are not the same as the 16th Street corridor, therefore a conservative estimate was that only half of the buffer time saving would be realized as a result of the 16th Street corridor project.
4. ***Monetize the time savings***. Buffer time savings are monetized in the same way as Travel Time benefits are monetized. Travel time savings are valued differently depending on the traveler and trip purpose. This analysis followed the TIGER Guidelines by assuming the 95.4% of the travel was personal and 4.6% of the travel was on the clock business travel. Personal travel is valued at $16.28 in 2015 dollars and business travel is valued at $26.65 in 2015 dollars. These values reflect current San Francisco Bay Area wage rates.
5. ***Sum the values***. Add the dollar values for personal and business benefits, year by year in 2015 dollars.
6. ***Discount the Annual Benefits***. Apply 3 and 7 present discount factors to the annual 2015 benefits and sum to estimate the net present value of time saved as shown in Exhibit 6-5.

The substantial amount of buffer time saved from 2020-2050 as a result of this project produces dollar benefits to travelers that reflect a large portion of project costs at both the 3 and 7 present discount rates. Key assumptions in this estimate include the buffer time savings estimate per trip and the number of travelers expected to utilize this corridor in the future. Without the project, higher congestion levels, additional crashes and more lost time will impact all travelers who travel in or close to this corridor.

Exhibit 6-3: Benefits of Transit Reliability on the 16th Street Corridor

Calender Year	Annual Boardings	No-Build Annual Buffer Time - Hours/Year	Build Annual Buffer Time Savings - Hours/Year	Value of Time - Personal, 2015 Dollars	Value of Time - Business, 2015 Dollars	Total Value of Time	Present Dollar Value (3%)	Present Dollar Value (7%)
2020	8,333,991	1,175,093	$ 158,638	$ 2,463,818	$ 194,474	$ 2,658,292	$ 2,293,066	$ 1,895,326
2021	8,385,800	1,182,398	$ 159,624	$ 2,479,135	$ 195,683	$ 2,674,817	$ 2,240,117	$ 1,782,344
2022	8,437,608	1,189,703	$ 160,610	$ 2,494,451	$ 196,892	$ 2,691,343	$ 2,188,308	$ 1,676,033
2023	8,489,417	1,197,008	$ 161,596	$ 2,509,768	$ 198,101	$ 2,707,868	$ 2,137,616	$ 1,576,004
2024	8,541,225	1,204,313	$ 162,582	$ 2,525,084	$ 199,310	$ 2,724,393	$ 2,088,021	$ 1,481,890
2025	8,593,034	1,211,618	$ 163,568	$ 2,540,400	$ 200,518	$ 2,740,919	$ 2,039,501	$ 1,393,344
2026	8,644,842	1,218,923	$ 164,555	$ 2,555,717	$ 201,727	$ 2,757,444	$ 1,992,036	$ 1,310,042
2027	8,696,651	1,226,228	$ 165,541	$ 2,571,033	$ 202,936	$ 2,773,970	$ 1,945,606	$ 1,231,676
2028	8,748,459	1,233,533	$ 166,527	$ 2,586,350	$ 204,145	$ 2,790,495	$ 1,900,191	$ 1,157,956
2029	8,800,268	1,240,838	$ 167,513	$ 2,601,666	$ 205,354	$ 2,807,020	$ 1,855,771	$ 1,088,611
2030	8,852,076	1,248,143	$ 168,499	$ 2,616,982	$ 206,563	$ 2,823,546	$ 1,812,326	$ 1,023,383
2031	8,903,885	1,255,448	$ 169,485	$ 2,632,299	$ 207,772	$ 2,840,071	$ 1,769,838	$ 962,030
2032	8,955,693	1,262,753	$ 170,472	$ 2,647,615	$ 208,981	$ 2,856,596	$ 1,728,288	$ 904,325
2033	9,007,502	1,270,058	$ 171,458	$ 2,662,932	$ 210,190	$ 2,873,122	$ 1,687,656	$ 850,053
2034	9,059,310	1,277,363	$ 172,444	$ 2,678,248	$ 211,399	$ 2,889,647	$ 1,647,925	$ 799,011
2035	9,111,119	1,284,668	$ 173,430	$ 2,693,564	$ 212,608	$ 2,906,172	$ 1,609,077	$ 751,010
2036	9,162,927	1,291,973	$ 174,416	$ 2,708,881	$ 213,817	$ 2,922,698	$ 1,571,094	$ 705,870
2037	9,214,736	1,299,278	$ 175,402	$ 2,724,197	$ 215,026	$ 2,939,223	$ 1,533,958	$ 663,421
2038	9,266,544	1,306,583	$ 176,389	$ 2,739,514	$ 216,235	$ 2,955,748	$ 1,497,653	$ 623,506
2039	9,318,353	1,313,888	$ 177,375	$ 2,754,830	$ 217,444	$ 2,972,274	$ 1,462,162	$ 585,974
2040	9,370,161	1,321,193	$ 178,361	$ 2,770,146	$ 218,653	$ 2,988,799	$ 1,427,467	$ 550,684
2041	9,421,970	1,328,498	$ 179,347	$ 2,785,463	$ 219,862	$ 3,005,324	$ 1,393,553	$ 517,503
2042	9,473,778	1,335,803	$ 180,333	$ 2,800,779	$ 221,071	$ 3,021,850	$ 1,360,404	$ 486,307
2043	9,525,587	1,343,108	$ 181,320	$ 2,816,096	$ 222,280	$ 3,038,375	$ 1,328,003	$ 456,978
2044	9,577,395	1,350,413	$ 182,306	$ 2,831,412	$ 223,489	$ 3,054,900	$ 1,296,336	$ 429,405
2045	9,629,204	1,357,718	$ 183,292	$ 2,846,728	$ 224,698	$ 3,071,426	$ 1,265,387	$ 403,484
2046	9,681,012	1,365,023	$ 184,278	$ 2,862,045	$ 225,906	$ 3,087,951	$ 1,235,141	$ 379,117
2047	9,732,821	1,372,328	$ 185,264	$ 2,877,361	$ 227,115	$ 3,104,477	$ 1,205,583	$ 356,211
2048	9,784,629	1,379,633	$ 186,250	$ 2,892,678	$ 228,324	$ 3,121,002	$ 1,176,700	$ 334,680
2049	9,836,438	1,386,938	$ 187,237	$ 2,907,994	$ 229,533	$ 3,137,527	$ 1,148,476	$ 314,441
						$ 86,937,290	**$49,837,262**	**$26,690,620**

Highlighted cells reflect values from the SF-CHAMP and SF Travel Time Visualizer models.

CHAPTER 7: ECONOMIC COMPETITIVENESS - OPERATING COST SAVINGS

The Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants lists five Long-Term Outcomes on page 7, along with the types of social benefits realized for each.[40] This chapter discusses and quantifies the Economic Competiveness long-term outcome, focusing on the Operating Cost Savings societal benefit.

The chapter is divided into five sections, including:

1. Description of the benefit
2. Justification as a TIGER benefit
3. The benefit in this project
4. Related research
5. Estimation methodology

7. 1 Description of the Operating Cost Savings Benefit

In passenger-related projects, the operating cost savings benefit results by providing lower-cost alternatives to private vehicle travel or by reducing vehicle operating costs.[41]

7.2 Justification as a TIGER benefit

Economic Competiveness is one of five Long-Term Outcomes specified in the United States Department of Transportation's (USDOT) TIGER grant program.[42] Operating Cost Savings is one of the two types of societal benefits in the category along with Travel Time Savings. The slice below, taken from the table on page 7 of the TIGER Guidance, shows the portion containing the Operating Cost Savings benefit.

Long-Term Outcome	Types of Societal Benefits
Economic Competitiveness	Travel Time Savings ✓**Operating Cost Savings**

The TIGER guidance cautions applicants to carefully demonstrate how the project would generate these benefits and not double count the value of fuel and other operating costs in the benefit cost analysis.

7.3 The Operating Cost Savings Benefit of his Project

Reduced operating costs are a real resource gain to society and a project benefit. The 22 Fillmore Transit Priority Project incorporates a number of corridor improvements to foster the operating cost savings benefit. Dedicated transit-only lanes are an important component of the project designed to speed bus service along the route and encourage drivers to use transit.

Reduced auto miles are a recognized operating cost savings. The project compares the reduced miles of vehicle travel by car and their operating costs for the build and no build scenarios.

[40] 2015 Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants, United States Department of Transportation April 6, 2015
[41] Ibid.
[42] Ibid.

Increasing transit speeds will result in fewer hours of transit operation. The total hours of operations times the operational cost per hour are the total operational costs. The project looks at the differences for various types of buses and model forecasts of bus usage and compares operational costs under the build and no build scenarios. Moving more people at lower cost is a benefit to society.

In addition, left hand turn restrictions will reduce waiting times for both motorists and commercial traffic resulting in less wear and tear on vehicles and transit. The reduced number of transit stops along routes will increase operational efficiency. Both of these improvements will reduce maintenance costs for vehicles and add to the operating cost savings.

7.4 Related Research

Mode switching, a key component of this project, is recognized as a societal benefit when motorists change from driving to transit.[43] Individuals who switch from driving an automobile to riding on a bus or train may realize savings based on auto travel costs and public transportation fares. Auto costs can be divided into vehicle ownership and vehicle operating costs.[44] Operating costs are usually defined as out-of-pocket expenses, for instance fuel and oil, tire ware, tolls and short-term parking fees. A portion of vehicle maintenance is sometimes included. Transit options allow some individuals to reduce vehicle ownership or defer the purchase of a new vehicle. At times, families can get by owning fewer vehicles. Lipman identifies various categories of savings that can result from reduced automobile ownership and use.[45]

Operating cost savings result from transit economies too. Previous data collection by the SFMTA provided the foundation of the operating cost benefit analysis for the proposed transit service. The SFMTA provided detailed information of hours of service for all buses in the build and no build scenarios. Changes in hours were used to estimate total operating costs based on SFMTA cost estimates for trolley and motor coaches.

7.5 Operating Cost Saving Benefit Estimation Methodology

This section describes the calculation of the operating cost savings benefits that will occur because of the implementation of the 22 Fillmore Transit Priority Project. If SFMTA implements the project, the 16th Street “Red Lanes” will allow trolley buses to operate at significantly higher speeds. Overall auto mileage will decrease as riders shift to transit. The Route 55 diesel bus shuttle will no longer operate. Operating hours of the 22 Fillmore trolley bus vehicles will increase slightly, but total operating hours to serve the corridors will decline, as the trolley buses will operate at increased speed.

Auto Travel and Cost Savings

The SF-CHAMP model predicts that auto travel will decline because of the project relative to the no-build. The build scenario results in the reevaluation of travel options. More travelers chose the transit option in the build scenario than did in the no-build scenario in both 2020 and 2040. For example in

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[43] Weisbrod, G. and Reno, A. Economic Impact of Public Transportation Investment. American Public Transportation Association, October, 2009, p. 9.

[44] Transportation Costs and Benefits, TMD Encyclopedia, Victoria Transport Policy Institute, August 2014 update.

[45] Lipman, T. Evaluating Public Transportation Benefits and Costs: Best Practices Guidebook, Victoria Transport Policy Institute, April 17, 2015, p. 30.

2040, the model predicts that daily auto miles will fall by 5,497 miles on a typical weekday. Exhibit 7-1 provides data on the change in auto travel and the resulting savings in auto operating costs.

Exhibit 7-1: Auto Operating Cost Savings

Year	No-Build Auto Miles (Daily)	Build Auto Miles (Daily)	Change in Auto Miles (Daily)	Change in Auto Miles (Yearly)	Auto Operating Costs (Per Mile)	Auto Operating Cost Saving (Yearly)
2020	2,667,888	2,662,957	4,931	1,671,636	0.57	952,833
2021	2,682,332	2,677,319	5,013	1,699,239	0.57	968,566
2022	2,696,776	2,691,682	5,094	1,726,842	0.57	984,300
2023	2,711,219	2,706,044	5,175	1,754,445	0.57	1,000,034
2024	2,725,663	2,720,406	5,257	1,782,048	0.57	1,015,767
2025	2,740,106	2,734,768	5,338	1,809,651	0.57	1,031,501
2026	2,754,550	2,749,130	5,420	1,837,254	0.57	1,047,235
2027	2,768,993	2,763,492	5,501	1,864,857	0.57	1,062,968
2028	2,783,437	2,777,854	5,582	1,892,460	0.57	1,078,702
2029	2,797,880	2,792,216	5,664	1,920,063	0.57	1,094,436
2030	2,812,324	2,806,578	5,745	1,947,666	0.57	1,110,169
2031	2,826,767	2,820,941	5,827	1,975,268	0.57	1,125,903
2032	2,841,211	2,835,303	5,908	2,002,871	0.57	1,141,637
2033	2,855,654	2,849,665	5,990	2,030,474	0.57	1,157,370
2034	2,870,098	2,864,027	6,071	2,058,077	0.57	1,173,104
2035	2,884,541	2,878,389	6,152	2,085,680	0.57	1,188,838
2036	2,898,985	2,892,751	6,234	2,113,283	0.57	1,204,571
2037	2,913,429	2,907,113	6,315	2,140,886	0.57	1,220,305
2038	2,927,872	2,921,475	6,397	2,168,489	0.57	1,236,039
2039	2,942,316	2,935,837	6,478	2,196,092	0.57	1,251,772
2040	2,956,759	2,950,200	6,560	2,223,695	0.57	1,267,506
2041	2,971,203	2,964,562	6,641	2,251,298	0.57	1,283,240
2042	2,985,646	2,978,924	6,722	2,278,901	0.57	1,298,974
2043	3,000,090	2,993,286	6,804	2,306,504	0.57	1,314,707
2044	3,014,533	3,007,648	6,885	2,334,107	0.57	1,330,441
2045	3,028,977	3,022,010	6,967	2,361,710	0.57	1,346,175
2046	3,043,420	3,036,372	7,048	2,389,313	0.57	1,361,908
2047	3,057,864	3,050,734	7,130	2,416,916	0.57	1,377,642
2048	3,072,307	3,065,096	7,211	2,444,519	0.57	1,393,376
2049	3,086,751	3,079,459	7,292	2,472,122	0.57	1,409,109
Total	**105,840,620**	**86,136,238**	**183,352**	**62,156,365**		**35,429,128**

The first two columns of the exhibit provide typical daily auto miles for the no-build and build scenarios. SF-CHAMP provides mileage estimates for 2020 and 2040 with and without the project. These mileages represent auto trips that originate terminate or pass through an area that extends one-half mile from the project corridor. The estimates interpolate ridership between 2020 and 2040 and extrapolate that trend to 2050 to produce annual mileage estimates. The next column calculates the difference in the mileages for the build and no-build scenarios. The next column converts the daily estimate of the change in auto miles to a yearly estimate. While the calculation assumes a 365-day year, it also assumes that the 52 Saturdays and 52 Sundays only have 75 percent as many trips. There are approximately two million less auto miles per year in the build scenario.

The analysis then multiplies the mileages by a cost per mile to estimate the auto operating cost saving. The IRS was the source for the operating cost estimate of 57.5 cents per mile, however, the American Automobile Association (AAA) estimates a sedan average that is virtual identical at 58.0 cents per mile. Auto cost saving are approximately a million dollars in 2020 and total approximately 37 million over the life of the project in undiscounted dollars.

Transit Travel and Cost Savings

SFMTA provided estimates of the operating hours for each of the routes that will use the transit-only lanes. Exhibit 7-2 provides this data for the Build and No-Build cases for both 2020 and 2040. Note that the Route 55 shuttle does not exist in the Build case and that operating hours for the Route 22 trolley bus increase.

Exhibit 7-2: Bus Operating Hours, 2020 and 2040

Scenario	Line	Sum of Platform Hours 2020	Sum of Platform Hours 2040
No-Build	Weekday		
	22	279	282
	33	149	149
	55	64	68
	Saturday		
	22	208	208
	33	114	114
	55	38	38
	Sunday		
	22	208	208
	33	114	114
	55	38	38
Build	Weekday		
	22	292	303
	33	149	149
	55	-	-
	Saturday		
	22	208	208
	33	114	114
	55	-	-
	Sunday		
	22	208	208
	33	114	114
	55	-	-
Change	Weekday		
	22	(13)	(21)
	33	-	-
	55	64	68
	Saturday		
	22	-	-
	33	-	-
	55	38	38
	Sunday		
	22	-	-
	33	-	-
	55	38	38

Exhibit 7-3 provides data on the change in transit operating hours and the resulting savings in transit operating costs. The first column of the exhibit provides the yearly Route 55 operating hours for the build scenario. The 2020 and 2040 estimates use the daily operating hours from Exhibit 7-2 and assume 261 weekdays, 52 Saturdays and 52 Sundays. The estimates interpolate ridership between 2020 and 2040 and extrapolate that trend to 2050 to produce annual mileage estimates.

Exhibit 7-3: Bus Operating Cost Savings

Year	Route 55 Diesel Bus Operating Hours (Yearly)	Route 55 Diesel Bus Cost Savings (@$197.16/ Hour)	No-Build Route 22 Trolley Operating Hours (Yearly)	Build Route 22 Trolley Operating Hours (Yearly)	Change in Route 22 Trolley Operating Hours (Yearly)	Route 22 Trolley Cost Savings (@$164.34/ Hour)	Bus Operating Cost Saving (Year)
2020	20,549	4,051,416	94,524	97,898	(3,374)	(554,496)	3,496,920
2021	20,610	4,063,422	94,558	98,033	(3,475)	(571,131)	3,492,291
2022	20,671	4,075,429	94,592	98,168	(3,577)	(587,766)	3,487,663
2023	20,732	4,087,435	94,625	98,303	(3,678)	(604,401)	3,483,035
2024	20,792	4,099,442	94,659	98,438	(3,779)	(621,035)	3,478,407
2025	20,853	4,111,449	94,693	98,573	(3,880)	(637,670)	3,473,778
2026	20,914	4,123,455	94,727	98,708	(3,981)	(654,305)	3,469,150
2027	20,975	4,135,462	94,760	98,843	(4,083)	(670,940)	3,464,522
2028	21,036	4,147,469	94,794	98,978	(4,184)	(687,575)	3,459,894
2029	21,097	4,159,475	94,828	99,113	(4,285)	(704,210)	3,455,265
2030	21,158	4,171,482	94,862	99,248	(4,386)	(720,845)	3,450,637
2031	21,219	4,183,488	94,895	99,383	(4,488)	(737,480)	3,446,009
2032	21,280	4,195,495	94,929	99,518	(4,589)	(754,114)	3,441,381
2033	21,341	4,207,502	94,963	99,653	(4,690)	(770,749)	3,436,752
2034	21,401	4,219,508	94,997	99,788	(4,791)	(787,384)	3,432,124
2035	21,462	4,231,515	95,030	99,923	(4,892)	(804,019)	3,427,496
2036	21,523	4,243,521	95,064	100,058	(4,994)	(820,654)	3,422,868
2037	21,584	4,255,528	95,098	100,193	(5,095)	(837,289)	3,418,239
2038	21,645	4,267,535	95,132	100,328	(5,196)	(853,924)	3,413,611
2039	21,706	4,279,541	95,165	100,463	(5,297)	(870,559)	3,408,983
2040	21,767	4,291,548	95,199	100,598	(5,399)	(887,193)	3,404,355
2041	21,828	4,303,555	95,233	100,733	(5,500)	(903,828)	3,399,726
2042	21,889	4,315,561	95,267	100,867	(5,601)	(920,463)	3,395,098
2043	21,950	4,327,568	95,300	101,002	(5,702)	(937,098)	3,390,470
2044	22,010	4,339,574	95,334	101,137	(5,803)	(953,733)	3,385,841
2045	22,071	4,351,581	95,368	101,272	(5,905)	(970,368)	3,381,213
2046	22,132	4,363,588	95,401	101,407	(6,006)	(987,003)	3,376,585
2047	22,193	4,375,594	95,435	101,542	(6,107)	(1,003,638)	3,371,957
2048	22,254	4,387,601	95,469	101,677	(6,208)	(1,020,272)	3,367,328
2049	22,315	4,399,607	95,503	101,812	(6,310)	(1,036,907)	3,362,700
Total	**642,957**	**126,765,347**	**2,850,403**	**2,995,657**	**-145,254**	**-23,871,048**	**102,894,298**

Exhibit 7-4 provides data on the San Francisco Muni Railway schedule of hourly rate per mode. The second column of Exhibit 7-3 uses the estimate of total modal expenses of $197.16 per hour for motor buses to convert operating hours to operating costs.

Exhibit 7-4: San Francisco Muni Railway Schedule of Hourly Rate per Mode

FY2014 SUMMARY - ALL MODES	LRV	SR	CABLE CAR	TROLLEY BUS	MOTOR BUS	TOTAL
VEHICLE OPERATIONS:						
Operating Expenses (F-30) line 15a	$ 59,766,618	$ 6,422,053	$ 28,120,593	$ 78,989,769	$ 154,378,118	$ 327,677,151
Transit Agency Svc (S-10) Revenue Hours	538,792	96,294	143,383	950,442	1,464,828	3,193,739
Hourly Rate per Mode	$ 110.93	$ 66.69	$ 196.12	$ 83.11	$ 105.39	$ 102.60
VEHICLE MAINTENANCE:						
Operating Expenses (F-30) line 15b	$ 64,039,917	$ 4,108,856	$ 6,453,773	$ 23,261,389	$ 56,757,582	$ 154,621,517
Transit Agency Svc (S-10) Revenue Hours	538,792	96,294	143,383	950,442	1,464,828	3,193,739
Hourly Rate per Mode	$ 118.86	$ 42.67	$ 45.01	$ 24.47	$ 38.75	$ 48.41
NON-VEHICLE MAINTENANCE:						
Operating Expenses (F-30) line 15c	$ 28,856,155	$ 3,141,069	$ 8,648,697	$ 15,736,542	$ 8,144,655	$ 64,527,118
Transit Agency Svc (S-10) Revenue Hours	538,792	96,294	143,383	950,442	1,464,828	3,193,739
Hourly Rate per Mode	$ 53.56	$ 32.62	$ 60.32	$ 16.56	$ 5.56	$ 20.20
GENERAL & ADMINISTRATIVE:						
Operating Expenses (F-30) line 15d	$ 42,300,323	$ 3,959,480	$ 10,370,941	$ 38,212,299	$ 69,523,150	$ 164,366,193
Transit Agency Svc (S-10) Revenue Hours	538,792	96,294	143,383	950,442	1,464,828	3,193,739
Hourly Rate per Mode	$ 78.51	$ 41.12	$ 72.33	$ 40.20	$ 47.46	$ 51.47
TOTAL MODAL EXPENSES:						
Operating Expenses Summary excl DR	$ 194,963,013	$ 17,631,458	$ 53,594,004	$ 156,199,999	$ 288,803,505	$ 711,191,979
Transit Agency Svc (S-10)/(FF10) Revenue Hours	538,792	96,294	143,383	950,442	1,464,828	3,193,739
FY2014 Total Hourly Rate per Mode	$ 361.85	$ 183.10	$ 373.78	$ 164.34	$ 197.16	$ 222.68
Operating Expenses Summary excl DR	$ 182,399,900	$ 16,075,401	$ 51,868,243	$ 141,409,025	$ 257,977,594	$ 649,730,163
Transit Agency Svc (S-10)/(FF10) Revenue Hours	552,256	103,006	141,863	947,295	1,461,447	$ 3,205,867
FY2013 Total Hourly Rate per Mode	$ 330.28	$ 156.06	$ 365.62	$ 149.28	$ 176.52	$ 202.67
Increase (Decrease) in:						
Operating Expenses Summary excl DR	$ 12,563,113	$ 1,556,057	$ 1,725,761	$ 14,790,974	$ 30,825,911	$ 61,461,816
Transit Agency Svc (S-10) Revenue Hours	(13,464)	(6,712)	1,520	3,147	3,381	(12,128)
$ Increase (Decrease) in Hourly Rate	$ 31.57	$ 27.04	$ 8.16	$ 15.07	$ 20.64	$ 20.01
% Increase (Decrease) in Hourly Rate	9.6%	17.3%	2.2%	10.1%	11.7%	9.9%

Exhibit 7-3 also estimates operating cost increases for the Route 22 trolley service. The third column of the exhibit calculates hours for the No-Build scenario, while the fourth column of the exhibit calculates hours for the Build scenario. The 2020 and 2040 estimates use the daily operating hours from Exhibit 7-2 and assume 261 weekdays, 52 Saturdays and 52 Sundays. The estimates interpolate ridership between 2020 and 2040 and extrapolate that trend to 2050 to produce annual mileage estimates. The fifth column subtracts the no-build from the build to estimate the increase in hours (shown as a negative number). The sixth column of Exhibit 7-3 uses the estimate of total modal expenses of $164.34 per hour for trolley bus from Exhibit 7-4 to convert operating hours to operating costs. Exhibit 7-3 does not include estimates relating to the transit service provided by the Route 33 trolley bus line. Although the 33 18th St/Ashbury line will increase service over current 2015 levels, it is projected to remain constant through 2050 in both the build or no-build scenarios. Therefore, Route 33 will have zero change in operating hours, and has not been included in the Summary of Bus Operating Cost Savings table.

Over the life of the project, the elimination of the Route 55 shuttle saves $126.8 million in operating costs, while the expanded Route 22 trolley bus service costs $23.9 million, for a net cost savings of $102.9 million.

Discounted Value of Operating Cost Savings

Exhibit 7-5 sums the yearly auto and transit operating cost savings and discounts the costs in each year to present values using both a 3 percent and a 7 percent real discount rate. The total undiscounted operating cost savings benefits are approximately $138.3 million. The total discounted operating cost savings benefits are approximately $79.9 million using a 3 percent discount rate and approximately $43.1 million using a 7 percent real discount rate.

Exhibit 7-5: Summary of Discounted Operating Cost Savings

Year	Auto Operating Cost Saving (Yearly)	Bus Operating Cost Saving (Year)	Total Auto and Bus Operating Cost Savings (Dollars)	Present Dollar Value of Project Costs at 3%	Present Dollar Value of Project Costs at 7%
2020	952,833	3,496,920	4,449,752	3,838,395	3,172,612
2021	968,566	3,492,291	4,460,858	3,735,898	2,972,458
2022	984,300	3,487,663	4,471,963	3,636,115	2,784,914
2023	1,000,034	3,483,035	4,483,069	3,538,976	2,609,187
2024	1,015,767	3,478,407	4,494,174	3,444,410	2,444,533
2025	1,031,501	3,473,778	4,505,279	3,352,351	2,290,256
2026	1,047,235	3,469,150	4,516,385	3,262,732	2,145,702
2027	1,062,968	3,464,522	4,527,490	3,175,491	2,010,260
2028	1,078,702	3,459,894	4,538,596	3,090,563	1,883,356
2029	1,094,436	3,455,265	4,549,701	3,007,888	1,764,453
2030	1,110,169	3,450,637	4,560,806	2,927,408	1,653,046
2031	1,125,903	3,446,009	4,571,912	2,849,064	1,548,665
2032	1,141,637	3,441,381	4,583,017	2,772,801	1,450,866
2033	1,157,370	3,436,752	4,594,123	2,698,563	1,359,235
2034	1,173,104	3,432,124	4,605,228	2,626,297	1,273,384
2035	1,188,838	3,427,496	4,616,334	2,555,952	1,192,948
2036	1,204,571	3,422,868	4,627,439	2,487,476	1,117,587
2037	1,220,305	3,418,239	4,638,544	2,420,822	1,046,981
2038	1,236,039	3,413,611	4,649,650	2,355,939	980,829
2039	1,251,772	3,408,983	4,660,755	2,292,783	918,852
2040	1,267,506	3,404,355	4,671,861	2,231,307	860,786
2041	1,283,240	3,399,726	4,682,966	2,171,467	806,386
2042	1,298,974	3,395,098	4,694,072	2,113,220	755,419
2043	1,314,707	3,390,470	4,705,177	2,056,523	707,669
2044	1,330,441	3,385,841	4,716,282	2,001,337	662,934
2045	1,346,175	3,381,213	4,727,388	1,947,621	621,023
2046	1,361,908	3,376,585	4,738,493	1,895,336	581,759
2047	1,377,642	3,371,957	4,749,599	1,844,445	544,974
2048	1,393,376	3,367,328	4,760,704	1,794,910	510,513
2049	1,409,109	3,362,700	4,771,809	1,746,697	478,228
Total	**35,429,128**	**102,894,298**	**138,323,426**	**79,872,788**	**43,149,813**

CHAPTER 8: SAFETY – PREVENTED ACCIDENTS (PROPERTY DAMAGE), INJURIES AND FATALITIES

The Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants lists five Long-Term Outcomes on page 7, along with the types of social benefits realized for each.[46] This chapter discusses and quantifies the Safety long-term outcome, focusing on the Prevented Accidents, Injuries, and Fatalities societal benefits.

The chapter is divided into five sections, including:

1. Description of the benefit
2. Justification as a TIGER benefit
3. The benefit in this project
4. Related research
5. Estimation methodology

8.1 Description of the Safety Benefit

There were 32,719 traffic fatalities in the U.S. in 2013 and almost 2.3 million injuries.[47] Total crashes reached almost 5.7 million occurrences. That same year 4,735 pedestrians were killed in traffic crashes, accounting for 14 percent of the total fatalities in traffic crashes, along with an estimated 66,000 injured.[48]

California experienced 3,000 traffic fatalities, and had the highest number of pedestrian fatalities in the nation (701), along with 141 bicyclist and other cyclist fatalities.[49] With the current emphasis on active transportation, bicycle and pedestrian risk are sure to grow. Transportation planning, technology, and design must be prepared to address this growing risk in the future. In San Francisco, more than 200 people a year are severely injured or killed in traffic collisions. About 800 pedestrians are injured and 100 severely injured or killed in the city each year.[50] There were 21 fatal pedestrian collisions in 2013.[51]

WalkFirst, a citywide, interdivisional working group reported that 70 miles of the city's streets accounted for 55 percent of total injuries and 60 percent of the severe and fatal injuries that occurred from 2007 to 2011.[52] Vehicle speed, failure to yield and left turning vehicles were the most common causes of injuries. Exhibit 8-1 shows that 16th Street from Church Street to San Bruno Avenue is a "high injury corridor." Walk and pedestrian injuries in this region are particularly high.

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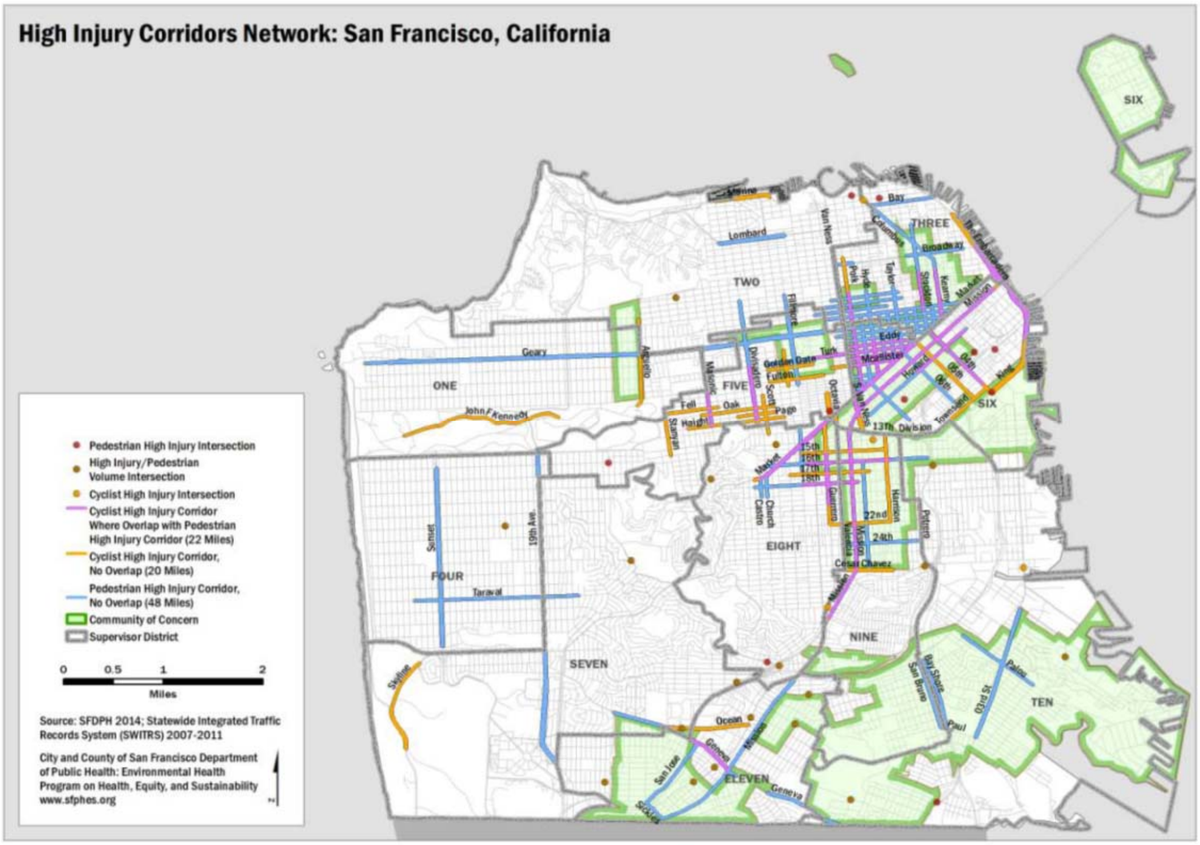
[46] 2015 Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants, United States Department of Transportation, April 6, 2015.
[47] Traffic Safety Facts: Research Note – 2013 Motor Vehicle Crashes: Overview. US DOT, National Highway Traffic Safety Administration, December 2014.
[48] Traffic Safety Facts: Pedestrians. NHTSA's National Center for Statistics and Analysis, February 2015.
[49] Traffic Safety Facts: California 2009-2013, National Highway Traffic Safety Administration.
[50] News – San Francisco Department of Public Health Releases TranBase. September 23, 2014.
[51] SFGate, January 16, 2014.
[52] WalkFirst http://walkfirst.sfplanning.org/index.php/home/streets

Exhibit 8-1: High Injury Corridors in San Francisco: Including the 16th Street Corridor



In 2014, a broad-based safety policy called Vision Zero was adopted for the city.[53] Vision Zero SF proclaimed "Safety is first," noting safety will help create a vibrant city that works for everyone. It aims for zero traffic deaths by 2024.

8.2 Justification as a TIGER Benefit

Safety was a top strategic goal adopted by the U.S. Department of Transportation under the first term of President Obama and then Secretary of Transportation Ray LaHood and remains so today. The goal was described in the agency's strategic plan: safety – improve public health and safety by reducing transportation-related fatalities, injuries and crashes.[54] The goals were reaffirmed under the second Obama term and the current Secretary Anthony Foxx. In fact, the safety mandate was expanded to include safety oversight to public transit. Safety was emphasized as a FY 2014-2018 Strategic Objective and is also a key component for the Federal Highway Administration's Research and Technology Agenda.[55]

[53] http://visionzerosf.org/
[54] Transportation for a New Generation – Strategic Plan I Fiscal Years 2014-18, U.S. Department of Transportation.
[55] Meeting the Challenge: Safety. U.S. DOT, Federal Highway Administration.

Transportation Investment Generating Economic Recovery, or TIGER grants allow the U.S. DOT to invest in road, rail, transit and port projects that benefit critical national objectives. The grants specify "safety" as one of five long-term outcome benefits that must be detailed as a deliverable, along with economic competitiveness, state of good repair, livability and economic sustainability.[56]

Safety is one of five long-term outcomes and primary selection criteria in the FHWA's TIGER Grant program.[57] The slice below, taken from the table on page 7 of the TIGER Guidance, shows the portion containing the Safety benefit.

Long-Term Outcome	Types of Societal Benefits
Safety	**✓Prevented Accidents (Property Damage), Injuries, and Fatalities**

Safety is also paramount to the California Department of Transportation (DOT). Its mission statement contains the phrase, "to provide a safe, sustainable, integrated and efficient transportation system to enhance California's economy and livability" and Safety and Health is one of its stated goals.[58]

SFMTA, San Francisco's Municipal Transportation Agency, endorses safer transportation experiences for all as the first of its four overarching goals. These four goals prioritize the agency's attention, resources and staff over a six year period.[59]

Safety is a key concern of SFMTA's 22 Fillmore Transit Priority Project. To meet this safety concern, the project aims to increase visibility of people walking, cycling, taking transit, driving cars, and other users through a series of streetscape and infrastructure improvements along this high injury corridor. These improvements (discussed in greater depth in section 8.3) include: transit boarding bulbs and islands, pedestrian bulbs, left-turn restrictions, new traffic and pedestrian signals, and high visibility crosswalks.

SFMTA Overarching Goals

1. **Create a safer transportation experience for everyone.**
2. **Make transit, walking, bicycling, taxi, ridesharing, and carsharing the preferred means of travel.**

3. Improve the environment and quality of life in San Francisco.

4. Create a workplace that delivers outstanding service.

8.3 Safety Benefits of this Project

Project elements designed to reduce collisions, improve pedestrian and user safety, and develop streetscape enhancements, are known as countermeasures. They are often categorized into three types:

- Intersection and signal improvements
- Roadway improvements
- Operations and enforcement

The effectiveness of countermeasures in reducing crashes is measured as a Crash Reduction Factor (CRF) – the percentage crash reduction that might be expected following the implementation of a given countermeasure.[60]

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56 About TIGER Grants. U.S. DOT. April 16, 2015.
57 TIGER Grant Guidance, 2015.
58 Caltrans: Mission-Vision-Goals-Values. 2015.
59 SFMTA Strategic Plan, FY 2013-FY 2018.

The 22 Fillmore Transit Priority Project is designed to deliver safety benefits and meet the SFMTA's primary goal, by initiating appropriate countermeasures and enhancements along the corridor, resulting in reductions in pedestrian, bicycle, transit and vehicle crashes. The safety improvements planned for the corridor include:

1. Upgraded traffic signals
2. Transit-only (bus) lanes
3. Transit bulbs (bus bulbs or bus bump outs)
4. Transit boarding islands
5. Relocation of bicycle lanes to a parallel street one block off the transit corridor
6. Pedestrian countdown signals
7. Pedestrian bulbs
8. New traffic and pedestrian signals
9. Left-turn restrictions
10. Left-turn pockets
11. High visibility ("continental") upgraded crosswalks
12. Pedestrian-scale lighting

8.4 Review of Safety Benefit Literature

As illustrated in the first section of the chapter, the safety of our streets is a serious concern in the United States, and California in particular. In the past decade, traffic planners, researchers and other transportation officials have studied traffic improvements and countermeasures in great depth to determine the effectiveness of these countermeasures and improve the safety and design of the city's streets. Most studies describe countermeasures and effectiveness as a reduction in crashes, or crashes remaining following the installation of a given countermeasure. The factors that planners need consider when evaluating the appropriateness of a given countermeasure include: types of turns, traffic volume and mix, environmental concerns, geometric considerations, and operational conditions, among others. Each has advantages and disadvantages and may be suitable for some installations and not others.
The project reviewed a number of selected sources to determine how to quantify the countermeasures, including:

- Desktop Reference for Crash Reduction Factors[61]
  The Abstract to this report states: "The Desktop Reference documents the estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to intersections, roadway departure and other non-intersection crashes, and pedestrian crashes. The estimates of crash reduction are known as Crash Reduction Factors (CRFs), and represent the information available to date. Where available, the Desktop Reference includes multiple CRFs for the same countermeasure to allow the reader to review the range of potential effectiveness. The CRFs are a useful as a guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions which will affect the safety impact of a countermeasure."

[60] Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes. U.S. DOT, Federal Highway Administration, 2008.
[61] Desktop Reference for Crash Reduction Factors, U.S. DOT, FHWA, Report No. FHWA-SA-08-011, September 2008.

- Crash Modification Factors Clearinghouse[62] - an online regularly updated online repository of CMFs and supporting documentation.

  The CMF Clearinghouse, available at www.CMFClearinghouse.org, offers transportation professionals a central, Web-based repository of CMFs, as well as additional information and resources related to CMFs. The CMF Clearinghouse was established to provide transportation professionals:

  - A regularly updated online repository of CMFs
  - A mechanism for sharing newly developed CMFs
  - Educational information on the proper application of CMFs

- Various "Toolboxes" of Countermeasures[63] [64]
  Summary reports from the FHWA detailing various countermeasures and their corresponding CRFs. The reports are specified for pedestrian crashes or intersection crashes.
- Assorted online studies and factsheets produced by state Departments of Transportation summarizing CMF information for use by traffic planners and engineers.

The following method was used to identify the appropriate countermeasures for the project corridor and estimate their effectiveness in collision reduction:

- Select the appropriate elements
- Research each in the CRF literature
- Enumerate the citations with sources for each countermeasure
- Calculate the numerical effect of combining the countermeasures
- Apply that measure to the collisions in the corridor

Safety improvements planned for the corridor, sources reviewed for the analyses and the levels of crash reduction identified for each are shown in Exhibit 8-2. We also suggested a single consensus crash reduction factor combining associated improvements, shown in Column 4.

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[62] Crash Modification Factors Clearinghouse, U.S. DOT, FHWA. www.CMFClearinghouse.org.
[63] Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes, U.S.DOT, FHWA, May 2008.
[64] Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes, September 2007.

Exhibit 8-2: Safety Improvements and Crash Reduction Factors (%)

Improvement	Citations	Findings	CRF
Upgraded traffic signals	Michigan Department of Transportation; Intersection crash reduction factors.	10% reduction by adding all red clearance interval - per ITE recommendations.	20%
	Michigan Department of Transportation; Intersection crash reduction factors.	30% reduction in left turn accidents by adding left turn signal phase.	
	Oregon Department of Transportation: Systemic Safety Measures: Pedestrian Enhancements	4% reduction in all crashes and 15% reduction in pedestrian crashes with Advanced Warning Signs.	
	Oregon Department of Transportation: Systemic Safety Measures: Pedestrian Enhancements	34% reduction in pedestrian crashes using Exclusive Pedestrian Phrasing.	
	Michigan Department of Transportation; Intersection crash reduction factors.	10% reduction in all crash types by signal optimization and timing updates.	
Upgraded traffic signals - Leading	Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes, U.S. DOT, FHWA, 2008. p. 4. Desktop Reference p.4.	5% reduction in misc. crashes.	5%
Larger Signal Heads (to 12")	Desktop Reference for Crash Reduction Factors, Report No. FHWA-SA-08-011. US DOT: FHWA, September 2008. Michigan DOT using 10%.	10% to 24% decrease in all types of crashes; mode is 10%.	10%
	Larsen, A. Low Cost Road Safety. Federal Highway Administration presentation.	33% to 47% decrease in angle crashes.	
New Mast Arms	Desktop Reference for Crash Reduction Factors, Report No. FHWA-SA-08-011. US DOT: FHWA, September 2008	29% to 49% reduction in all accidents; 44% in fatal/injury accidents	40%
Transit-only lanes	François Rambaud, Sébastien Rabuel, Thierry Du Crest, and Pascal Deprez, "BHLS: The French BRT Approach: The Key Messages" (2008), http://www.bhls.eu/IMG/pdf/French_BHLS_Abstract_presentation__Dublin_2008.pdf (accessed June 12, 2009), 3-4.	24% reduction in bus accidents in Paris.	24%
	Régie Autonome des Transports Parisens (RATP), *Le Programme Mobilien à Paris: Contribution de la RATP à un Bilan D'étape* (Paris: RATP, 2007), http://bhns.fr/IMG/pdf/bilanMobilienParisRATP_sept2007.pdf (accessed June 12, 2009), 6.	24% to 38% reduction in accidents in Paris.	
Transit Boarding Islands/Pedestrian Islands/Refuge Islands	Bahar, G., Parkhill, M., Hauer, E., Council, F., Persaud, B., Zegeer, C., Elvik, R., Smiley, A., and Scott, B. "Prepare Parts I and II of a Highway Safety Manual: Knowledge Base for Part II". Unpublished material from NCHRP Project 17-27, (May 2007).	36% fatal and injuries using pedestrian islands	25%
	Median and Pedestrian Crossing Islands in Urban and Suburban Areas, Federal Highway Administration, U.S. DOT	Reduce pedestrian crashes by 46% and motor vehicle crashes by 39%	
	Desktop Reference for Crash Reduction Factors; Bahar, Geni; Masliah, Maurice; Wolff, Rhys; Park, Peter: US DOT 2008, p. 32	15% reduction in all crash types by installing painted median islands.	
	Desktop Reference for Crash Reduction Factors; Bahar, Geni; Masliah, Maurice; Wolff, Rhys; Park, Peter: US DOT 2008, p. 32	25% reduction in all crash types with physical median islands.	
	Desktop Reference for Crash Reduction Factors; Bahar, Geni; Masliah, Maurice; Wolff, Rhys; Park, Peter: US DOT 2008, p. 33	56% reduction in pedestrian accidents by installing refuge islands.	
Removal of bike lanes to alt street			
Pedestrian countdown signals	Markowitz, F., Sciortino, S., Fleck, J. L., and Yee, B. M., "Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation." *Institute of Transportation Engineers Journal*, Vol. January 2006, ITE, (1-1-2006) pp. 43–48. Updated by Memorandum, Olea, R., "Collision changes 2002–2004 and countdown signals," (February 7th, 2006).	5%	15%
	Michigan Department of Transportation; Intersection crash reduction factors.	30% reduction in pedestrian and bicycle accidents when installed w/o existing signal.	
	Oregon Department of Transportation: Systemic Safety Measures: Pedestrian Enhancements	25% reduction in pedestrian crashes using Countdown Pedestrian Heads vs. traditional heads.	
Pedestrian bulbs	Michigan Department of Transportation; Intersection crash reduction factors.	30% reduction in all crashes	30%
Pedestrian scale lighting	Pedestrian Safety at Bus Stops Study, New Jersey Bicycle and Pedestrian Resource Center, Voorhees Transportation Center, Rutgers University in coordination with Michael Baker, Jr., Inc.	No sig. diffs.	0
New traffic signals	Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes, U.S. DOT, FHWA, 2008.	20% to 38% reduction in all types of accidents; 38% in fatal.	29%
Left-turn restrictions	Brich, S. C. and Cottrell Jr, B. H., "Guidelines for the Use of No U-Turn and No-Left Turn Signs." VTRC 95-R5, Richmond, Virginia Department of Transportation, (1994)	64% reduction in left turn accidents	65%
	Brich, S. C. and Cottrell Jr, B. H., "Guidelines for the Use of No U-Turn and No-Left Turn Signs." VTRC 95-R5, Richmond, Virginia Department of Transportation, (1994)	68% reduction in all accidents	
Left-turn pocket	El-Basyouny, K. and Sayed, T. "A full Bayes multivariate intervention model with random parameters among matched pairs for before-after safety evaluation." Accident Analysis and Prevention, Vol. 43, No. 1, Oxford, N.Y., Pergamon Press, (2011) pp. 87-94.	21% reduction in all accidents	20%
High visibility (Continental) crosswalks	Chen, L., C. Chen, and R. Ewing. "The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience." Presented at the 91st Annual Meeting of the Transportation Research Board, January 22-26, Washington, DC, 2012.	40% CRF vehicle/pedestrian	30%
	Chen, L., C. Chen, and R. Ewing. "The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience." Presented at the 91st Annual Meeting of the Transportation Research Board, January 22-26, Washington, DC, 2012.	19% CRF Angle,Head on,Left turn,Rear end,Rear to rear,Right turn,Sideswipe	
	Feldman, M., J. Manzi, and M. Mitman. "An Empirical Bayesian Evaluation of the Safety Effects of High-Visibility School (Yellow) Crosswalks in San Francisco." TRB 89th Annual Meeting Compendium of Papers CD-ROM. Washington, D.C. 2010.	37% CRF at school crossings in San Francisco	
	Oregon Department of Transportation: Systemic Safety Measures: Pedestrian Enhancements.	37% reduction in pedestrian crashes	

8.5 Safety Benefit Estimation Methodology

This section describes the data and methodologies used in the project to calculate the benefits of the safety countermeasures. The steps were:

1. Develop estimates of current collisions
2. Convert collision to Federal injury severity codes
3. Monetize collision codes
4. Identify safety improvements and crash reduction factors
5. Calculate yearly safety values and present values

Development of Collision Data

California's Statewide Integrated Traffic Records System (SWITRS) maintains a Collision Severity database recording five levels of injury severity, including a "property damage only" rating. All fatal and injury collisions are reported as specified on Collision Report Form (Form 555) of the California Highway Patrol Manual 2. The severity injury scale range in SWITRS is:

- 1 = fatal
- 2 = injury severe
- 3 = injury other visible
- 4 = injury complaint of pain
- 0 = property damage only

The San Francisco Municipal Transportation Agency (SFMTA) provided seven years (2005-2012) of injury data from the project area, 16th Street, from Church Street to Third Street. They included cyclist, pedestrian and vehicle victims; a total of 661 individual fatalities or injuries. The injury data included midblock incidents on 16th Street and adjacent streets and intersections with 16th Street. Exhibit 8-3 presents data on incidents by mode (type of victim), severity of injury and collision location. The collision report were generated from TransBase, a database developed and maintained by the San Francisco Department of Public Health (http://transbasesf.org/).[65]

[65] transbasesf.org *San Francisco Department of Public Health (SFDPH). Note: This data is being provided as public information as defined under San Francisco and California public records laws. Where the data is communicated, distributed, reproduced, mapped, or used in any other way, the user should acknowledge SFDPH as the source of the data,* provide a reference to the original data source where also applicable (SWITRS in the case), and note any caveats specified in the associated methodological documentation provided by the Department. However, users should not attribute their analysis or interpretation of this data to SFDPH.

Exhibit 8-3: Collision Victims by Mode, Severity of Injury and Location

Severity of Injury	Midblock on 16th Street (outside 20 feet of intersection)	Intersection with 16th Street (within 20 feet of intersection)	Midblock on Adjacent Streets (not 16th Street)	Total	Percent
Cyclist Victims					
Severe Injury	1	3	2	6	
Visible Injury	13	26	7	46	
Complaint of Pain	12	35	4	51	
Total	26	64	13	**103**	15.6
Pedestrian Victims					
Severe Injury	4	6	2	12	
Visible Injury	7	29	8	44	
Complaint of Pain	6	50	14	70	
Total	17	85	24	**126**	19.1
Vehicle Victims					
Fatality	1	1	0	2	
Severe Injury	1	7	5	13	
Visible Injury	16	71	17	104	
Complaint of Pain	48	228	37	313	
Total	66	307	59	**432**	65.4
Grand Total	109	456	96	**661**	
Percent	16.5	69.0	14.5	100.0	100.0

Exhibit 8-4 summarizes the above collision victim data by mode and severity.

Exhibit 8-4: Collision Victims by Mode and Severity

Severity of Injury	Type of Victim			Total	Percent
	Cyclist	**Pedestrian**	**Vehicle**		
Fatality	0	0	2	2	0.3
Severe Injury	6	12	13	31	4.7
Visible Injury	46	44	104	194	29.3
Complaint of Pain	51	70	313	434	65.7
Total	**103**	**126**	**432**	**661**	100.0

The current estimates do not include property damage estimates. However, reduction of property damage is a potential benefit and would be affected by the countermeasures, for example, restrictions on left hand turns reducing auto crashes in intersections.

Conversion to Federal Collision Severity Data Categories

To determine the benefit of proposed countermeasures for the corridor, the four-category state SWITRS data was converted to the six-point Abbreviated Injury Scale (AIS) used by federal agencies. The six-levels of injury in the AIS scale are:

- 1 = minor
- 2 = moderate
- 3 = serious
- 4 = severe
- 5 = critical
- 6 = maximum/fatal (unsurvivable)
- 9 = not further specified

Three of the six injury severity categories from SWITRS matched the AIS designations. However Category 2 "Severe Injury" corresponded to three of the six federal classifications. This analysis distributed the collisions in this combined SWITRS collision category to the Federal AIS categories using the Fehr and Peers' WalkFirst Crash Cost Analysis methodology.[66] The results of the redistribution are shown in Exhibit 8-5.

Exhibit 8-5: Conversion of SWITRS Collision Severity Codes to AIS Collision Severity Codes

SWITRS Collision Severity Code	SWITRS Severity of Injury	Number of Injuries (2007-2012)	AIS Collision Severity Code	AIS Collision Severity	SWITRS Category 2 to AIS Categories 3-5 Conversion Percentages	Number of Adjusted Injuries
4	Injury-Complaint of Pain	434	1	Minor		434
3	Injury-Other Visible	194	2	Moderate		194
2	Severe Injury	31	3	Serious	19%	5.89
			4	Severe	45%	13.95
			5	Critical	36%	11.16
1	Fatal	2	6	Maximum/fatal		2
Total		661				661

Monetization of Collision Codes

The collisions were monetized in this step using TIGER values of injury prevention and DOT guidance for updating the Value of Statistical Life (VSL) to 2015.[67] Exhibit 8-6 provides the number of injuries, the fraction of VSL per injury category and the five-year values of injury prevention adjusted to one year. When the five-year values were converted to annual incidents, total annual value of injuries in the 16th Street corridor exceeded $45.5 million.

[66] Fehr & Peers. WalkFirst Crash Cost Analysis Methodology, November 18, 2013.

[67] Rogoff, P. Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses - 2014 Adjustment, June 13, 2014.

Exhibit 8-6: Values of Injury in Corridor Based on Converted Collision Data and VSL Values

Number of Adjusted Injuries	Value of Statistical Life (VSL), 2015	Fraction of VSL	Value of Injury Prevention	Five Year Values of Injury in Corridor	Values of Injury in Corridor Adjusted to Annual Values
434	$9,741,446	0.003	$29,224	$12,683,363	$2,536,673
194	$9,741,446	0.047	$457,848	$88,822,505	$17,764,501
6	$9,741,446	0.105	$1,022,852	$6,024,597	$1,204,919
14	$9,741,446	0.266	$2,591,225	$36,147,584	$7,229,517
11	$9,741,446	0.593	$5,776,677	$64,467,721	$12,893,544
2	$9,741,446	1.000	$9,741,446	$19,482,892	$3,896,578
661				$227,628,661	**$45,525,732**

Reduction of Collisions Due to Countermeasures

Specific collision reduction is difficult to estimate with precision given the many variables affecting the corridor. At least two problems were noted concerning combining the CRFs. The countermeasures could not be summed to determine the combined effect for this project, since combined countermeasures are not additive and in fact their total would exceed 100 percent. Furthermore, not all CRFs apply to every collision. Some do not apply for a given intersection. Others do not apply to the type of collision. For example, high-visibility crosswalks would have little, if any, effect on left-turn intersection motorist collisions.

There is a method to calculate the effectiveness of combinations of countermeasures at the same intersection; however without data detailing collisions by type and intersections, it was not possible to adapt this level of detail. While the multiple countermeasures may have more of an effect than one, it is assumed unlikely to exhibit the full impact of each when implemented concurrently, particularly if targeting the same type of crash.

The method to determine the reduction of collisions in the corridor requires matching countermeasures to each collision at each location, combining their effects as suggested in the FHWA formula:[68]

$CRF_t = 1 – (1-CRF_1)\ (1-CRF_2)\ (1-CRF_3)\ (1-CRF_4)….$

Where,

CRF_t = Total CRF

CRF_1 = CRF for the first countermeasure

CRF_2 = CRF for the second countermeasure

CRF_3 = CRF for the third countermeasure

In fact where an intersection has multiple countermeasures in which one only impacts a portion of the total crashes more complex calculations are recommended. An example might be lighting that affects only 25 percent of the crashes, the ones that happen at night.

[68] Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections, U.S. DOT, FHWA.

This level of detail for the available collision data was beyond the scope of this study. The CRFs were combined using a simple numerical average (26.1%) and assumed to be the combined collision reduction factor for the corridor. Thus, this analysis uses a more conservative approximation. Note that nine of the combined countermeasures were estimated at a CRF of 20 percent or more.

Applying the average of the CRFs in Exhibit 8-2 (26.1 percent) to the total annual value of injuries resulted in $11,882,216 in annual safety benefits ($45,525,732 x 26.1% = $11,882,216). The value of accidents declined to $33,643,516.

8.6 Calculation of the Yearly Safety Values and Present Value

The safety benefit of $11,882,216 for 2020 applies to the initial year of the project following construction of the improvements. The analysis assumes no safety benefits occur prior to project construction, 2015 through 2019.

To estimate the cost of accidents in each year, the analyses used data on the number of auto vehicle, bike and walking trips from the SF-Champ model. The first column in Exhibit 8-7 provides trips for the no-build, which scale the 2020 estimate of the cost of accidents in the no-build in the second column. The third column provides trips for the build, which scale the 2020 estimate of the cost of accidents in the build in the fourth column. The fifth column subtracts the results from the forth column from the second column to estimate the decline in accident costs. The present dollar value of safety benefits in each year are shown in the last two columns. The estimates are $227.4 million at a 3 percent discount rate or $121.1 million at 7 percent over a thirty year period.

Exhibit 8-7: Safety Benefits from 2015 to 2050

Year	Auto Vehicle, Bike and Walk Trips (No-Build)	Cost of Accidents (No-Build)	Auto Vehicle, Bike and Walk Trips (Build)	Cost of Accidents (No-Build)	Safety Benefits (Dollars)	Present Dollar Value of Safety Benefits at 3%	Present Dollar Value of Safety Benefits at 7%
2020	761,319	45,525,732	760,820	33,651,104	11,874,628	10,243,159	8,466,446
2021	767,059	45,868,962	766,559	33,904,923	11,964,040	10,019,695	7,972,145
2022	772,799	46,212,193	772,297	34,158,742	12,053,451	9,800,559	7,506,284
2023	778,539	46,555,423	778,036	34,412,561	12,142,863	9,585,688	7,067,257
2024	784,279	46,898,653	783,774	34,666,379	12,232,274	9,375,019	6,653,546
2025	790,018	47,241,884	789,513	34,920,198	12,321,685	9,168,491	6,263,720
2026	795,758	47,585,114	795,252	35,174,017	12,411,097	8,966,040	5,896,423
2027	801,498	47,928,344	800,990	35,427,836	12,500,508	8,767,605	5,550,375
2028	807,238	48,271,574	806,729	35,681,655	12,589,919	8,573,122	5,224,369
2029	812,977	48,614,805	812,467	35,935,474	12,679,331	8,382,531	4,917,263
2030	818,717	48,958,035	818,206	36,189,293	12,768,742	8,195,770	4,627,980
2031	824,457	49,301,265	823,945	36,443,112	12,858,153	8,012,776	4,355,501
2032	830,197	49,644,496	829,683	36,696,931	12,947,565	7,833,490	4,098,867
2033	835,937	49,987,726	835,422	36,950,750	13,036,976	7,657,849	3,857,171
2034	841,676	50,330,956	841,161	37,204,569	13,126,387	7,485,795	3,629,555
2035	847,416	50,674,186	846,899	37,458,388	13,215,799	7,317,267	3,415,214
2036	853,156	51,017,417	852,638	37,712,207	13,305,210	7,152,206	3,213,382
2037	858,896	51,360,647	858,376	37,966,026	13,394,621	6,990,552	3,023,342
2038	864,636	51,703,877	864,115	38,219,845	13,484,033	6,832,248	2,844,415
2039	870,375	52,047,108	869,854	38,473,664	13,573,444	6,677,235	2,675,959
2040	893,334	53,420,029	892,808	39,488,939	13,931,089	6,653,566	2,566,792
2041	900,087	53,823,829	899,559	39,787,550	14,036,279	6,508,549	2,416,984
2042	906,840	54,227,629	906,311	40,086,160	14,141,469	6,366,335	2,275,792
2043	913,593	54,631,430	913,062	40,384,771	14,246,659	6,226,883	2,142,729
2044	920,345	55,035,230	919,813	40,683,381	14,351,849	6,090,155	2,017,336
2045	927,098	55,439,030	926,565	40,981,992	14,457,038	5,956,108	1,899,179
2046	933,851	55,842,831	933,316	41,280,602	14,562,228	5,824,704	1,787,849
2047	940,603	56,246,631	940,067	41,579,213	14,667,418	5,695,902	1,682,956
2048	947,356	56,650,431	946,818	41,877,823	14,772,608	5,569,661	1,584,136
2049	954,109	57,054,232	953,570	33,891,053	14,920,334	5,461,512	1,495,306
Total	**25,554,163**	**1,528,099,699**	**25,538,625**	**1,121,289,158**	**398,567,696**	**227,390,472**	**121,128,272**

CHAPTER 9: STATE OF GOOD REPAIR – MAINTENANCE & REPAIR SAVINGS

The Benefit-Cost Analyses Guidance for TIGER Grants Applicants lists five Long-Term Outcomes on page 7, along with the types of social benefits realized for each.[69] This chapter discusses and quantifies the State of Good Repair long-term outcome, focusing on the Maintenance and Repair Savings societal benefit.

The chapter is divided into five sections, including:

6. Description of the benefit
7. Justification as a TIGER benefit
8. The benefit in this project
9. Related research
10. Estimation methodology

9.1 Description of the State of Good Repair Benefit

The American Public Transportation Association has noted that the State of Good Repair is an issue of National Importance.[70] State of Good Repair relates to improving the condition and resilience of existing transportation facilities and systems. In a state of good repair, total replacement of the asset can be postponed and savings are realized from reduced expenses for maintenance and repair. Other benefits include reduced operating costs and congestion, as assets are not out of service due to maintenance and repair.

9.2 Justification as a TIGER benefit

State of Good Repair is one of five long-term outcomes and primary selection criteria in the FHWA's TIGER grant program.[71] The slice below, taken from the table on page 7 of the TIGER Guidance, shows the portion containing the Maintenance and Repair Savings benefit.

Long-Term Outcome	Types of Societal Benefits
State of Good Repair	Deferral of Complete Replacement ✓**Maintenance & Repair Savings** Reduced VMT from Not Closing Bridges

As stated in the TIGER Notice of Funding Availability,[72] projects should 1) be consistent with relevant plans to maintain transportation facilities or systems in a state of good repair and address current and projected vulnerabilities; 2) if left unimproved, the poor condition of the asset will threaten future transportation network efficiency, mobility of goods or mobility of people, or economic growth; 3) is

[69] 2015 Benefit-Cost Analysis Analyses Guidance for TIGER Grants Applicants, United States Department of Transportation April 6, 2015
[70] American Public Transportation Association, Resources, Standards, State of Good Repair, 2015: www.apta.com.
[71] Ibid.
[72] Notice of Funding Availability for the Department of Transportation's National Infrastructure Investments under the Consolidated and Further Continuing Appropriations Act, United States Department of Transportation, 2015

appropriately capitalized up front and uses asset management approaches that optimize its long-term cost structure; and 4) a sustainable source of revenue is available for operations and maintenance of the project, and 5) the project improves the transportation asset's ability to withstand probable climate change impacts.

The guidance also states the importance of the project contributing to improve the overall reliability of a multimodal transportation system that serves all users and offer significant transformational improvements to the condition of existing transportation systems and facilities.

9.3 The State of Good Repair Benefit of this Project

This 22 Fillmore Multimodal Corridor Project incorporates a number of transportation improvements that contribute to the state of good repair, specifically targeting maintenance and repair savings. Improved overhead wire infrastructure along the corridor and installation of new traffic lights and pedestrian signals should reduce maintenance costs and keep them in operation for extended time periods. High maintenance costs of repairing the current support poles, some from the 1940s, are expected to decline while newer poles will require less frequent replacement. The City will investigate the potential to improve green storm water infrastructure which should reduce flooding of streets due to limited capacity of the sewer system thus reducing transit, pedestrian and commuter delays.

9.4 Related Research

In conducting the project analysis the team followed the concepts and methods as described by Rabinder Bains of the FHWA on State of Good Repair as presented in a workshop targeted to transportation analysts.[73] These include establishing alternative design strategies for the analysis period, estimating agency costs, identifying alternative strategies for the design period and conducting a life cycle cost analysis. User costs are estimated based on factors including schedule, maintenance, future demand for services and projections of user speeds of travel and distance.

9.5 State of Good Repair Benefit Estimation Methodology

This section describes the calculation of on-going maintenance and repair costs that will occur in the absence of implementation of the 22 Fillmore Multimodal project. If SFMTA implements the project, the 16th Street Corridor will undergo significant reconstruction and investment. SFMTA will repave the entire corridor and install new sidewalks, curbs, traffic lights, and bus stops as well as new wires and poles for the trolley system. In the absence of this investment, the corridor will require significant periodic investments in order to maintain the various elements in working order.

The SFMTA engineering personnel developed maintenance costs in the absence of the project. Exhibit 9-1 lists each maintenance item along with the unit cost, units, number of units, year of implementation assumptions, and scheduling rationale. Note that there are no quantities for one of the maintenance items, as the red "Transit Only Lane" paint is not required in the no-build scenario.

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[73] Bains, Rabinder. Benefit Cost Analysis for Transportation Infrastructure – A Practitioner's Workshop. May 17, 2010.

Exhibit 9-1: Maintenance Costs by Item – Unit Costs, Units, and Quantities

Item	Unit Cost	Units	Quantity	Years of Implementation	Total Cost	Maintenance Schedule
Traffic Signal Conduits	$ 100,000	intersection	36	1 intersection every year	$ 3,600,000	20 years lifecycle; age of signals unknown; 19 signals currently on corridor, assume one intersection upgrade a year
Full Signal Upgrade	$ 350,000	intersection	18	1 intersection every other year	$ 6,300,000	40 years life cycle; includes conduit work and above grade work; signal age unknown; assume one signal upgrade every other year to upgrade 17 signals on corridor through 2050
Transit Signal Priority	$ 30,000	intersection	76	19 intersections in 2020, 2030, 2040	$ 2,280,000	Update every 10 years; 19 intersections x 4 cycles = 76
Signage	$ 2,000	block	148	37 blocks in 2020, 2030, 2040	$ 296,000	As needed - signs typically last 10 years; $200 per sign (inclusive of labor, etc.); consider average of 10 signs per block = $2000/block for 33 blocks
Lighting						Replace Bulbs 3-5 years and fixture life cycle 15 year, poles 50 years
Curb Return	$ 60,000	intersection	37	37 intersections in 2039	$ 2,220,000	Would be upgraded on corridor along with the 2039 repaving; approx. $15,000/corner
Sewer	$ 3,750,000	mile	1	1 mile replaced on repaving schedule in 2039	$ 3,750,000	Replace every 100 years; given age of neighborhood, assume half of the corridor will need to be replaced in this time period
Potable Water	$ 1,250,000	mile	1	1 mile replaced on repaving schedule in 2039	$ 1,250,000	Replace every 50 years; given age of neighborhood, assume half of the corridor will need to be replaced in this time period
AWSS (fire hydrant water)	$ 2,500,000	mile	1	1 mile replaced on repaving schedule in 2039	$ 2,500,000	Replace every 50 years; given age of neighborhood, assume half of the corridor will need to be replaced in this time period
Red Transit only Lane Paint	$ 35,000	blocks	0	n/a	$ -	No project, no paint.
OCS Pole and Duct Bank Replacement	$ 18,600	pole, foundation and grounding	120	1 segment (60 poles) in 2015; other in 2032	$ 2,232,000	Install new poles on the Church to Valencia and Kansas/17th Street segments; already nearing end of useful life; ref CIP estimate PDF in 2012 dollars; assumed double the cost to cover both the Kansas/17th St segments and the 16th/Church to Valencia segments as they are similar distances
OCS Wire Replacement	$ 50	linear foot	92800	2015, 2030	$ 4,640,000	Every 20 years, start 2015 for segments
OCS Wire Retensioning	$ 6,000	year	36	every year	$ 216,000	3/4 mile for the Church to Valencia and Kansas/17th Street segments. Three-person crew. Six hours, every year. $500/hour for the crew, equipment; maintenance every year for 35 years
OCS Inspection and Debris Removal	$ 3,000	year	36	every year	$ 108,000	3/4 mile for the segment on Kansas and 17th Street (OCS Overhead Feeder System). Three-person crew. 3 hours, every year. Maintenance every year for 35 years
OCS Special Work	$ 6,000	year	36	every year	$ 216,000	Every 2 years; adjusts the switches and enables turns for the buses (9 intersections with turns plus 3 more where the 22 Fillmore intersects with other trolley lines), start 2015; assume same level of effort as wire retensioning; maintenance every year for 35 years
Paving and Striping	$ 165,000	blocks	5	2016	$ 825,000	Start resurfacing in 2016 for 5 blocks (segment 2)
	$ 21,600	blocks	32	2022	$ 691,200	First pavement preservation in 2022 for 32 blocks (segment 1 and segment 3)
	$ 21,600	blocks	5	2026	$ 108,000	Segment 2 first preservation in 2026
	$ 21,600	blocks	37	2032	$ 799,200	Segments 1, 2, and 3 second preservation in 2032
	$ 120,000	blocks	37	2039	$ 4,440,000	Segments 1, 2, and 3 repaved in 2039
	$ 21,600	blocks	37	2049	$ 799,200	Segments 1, 2, and 3 first preservation in 2049
TOTAL					**$37,270,600**	

The largest cost item is paving and striping. As described in the earlier chapter on costs for the build scenario, San Francisco Public Works has a goal to maintain a "good" PCI score of 70 citywide and uses this goal as a street-level goal as well. Exhibit 9-2 provides current PCI scores for each block of the project corridor with darker shading representing lower scores. Note that the portion of the corridor near Kansas St. was in the worst condition with two blocks scoring 40 or below and three surrounding blocks at 58 or below.

Exhibit 9-2: 16th Street Corridor Pavement Conditions by Block[74]

From Street	To Street	PCI Score
Landers St	Church St	80
Dolores St	Landers St	79
Spencer St	Dolores St	76
Guerrero St	Spencer St	79
Albion St	Guerrero St	75
Albion St	Albion St	84
Valencia St	Albion St	80
Caledonia St	Valencia St	80
Rondel Pl	Caledonia St	84
Julian Ave	Rondel Pl	79
Hoff St	Julian Ave	84
Wiese St	Hoff St	84
Mission St	Wiese St	79
Capp St	Mission St	79
Capp St	Capp St	85
South Van Ness Ave	Capp St	80
Shotwell St	South Van Ness Ave	80
Folsom St	Shotwell St	79
Harrison St \ Treat Ave	Folsom St	84
Alabama St	Harrison St \ Treat Ave	81
Florida St	Alabama St	83
Bryant St	Florida St	82
Hampshire St	Bryant St	78
Potrero Ave	Hampshire St	76
Utah St	Potrero Ave	70
San Bruno Ave	Utah St	51
Vermont St	San Bruno Ave	68
Kansas St	Vermont St	40
Rhode Island St	Kansas St	37
De Haro St	Rhode Island St	58
Carolina St	De Haro St	72
Wisconsin St	Carolina St	72
08th St	Wisconsin St	65
Arkansas St	08th St	71
Hubbell St	Arkansas St	73
Connecticut St	Hubbell St	75
Daggett St \ Missouri St	Connecticut St	76
07th St \ Mississippi St	Daggett St \ Missouri St	72
Owens St	07th St \ Mississippi St	75
04th St	Owens St	74
03rd St	04th St	65

Exhibit 9-3, which the cost chapter also provides, details for pavement condition ranges, the improvements required and the costs. Note that according to policy, the portion of the corridor near Kansas St is in poor condition and requires resurfacing with road base repair.

[74] Based on PCI score generated by San Francisco Public Works and posted to SFOpenData: https://data.sfgov.org/City-Infrastructure/Paving-PCI-Scores/5aye-4rtt

Exhibit 9-3: Pavement Conditions, Improvements Required and Costs

Pavement Condition Index (PCI)	Improvement Required	Cost
85 – 100 “excellent”	No improvement needed	$0
70 – 84 “good”	Pavement preservation – specialized sealing treatments to extend life of street	$21,600
50 – 69 “at-risk”	Repave - grind off and replace the top two inches of asphalt	$120,000
25 – 49 “poor”	Resurface with base repair - grind off and replace the top two inches of asphalt and repair the concrete base	$165,000
0 – 24 “very poor”	Reconstruction - reconstruct the street including concrete base and top layer of asphalt	$520,000

San Francisco Public Works also suggests the following improvement schedules:

- A first preservation treatment is required in approximately 10 years to maintain a “good” rating
- After the second preservation treatment the pavement will move to at "at risk" in approximately 7 years
- Repaving needed after two preservation treatments in approximately 27 years

The base case follows these rules. To simulate the cost of paving maintenance and repair, the analysis divided the corridor into three segments. The first segment runs from Church St. to Utah St. Every segment in this segment has a PCI of 70, which is at least “good,” and one segment even has a PCI of 85, the lower threshold for “excellent.” Given the average rating of the blocks currently classified as "good," the analysis assumes that the pavement is approximately 3-years old and the first round of pavement preservation will occur after seven years in 2022. The second round of pavement preservation will occur, as normal, in 2032, ten years after the first preservation. The city will repave the segment in 2039, the normal seven years after the second preservation. A first round of pavement preservation will occur, as normal, in 2049, ten years after the first preservation.

The second segment runs from Utah St to De Haro St. Every segment in this segment has a PCI of 58 or below which is “at risk,” and two segments had a PCI of 40 or below, well into the “poor” category. Given these low ratings of these five contiguous blocks, the analysis assumes that the road will need resurfacing in 2016, with a first preservation in 2026, a second preservation in 2033, a repave in 2040, and a first preservation in 2050.

The third segment runs from De Haro St. to 3rd St. The PCI scores for this segment are lower than the first segment, but still nine of 11 are in the “good” range. Therefore, the analysis assumed the same paving schedule.

Exhibit 9-4 summarizes the maintenance costs for the "no-build" case. The total undiscounted costs of the project are approximately $36.5 million. The largest cost is for paving followed by traffic signal upgrades.

Exhibit 9-4: Maintenance Costs by Year without the Project

Year	Traffic Signal Conduits	Traffic Signal Upgrade	Transit Signal Priority	Signage	Curb Returns	Sewer	Potable Water	AWSS (Fire Hydrant Water)	OCS Pole and Duct Bank	OCS Wire	OCS Maint. (All Three)	Paving Maint.	Total
2015	100,000	350,000							1,116,000	2,320,000	15,000		3,901,000
2016	100,000										15,000	825,000	940,000
2017	100,000	350,000									15,000		465,000
2018	100,000										15,000		115,000
2019	100,000	350,000									15,000		465,000
2020	100,000		570,000	74,000							15,000		759,000
2021	100,000	350,000									15,000		465,000
2022	100,000										15,000	691,200	806,200
2023	100,000	350,000									15,000		465,000
2024	100,000										15,000		115,000
2025	100,000	350,000									15,000		465,000
2026	100,000										15,000	108,000	223,000
2027	100,000	350,000									15,000		465,000
2028	100,000										15,000		115,000
2029	100,000	350,000									15,000		465,000
2030	100,000		570,000	74,000							15,000		759,000
2031	100,000	350,000									15,000		465,000
2032	100,000								1,116,000		15,000	799,200	2,030,200
2033	100,000	350,000									15,000		465,000
2034	100,000										15,000		115,000
2035	100,000	350,000								2,320,000	15,000		2,785,000
2036	100,000										15,000		115,000
2037	100,000	350,000									15,000		465,000
2038	100,000										15,000		115,000
2039	100,000	350,000			2,220,000	3,750,000	1,250,000	2,500,000			15,000	4,440,000	14,625,000
2040	100,000		570,000	74,000							15,000		759,000
2041	100,000	350,000									15,000		465,000
2042	100,000										15,000		115,000
2043	100,000	350,000									15,000		465,000
2044	100,000										15,000		115,000
2045	100,000	350,000									15,000		465,000
2046	100,000										15,000		115,000
2047	100,000	350,000									15,000		465,000
2048	100,000										15,000		115,000
2049	100,000	350,000									15,000	799,200	1,264,200
Total	**3,500,000**	**6,300,000**	**1,710,000**	**222,000**	**2,220,000**	**3,750,000**	**1,250,000**	**2,500,000**	**2,232,000**	**4,640,000**	**525,000**	**7,662,600**	**36,511,600**

Exhibit 9-5 sums the capital and maintenance costs and discounts the costs in each year to present values using both a 3 percent and a 7 percent real discount rate. The total discounted costs are approximately $22.4 million using a 3 percent and approximately $13.7 million using a 7 percent real discount rate.

Exhibit 9-5: Summary of Discounted State of Good Repair Benefits

Year	Maintenance Costs (Dollars)	Present Dollar Value of State of Good Repair Benefits at 3%	Present Dollar Value of State of Good Repair Benefits at 7%
2015	3,901,000	3,901,000	3,901,000
2016	940,000	912,621	878,505
2017	465,000	438,307	406,149
2018	115,000	105,241	93,874
2019	465,000	413,146	354,746
2020	759,000	654,720	541,157
2021	465,000	389,430	309,849
2022	806,200	655,514	502,061
2023	465,000	367,075	270,634
2024	115,000	88,138	62,552
2025	465,000	346,004	236,382
2026	223,000	161,100	105,946
2027	465,000	326,142	206,466
2028	115,000	78,309	47,721
2029	465,000	307,420	180,335
2030	759,000	487,173	275,097
2031	465,000	289,773	157,512
2032	2,030,200	1,228,304	642,709
2033	465,000	273,138	137,577
2034	115,000	65,583	31,798
2035	2,785,000	1,541,987	719,697
2036	115,000	61,818	27,774
2037	465,000	242,680	104,957
2038	115,000	58,270	24,259
2039	14,625,000	7,194,531	2,883,269
2040	759,000	362,503	139,845
2041	465,000	215,618	80,071
2042	115,000	51,772	18,507
2043	465,000	203,241	69,937
2044	115,000	48,800	16,165
2045	465,000	191,574	61,086
2046	115,000	45,999	14,119
2047	465,000	180,577	53,355
2048	115,000	43,358	12,332
2049	1,264,200	462,754	126,697
Total	**36,511,600**	**22,393,620**	**13,694,139**

CHAPTER 10: ENVIRONMENTAL SUSTAINABILITY - EMISSIONS REDUCTIONS

10.1 Description of the Environmental benefit

Emission Benefits are defined as saved Social Costs of air pollution. Air is a public good and damage to air quality causes health impacts, damage to surfaces, climate change, and impairment to visibility. Public investments that reduce mobile source emissions reduce the amount of pollutants emitted to the atmosphere and reduced the impacts on individuals, structures, agriculture and the climate. These pollutants are counted in form of tailpipe emissions from automobiles, trucks and buses. Emissions are measured as a mass unit, since pollutants are small solid components being given off into the air. What amount of mass is being released into the atmosphere per mile driven is quantified by *Emission Factors.* Such factors provide a ratio of travelled distance to the amount of solid components that certain types of vehicles release. Typically, they are measured in *grams per mile*. Emissions can be reduced by advanced low emissions vehicle and fuel technology, and by reducing vehicle miles traveled (VMT). When *Saved Mileage* and Emission Factors are multiplied together, the result is reduced emissions mass, specified by pollutant and vehicle type. The 22 Fillmore Transit Priority Project does not influence which pollutants are emitted into the air, but it will changes miles driven and the bus technology deployed. By providing a more sustainable and efficient infrastructure and BRT buses powered by electricity instead of conventional transportation fuels, the project can reduce the annual emissions of automobiles, trucks and buses.

10.2 Justification as a TIGER Benefit

Transportation by autos, trucks and buses in the 16th Street corridor generate environmental costs in the form of emissions of "criteria pollutants" (e.g., SOx, NOx, and particulates) and from the emission of greenhouse gases, such as carbon dioxide (CO2). Increased development causes traffic congestion along 16th Street which results in increased levels of these emissions. The 22 Fillmore Transit Priority Project will reduce congestion and provide bus service with cleaner vehicles which will reduce these emissions and produce Environmental Benefits from reduced vehicle-miles travelled as drivers shift to transit for faster, higher level of service trips than would be available in the future without the project. This section of the BCA will show how diesel powered motor coach service will be replaced by clean electric powered trolley service and how dedicated lanes and other corridor improvements will provide substantially quicker transit trips leading to mode shift from auto to transit. These types of benefits are clearly demonstrated along with how they will reduce emissions. Emissions reduction quantification is followed by an estimate the dollar value of these benefits.

One of the five log term goals of TIGER projects is TIGER BCA Resource Guide includes recommended emission types. These are Carbon Dioxide (CO2), Volatile Organic Compounds (VOCs), Nitrogen Oxides (NOx) and Particulate Matter (PM). Emission factors for each of these pollutants have been included in this analysis and will be described later on in this chapter. The fifth emission type mentioned is Sulfur Oxides (SOx). However, data forecasts up to 2050 for SOx were not available for this analysis, which is why SOx is not included in this analysis.

This chapter describes how *Saved Mileage*, *Emission* and *Cost Factors* have been prepared, estimated and used in order to quantify Emission Benefits for 22 Fillmore Transit Priority Project, and what results have been concluded. Please take into consideration that CO2 takes a special place in this chapter, because USDOT requires an independent form of CO2 Cost Factor estimation, whereas Emission Cost Factors for criteria pollutants are provided in the *TIGER BCA Resource Guide*. This is why CO2 is mostly being described separately in following sections.

10.3 Environmental Benefits of this Project

Emission Factors and *Saved Mileage* are needed in order to calculate the reduction in Emissions. By reducing emissions, some of the cost to the public is avoided, providing an emissions benefit of the project. Vehicle emissions are regulated by the USEPA and the California Air Resources Board by controlling the acceptable level of emissions from vehicles. These regulations become more stringent over time for new vehicles and thus improve the emissions characteristics of the vehicle fleet over time as lower emissions vehicles enter the fleet and higher emissions vehicles are retired. In order to quantify Emission Benefits, the vehicle mileage saved from auto and bus use as a result of the 22 Fillmore Transit Priority Project is associated with Emission Factors for each pollutant. This mileage reduction results in estimated emissions reductions that are multiplied by Cost Factors associated with each pollutant, giving us dollar amounts of Emission Benefits. The dollar amounts for each year over the project period until 2049 are discounted to 2015 Dollar values at 3 and 7 percent discount rates. [75]

The sources of emissions reductions quantified and monetized in this chapter stem from:

1. ***Replace Diesel Powers Motor Coaches.*** Diesel motor coach buses currently provide service from the 16th Street BART Station to 3rd Street. This project will reconfigure the 22 Fillmore, 33 Fillmore, and the 55, eliminating the 55 motor coach service and replacing it with electric powered trolley service made possible new technology at the 16th and 3rd intersection allowing the T and Trolley service to cross paths.
2. ***Reduce Auto Miles Traveled.*** The 22 Fillmore Transit Priority Project will provide a thirty present reduction in trolley travel time resulting in expected mode shifts. The mode shift and VMT reductions are estimated using the state of the art San Francisco Activity Based Travel Demand Model

10.4 Review of Environmental Benefit of BRT Literature

There is a wealth of literature on the potential emissions reductions and environmental benefits to the public of improved transit service. See for example NCHRP REPORT 456: Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration - *Guidebook for Assessing the Social and Economic: Effects of Transportation Projects* or *Environmental Benefits of Alternative Fuels and Advanced Technology in Transit*, West Virginia University.

For this BCA we followed closely the NCHRP report Research Results Digest 352: *Cost/Benefit Analysis of Converting a Lane for Bus Rapid Transit—Phase II Evaluation and Methodology*, April 2011. This study reports that Bus Rapid Transit (BRT) such as proposed for the 22 Fillmore Transit Priority Project has emerged as a viable option to enhance transportation capacity and provide increased levels of mobility and accessibility. BRT systems vary from one application to another but all provide a higher level of service than traditional bus transportation. Service on BRT systems is generally faster than regular bus service because the buses make fewer stops and may run as often as comparable rail systems during

[75] TIGER Benefit-Cost Analysis (BCA) Resource Guide (2015): http://www.dot.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf

peak travel times. BRT lines can transport large numbers of people efficiently and cost-effectively and can be an attractive way to get drivers out of their cars and onto transit. The report conducts with a hypothetical BCA for a major arterial BRT system similar to that proposed for the 16th Street corridor.

10.5 Benefit Estimation Methodology

This section provides a step by step discussion of how the two environmental benefit sources for the 22 Fillmore Transit Priority Project were calculated. In one case the project will replace the diesel powered 55 Motor Coach service and in the other, the SF-CHAMP activity based TDM estimated mode shift from auto to transit. This reduces auto trips and lowers the expected auto emissions.

Exhibit 10-0 Annual Reduction of Auto and Bus Miles

Year	Reduction in auto miles per year	trended bus miles / year
2020	1,671,636	274,474
2021	1,699,239	277,718
2022	1,726,842	280,962
2023	1,754,445	284,205
2024	1,782,048	287,449
2025	1,809,651	290,692
2026	1,837,254	293,936
2027	1,864,857	297,180
2028	1,892,460	300,423
2029	1,920,063	303,667
2030	1,947,666	306,911
2031	1,975,268	310,154
2032	2,002,871	313,398
2033	2,030,474	316,642
2034	2,058,077	319,885
2035	2,085,680	323,129
2036	2,113,283	326,373
2037	2,140,886	329,616
2038	2,168,489	332,860
2039	2,196,092	336,104
2040	2,223,695	339,347
2041	2,251,298	342,591
2042	2,278,901	345,835
2043	2,306,504	349,078
2044	2,334,107	352,322
2045	2,361,710	355,566
2046	2,389,313	358,809
2047	2,416,916	362,053
2048	2,444,519	365,297
2049	2,472,122	368,540

1. Mileage Saved

This section describes how annual amounts of *Saved Mileage* have been estimated over the years 2020 through 2049. Since the corridor is almost exclusively used by cars and buses, the efforts of this chapter are narrowed down onto these two types of vehicles. Nevertheless different types of cars have been taken into account and a *Weighted Emission Factor* has been generated in order to calculate the most realistic result of Emission Benefits for cars.

This second section will be split up in two parts: a) Saved Car Mileage Estimation and b) Saved Bus Mileage Estimation. This separation between cars and buses will be used in part 3 describing Emission Factor.

a. Saved Car Mileage Estimation

SFCTA provided SF-CHAMP Model Runs for No-Build and Build scenarios on which this chapter is based. Mileage Data for cars from 2020 and 2040 Build-Scenarios and 2040 No-Build-Scenarios have been analyzed and used to estimate annual mileage savings. The model data includes *miles per day* estimations. In order to convert these numbers into annual mileage savings, Build miles values have been subtracted from No-Build miles values, which results in the average difference of daily auto miles from No-Build (or Base Case) scenario to Build-Case. This number was multiplied by 261, the average amount of weekdays in a year. Additionally, this number of daily auto miles has been multiplied by 104, which corresponds to the average annual weekend days and by .75, given the assumption of 25% less traffic on weekends. Since the 22 Fillmore Transit Priority Project is not expected to be finished before 2020, our estimations only include Emission Benefits from 2020 onwards. Annual mileage reduction in 2020 and 2040 are calculated, and values for years in between have been interpolated linearly. Numbers from 2040 to 2049 have been extrapolated linearly. Exhibit 10-1 shows the annual reduction of auto miles from 2020 to 2049.

The increased efficiency in transit functionality of the newly installed BRT system along 16th Street will substantially reduce travel time (over 30 percent reduction in trip time) and lead to mode shift by passengers from car to transit. This mode shift will cause the annual reduction in auto miles to rise in the long run. SF-CHAMP Model Data support this assumption. Exhibit 10-1 shows the annual reduction of auto miles from 2020 to 2049.

b. Bus Mileage Reduction

In order to generate annual mileage reduction data for buses, SFMTA compiled daily bus miles travelled in the corridor in 2015. These were multiplied by 261 weekdays per year and, in case of weekdays, 104 weekend days. The resulting number has been integrated as 2015 annual bus miles. Bus mileage reduction was trended through 2049 according to percentages of increase from year-to-year in No-Build-Scenario. These percentages were derived from an SF-CHAMP Model Run. Exhibit 10-1 shows the annual reduction of bus miles from 2020 to 2049.

2. Emission Factors

As explained within the introduction section emission factors quantify a mass amount of pollutants in relation to distance travelled. These have mainly been extracted from EPA and EMFAC and adjusted in regard to reasonable assumptions fitting 22 Fillmore Transit Priority Project.[76] [77] In the following, such assumptions are shown in greater detail. This section thus explains how emission factor values have been applied in order to satisfy specific needs and requirements of the BCA of 22 Fillmore Transit Priority Project. In this section it will be shown how auto and bus emission factors have been concluded. The first section depicts the emission factor methodology for autos, the second one describes it for buses.

a. Auto Emission Factors

Auto Emission Factors for every tenth year (with exception of the last decade; 2010, 2020, 2030, 2040 and 2049) have been extracted from the CARB version of the current VISION Model, which contains EMFAC emission factor Data. Values for missing years are estimated through a linear interpolation. Also, figures taken from the VISION Model have been highlighted in annexed Microsoft Excel files.

b. Bus Emission Factors

In order to estimate bus emission factors from 2015 through 2049, data has been gathered from USEPA and EMFAC Model for the years 2008, 2035 and 2049. EMFAC data was used for 2035 and 2049 values, while 2008 values have been extracted from USEPA reports. Values for 2008 and 2049 could be extracted and did not need any change, while 2035 emission data were only available as *metric tons per day.* In addition to that *Vehicle Miles Travelled* (VMT) were given as well, which allowed the calculation of the average daily *Grams per mile.* Exhibit 10-2 shows this calculation in greater detail.

Exhibit 10-2 Bus Emission Factors for 2035

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[76] USEPA (2008): *Average In-Use Emissions from Urban Buses and School Buses, Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks*

[77] EMFAC 2014 Database (2015): (http://www.arb.ca.gov/emfac/2014/)

Pollutant	Metrc tons/day	Grams/day	VMT/day	Grams/Mile
VOC	0.77	765,551	2,149,268	0.36
CO2	5,460	5,460,078,000		2,540
NOx	15.49	15,488,090		7.21
PM	0.34	335,380		0.16

Values from above were integrated in our estimation for the year 2035. Based on values from 2008, 2035 and 2049, figures for the missing years were linearly interpolated.

Exhibit 10-3 shows all emission factors from 2020 onwards, which is the point in time that 22 Fillmore Transit Priority Project is expected to be completed and benefits are expected to occur. These results have been integrated into the emissions reduction calculation and used as emission factors.

Exhibit 10-4 Overview of Auto and Bus Emission Factors

Year	Automobile (Grams/Mile)				Transit Buses (Grams/Mile)			
	CO2	VOC	NOx	PM	CO2	VOC	NOx	PM
2020	390	0.00036	0.00030	0.00004	2,842	0.35220	-3.09091	0.23435
2021	392	0.00036	0.00028	0.00004	2,822	0.35246	-3.37190	0.22913
2022	393	0.00035	0.00027	0.00004	2,802	0.35273	-3.65290	0.22391
2023	395	0.00034	0.00026	0.00004	2,782	0.35300	-3.93389	0.21869
2024	397	0.00033	0.00024	0.00004	2,762	0.35326	-4.21488	0.21347
2025	399	0.00032	0.00023	0.00004	2,742	0.35353	-4.49587	0.20825
2026	401	0.00032	0.00022	0.00004	2,721	0.35379	-4.77686	0.20303
2027	402	0.00031	0.00020	0.00004	2,701	0.35406	-5.05786	0.19781
2028	404	0.00030	0.00019	0.00004	2,681	0.35433	-5.33885	0.19259
2029	406	0.00029	0.00018	0.00004	2,661	0.35459	-5.61984	0.18737
2030	408	0.00028	0.00016	0.00004	2,641	0.35486	-5.90083	0.18215
2031	410	0.00028	0.00016	0.00004	2,621	0.35513	-6.18182	0.17693
2032	411	0.00028	0.00016	0.00004	2,601	0.35539	-6.46282	0.17171
2033	413	0.00028	0.00016	0.00004	2,581	0.35566	-6.74381	0.16648
2034	415	0.00028	0.00016	0.00004	2,561	0.35593	-7.02480	0.16126
2035	417	0.00028	0.00016	0.00004	2,540	0.35619	7.20622	0.15604
2036	403	0.00028	0.00015	0.00004	2,505	0.33242	6.79996	0.14546
2037	389	0.00028	0.00015	0.00004	2,470	0.30865	6.39370	0.13488
2038	375	0.00028	0.00015	0.00004	2,436	0.28488	5.98744	0.12430
2039	361	0.00028	0.00015	0.00004	2,401	0.26111	5.58118	0.11372
2040	347	0.00028	0.00012	0.00004	2,366	0.23734	5.17493	0.10314
2041	333	0.00028	0.00012	0.00004	2,331	0.21357	4.76867	0.09256
2042	319	0.00027	0.00012	0.00004	2,296	0.18980	4.36241	0.08198
2043	305	0.00027	0.00011	0.00004	2,261	0.16603	3.95615	0.07139
2044	292	0.00027	0.00011	0.00004	2,226	0.14226	3.54989	0.06081
2045	278	0.00027	0.00010	0.00004	2,191	0.11850	3.14363	0.05023
2046	264	0.00027	0.00010	0.00004	2,156	0.09473	2.73738	0.03965
2047	250	0.00027	0.00010	0.00004	2,121	0.07096	2.33112	0.02907
2048	236	0.00027	0.00009	0.00004	2,086	0.04719	1.92486	0.01849
2049	222	0.00027	0.00008	0.00004	2,051	0.02342	1.51860	0.00791

3. Emission Cost Factors

Emission Cost Factors could be entirely extracted from TIGER BCA Resource guide, with the exception of CO_2.[78] Values (*Dollar per short ton*) for VOCs, NOx, SOx and PM were given in 2013 Dollars and thus changed to 2015 Dollar values using CPI ratio. Exhibit 10-4 shows given values extracted from TIGER BCA Resource Guide and adjusted to 2015 Dollars; Dollar values don't change over time and have been implemented throughout 2020-2050. These are marked in the Exhibit below.

Exhibit 10-5 CO Emissions Factors

Calender Year	Cost factor CO2 ($ / Metric Ton)
2020	49.02
2021	49.93
2022	50.84
2023	51.76
2024	52.67
2025	53.58
2026	54.72
2027	55.86
2028	57.00
2029	58.14
2030	59.28
2031	60.19
2032	61.10
2033	62.02
2034	62.93
2035	63.84
2036	64.98
2037	66.12
2038	67.26
2039	68.40
2040	69.54
2041	70.68
2042	71.82
2043	72.96
2044	74.10
2045	75.24
2046	76.38
2047	77.52
2048	78.66
2049	79.80

Exhibit 10-4 Emissions Cost Factors

2015 Dollar Emission Costs by Types	$ / Short Ton
Volatile Organic Compounds* (VOCs)	1,849
Nitrogen Oxides (NOx)	7,290
Particular Matter (PM)	333,474

For CO_2 Emission Cost Factors, values of every fifth year from 2015 to 2050 were gathered[79] from TIGER Guidance. Above mentioned values were changed from 2007 Dollars to 2015 Dollars using a CPI exchange rate and afterwards linearly interpolated for the missing years. This is also the reason why CO_2 Emission Factors are the only ones displayed from 2015 onwards and not 2020. Exhibit 10-5 shows Emission Cost Factors from 2020 to 2050 and displays how they have been interpolated.

4. Calculation

After all factors and values mentioned in sections above had been estimated, they were integrated into an Excel spreadsheet. Emission Benefits for each pollutant have been calculated and afterwards discounted to 2015 value at both 3% and 7%. This was conducted with the exception of CO_2 Emission Benefits, which are only to be discounted at 3% according to TIGER BCA Resource Guidance. [80]

CO_2 Emission Benefit values discounted at 3% must be added to other pollutant's Emission Benefits discounted at 7%. Exhibit 10-8 on page 85 shows the results of summarized Emission Benefits. Each pollutant is shown separately. For CO_2 the chart already includes discounted values in 2015 Dollars at 3%. The sum of these CO_2 Emission Benefits has been separately added to the sum of the other pollutants Emissions.

[78] USDOT (2015): *TIGER Benefit-Cost Analysis (BCA) Resource Guide*
[79] USDOT (2013): *Technical Update of the Social Cost of Carbon of Regulatory Impact Analysis Under Executive Order 12866*
[80] USDOT (2015): *TIGER Benefit-Cost Analysis (BCA) Resource Guide*

Exhibit 10-8: Present Value of Auto and Diesel Bus Emissions Reductions

Calender Year	Total 2015 Dollar Amount						
	Present Value CO2 (3%)	VOC	NOx	PM	All Pollutants (except CO2)	Present Value (3%)	Present Value (7%)
2019	-	-	-	-	-	-	-
2020	60,545	198	25,194	23,672	49,064	42,323	34,982
2021	60,604	201	24,865	23,418	48,484	40,604	32,307
2022	60,633	203	24,521	23,153	47,876	38,928	29,815
2023	60,633	206	24,162	22,874	47,242	37,293	27,495
2024	60,604	208	23,788	22,584	46,580	35,700	25,337
2025	60,548	211	23,400	22,281	45,892	34,148	23,329
2026	60,718	213	22,997	21,965	45,176	32,636	21,463
2027	60,853	216	22,580	21,637	44,433	31,164	19,729
2028	60,955	218	22,148	21,297	43,663	29,732	18,118
2029	61,023	221	21,701	20,944	42,865	28,339	16,624
2030	61,060	223	21,240	20,578	42,041	26,985	15,238
2031	60,836	226	20,764	20,200	41,190	25,668	13,953
2032	60,591	228	20,273	19,810	40,312	24,389	12,762
2033	60,325	231	19,768	19,408	39,407	23,147	11,659
2034	60,040	233	19,249	18,993	38,475	21,941	10,639
2035	59,737	236	18,714	18,565	37,515	20,771	9,695
2036	58,297	222	17,836	17,482	35,541	19,105	8,584
2037	56,832	209	16,938	16,374	33,520	17,494	7,566
2038	55,343	195	16,018	15,240	31,453	15,937	6,635
2039	53,833	180	15,076	14,082	29,338	14,432	5,784
2040	52,305	165	14,114	12,896	27,175	12,979	5,007
2041	50,761	150	13,130	11,687	24,967	11,577	4,299
2042	49,204	135	12,125	10,452	22,713	10,225	3,655
2043	47,635	119	11,099	9,193	20,412	8,921	3,070
2044	46,059	103	10,052	7,908	18,064	7,665	2,539
2045	44,475	87	8,984	6,598	15,669	6,455	2,058
2046	42,887	71	7,895	5,262	13,227	5,291	1,624
2047	41,296	54	6,784	3,901	10,739	4,170	1,232
2048	39,705	36	5,652	2,516	8,204	3,093	880
2049	38,115	19	4,499	1,104	5,622	2,058	563
Total	**$1,646,449**	**$5,218**	**$515,567**	**$476,073**	**$996,858**	**$633,174**	**$376,639**
Add NPV CO2 @ 3% Discount						**$1,646,449.0**	
Total NPV of Reduced Emissions						**$2,279,623**	**$2,023,088**

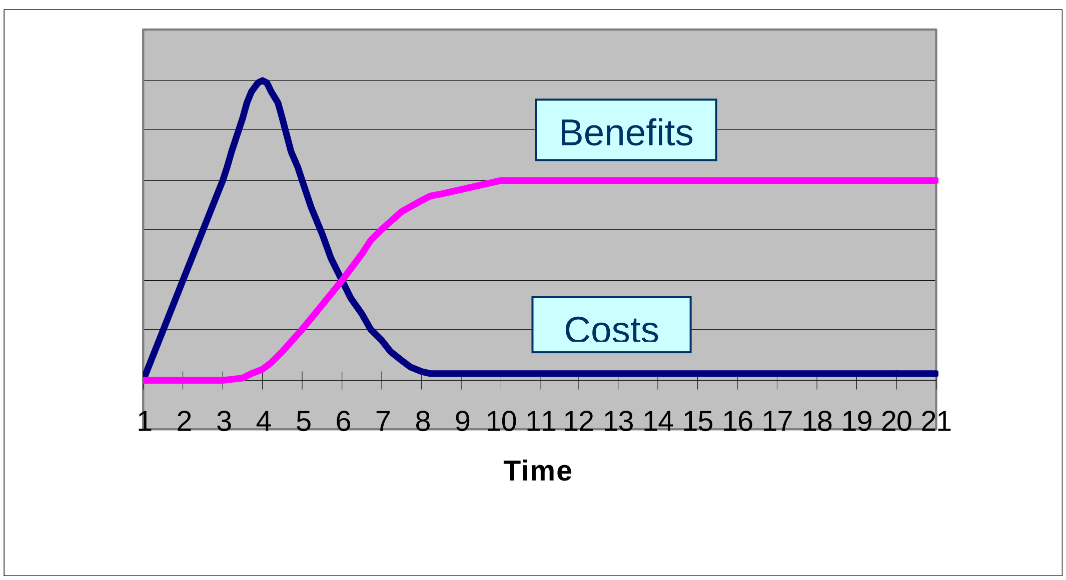
<u>Note:</u> According to "TIGER Benefit Cost Analysis Resource Guide", CO2 is only to be discounted to present value at 3% discount rate. Thus CO2 Present Value (3%) have been added to Total Present Value (3%) *and* Total Present Value (7%).

CHAPTER 11: BENEFIT-COST RESULTS

A Benefit-Cost Analysis (BCA) quantifies the benefits and costs of a particular project to determine whether an investment is justifiable. In order to be meaningful, a BCA must not only express all benefits and costs in monetary terms, it must also account for the change in value of the dollar over time. The value of a dollar changes not only with inflation, but also because today's dollar is worth more than a dollar available years from now. For example, a single dollar available today would be worth more than one single dollar in five years because it could be invested and earn interest for five years. An economic concept called "net present value", accounts for the impact of time on the value of money and discounts the future value of a dollar.

This concept of net present value is important because the timing of costs and benefits are different. The project sponsor experiences costs both immediately and over time, while benefits accrue over time after the project sponsor has incurred the costs. Exhibit 11-1 provides a sample of typical project benefit and cost flows. Costs, as considered by an engineer for example, inflate over time to reflect generally accepted increases in the costs for goods and services. This provides an estimate of the cash that is going to be necessary to complete a project. However, benefits, as considered in economics, discount as they move into the future. Net present value provides the common ground against which the analysis can consider costs and benefits.

Exhibit 11-1: Sample Project Costs and Benefit Streams



For this study, the analysis assumes a 30-year benefit horizon starting after project completion in 2020. These types of projects typically provide a stream of benefits that last at least 20 years. The timeframe for analysis of the benefits and costs must therefore extend well into the future to measure project benefits accurately.

The benefit-cost ratio is the net present value of benefits divided by the net present value of costs. A benefit to cost ratio of over one indicates that benefits probably exceed costs and that the investment is promising. A ratio under one indicates that benefits are probably less than costs and that the project sponsor should consider further study or innovative strategies to justify the project.

Exhibit 11-2 summarizes the benefits of each of the seven benefit categories in discounted present value dollars using a 3 percent discount rate. The largest category of benefits is the prevention of accidents at $227.4 million. The analysis estimates that travel time savings are the second largest category of benefits at $139.6 million.

Exhibit 11-2: Benefits by Category Using a 3 Percent Discount Rate

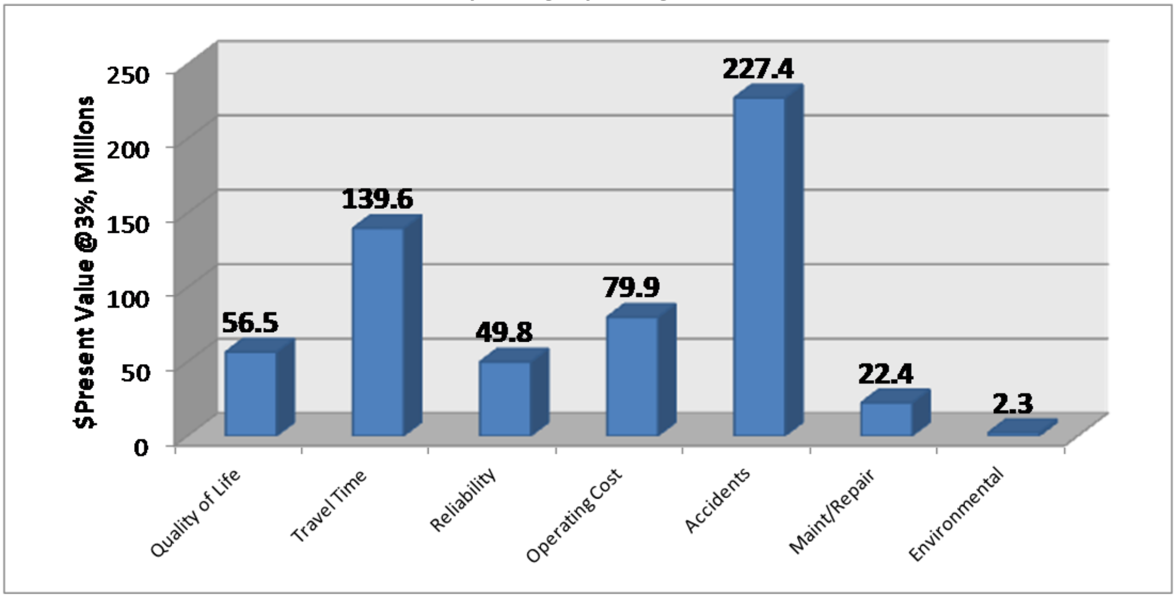


Exhibit 11-3 summarizes the benefits of each of the seven benefit categories in discounted present value dollars using a 7 percent discount rate. The largest category of benefits is still accident prevention followed by travel time. The use of a higher discount rate does not change the relative value of the various benefit categories with the exception of quality of life which is a one-time benefit accruing to the owners of the property near the revitalized corridor.

Exhibit 11-3: Benefits by Category Using a 7 Percent Discount Rate

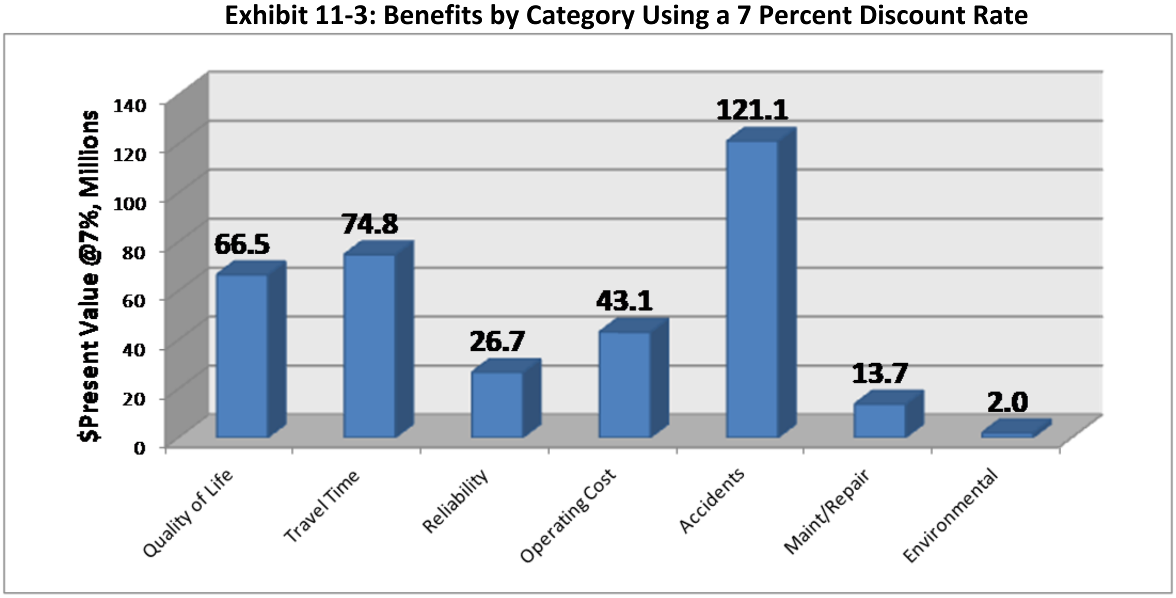


Exhibit 11-4 summarizes the benefits and costs of the project in discounted present value dollars using a 3 percent discount rate. The cost borne by the SFMTA is equal to $68.3 million in discounted present value dollars at 3 percent and $57.3 million in discounted present value dollars at 7 percent. In contrast, the analysis calculates that the project will create $577.9 in benefits assuming a 3 percent discount rate and $348.0 in benefits assuming a 7 percent discount rate.

Exhibit 11-4: Benefits and Costs of the Project Using 3 and 7 Percent Discount Rates

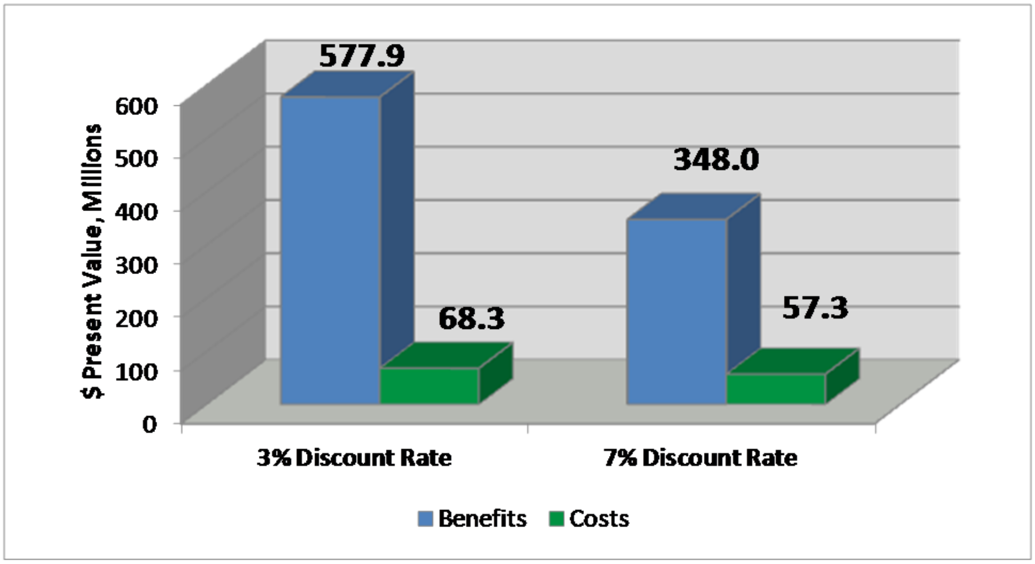
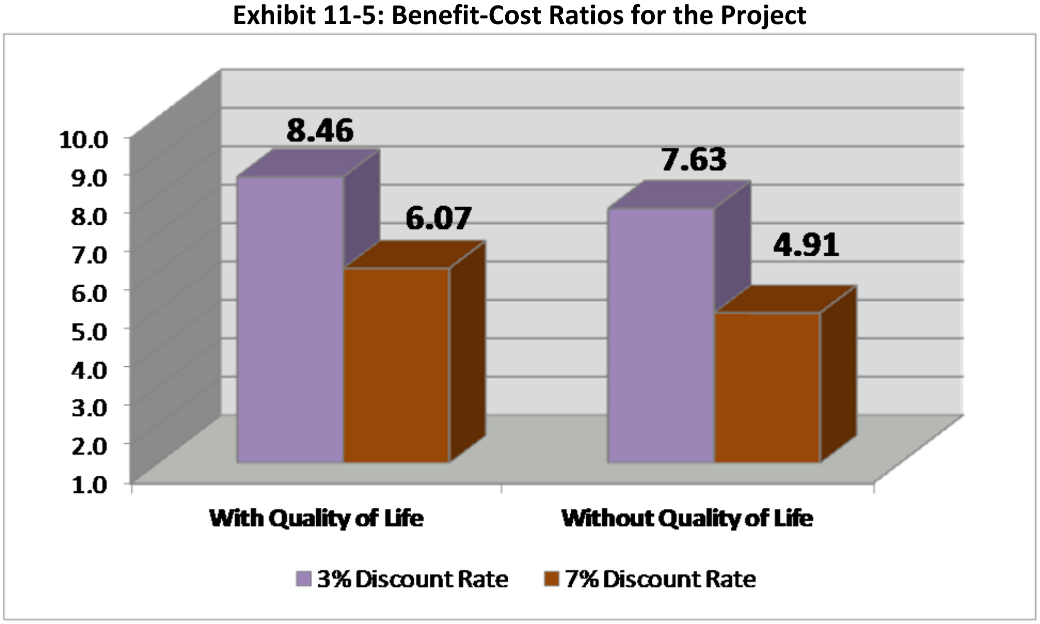


Exhibit 11-5 compares the benefits and costs using benefit-cost ratios, or the net present value of the benefits divided by the net present value of costs. According to this analysis, the benefit-cost ratios are far greater than one, indicating that this project presents a desirable investment. The benefits outweigh costs by a ratio of 8.46 at a 3 percent discount rate and by a ratio of 6.07 at a 7 percent discount rate

Exhibit 11-5: Benefit-Cost Ratios for the Project



The estimation of quality of life benefits, as reflected in an increase in property values is the most difficult to measure benefit and the analysis approaches the estimates of this benefit with caution. Therefore, Exhibit 11-5 also provides the benefit-cost ratios omitting this benefit for reference. Even without factoring in the Quality of Life benefit, the project's benefits outweigh costs by a ratio of 7.63 at a 3 percent discount rate and by a ratio of 4.91 at a 7 percent discount rate.

It is the conclusion of this study that the benefits of the Project outweigh the costs and that the project provides a promising investment of public funds.