Economic Evaluation: I-10 Broadway Curve Reconstruction and Expansion

Submitted To: Maricopa Association of Governments (MAG)
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Table of Contents

1. Executive Summary

The I-10 Broadway Curve Project consists of a $663 million investment over five years to reconstruct, expand, and improve sections of I-10 from I-17 and State Route 202/Santan Freeway. Using the Maricopa Association of Governments' (MAG) VIA Toolkit, the analysis found the net benefits of the project exceed the implementation and long-term maintenance costs of the project. The benefit-cost analysis (BCA) performed with the VIA Toolkit produced a benefit cost ratio of 3.1 using a three percent discount rate.[1] Total undiscounted benefits for the project over its entire life cycle are $2.9 billion or $1.7 billion discounted at three percent. The project will also provide the following economic impacts to the region due to construction and the improved travel efficiencies that will reduce costs and improve competitiveness for local businesses through 2050:

- produce $1.4 billion in Gross Regional Product (GRP)
- increase local business sales by $2.7 billion
- generate $945 million in net new local income

Once the I-10 Broadway Curve is operational, these access and speed improvements will generate 250 net new long-term jobs for the region.[2] The detailed benefit-cost analysis and economic impact results and methodology are described in the following sections.

Project Background

The I-10 Broadway Curve project is planned to improve Interstate 10 (I-10) between Interstate 17 (I-17) and State Route 202/Santan Freeway. The project encompasses one of the most heavily traveled segments of freeway in the Valley. I-10 is a vital connector to I-17, State Route 143, US-60, and State Route 202. The I-10 Broadway Curve project will address state-of-good repair objectives along the corridor and represents the region's first major freeway reconstruction project within the urban core.

The project will:

- Add general purpose and high occupancy vehicle lanes
- reconstruct the I-10/State Route 143 interchange
- improve the I-10/US-60 interchange
- construct the region's first collector-distributor system

The economic and benefit-cost analyses were performed using MAG's VIA Toolkit to assess and communicate the value and benefit of the I-10 Broadway Curve project.[3] Map 1 below shows the project area.

[1] The benefit-cost ratio at a seven percent discount rate is 1.7

[2] Average of operational years 2025 through 2050

[3] VIA Toolkit is being developed through the Sun Corridor Value Impact Analysis (SCVIA) grant project. This analysis does not factor in any real estate impacts or other land use changes. The VIA Toolkit is based on the TREDIS model.

Map 1: I-10 Broadway Curve Study Area

Source: ADOT, “Interstate 10: Broadway Curve Environmental Study Factsheet” February 2020

Analysis Approach

This report describes both the results of the benefit cost analysis (BCA) and economic impact analysis (EIA) of the I-10 Broadway Curve Project. BCA quantifies and monetizes benefits and costs over the expected lifespan of the project. Benefits quantified include direct user benefits, such as time savings and safety, and benefits to society, such as, reduced vehicle emissions. Costs include construction, design, maintenance and operation costs. The analysis uses input data on travel patterns, safety, and costs from MAG and ADOT.

The EIA quantifies the impacts of the short-term construction activity, on-going maintenance, and efficiency improvements to local business from improved access, faster travel times, and reduced delay. The EIA captures the multiplier effects of spending in terms of direct, indirect (supplier effect), and induced (income effects). These impacts are estimated using the same project cost data used in the BCA and travel data. Table 1 summarizes the proposed project and the main sources of benefits and impacts.

Table 1: Project Benefits Summary

Analysis Method	Baseline & Problem to be Addressed	Change to Baseline/Alternatives	Benefits/Impacts
BCA	• Approaching end of useful life • State of good repair requirements	• Construction and repaving of I-10 Broadway Curve	• Reduced crash rates • Travel time savings from increased speeds • Vehicle operating cost savings from reduced VMT
EIA	• Changes in maintenance spending due to capital investment	• Construction and repaving of I-10 Broadway Curve • Capital Spending	• Travel time savings from increased speeds • Vehicle operating cost savings from reduced VMT

Summary of Benefits and Costs

The BCA identified reduced travel time and improved travel time reliability as the most significant sources of monetized benefits. Other important but less significant monetized benefits include safety improvements and reduced freight and logistics costs. Table 2 summarizes the benefits by category showing the undiscounted values, and values discounted at a three and seven percent discount rate.[4] Discounting accounts for the "time value of money," where the benefits and costs that occur sooner are considered more valuable than benefits and costs that occur further in the future. The sources of each benefit category are described in more detail in section 3 of this report.

Table 2: Summary of Benefits

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Business Time and Reliability Costs	$1,596	$914	$480
Value of Personal Time and Reliability	$1,482	$906	$514
Logistics/Freight Costs	$171	$100	$54
Vehicle Operating Costs	-$783	-$467	-$258
Safety	$469	$248	$115
Environmental[5]	n/a	n/a	n/a
Total Benefits	$2,935	$1,701	$905

Table 3 shows the estimated costs, including capital, operations and maintenance, and residual costs for the reconstruction of the I-10 Broadway Curve and interchange enhancements. With the reconstruction of the I-10 Broadway Curve, there will be a marginal operations and maintenance cost savings of $57 million. The Estimation of Benefits and Costs section outlines the cost assumptions.

[4] , The 2020 U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs (U.S. DOT BCA Guidance) requires a 7% discount rate for projects seeking Federal Grants

[5] The VIA Tool Kit and TREDIS can estimate the environmental benefits using national level parameters. Since MAG has more sophisticated localized modeling available, the environmental benefits were excluded. If included, the default environmental analysis was negligible, impacting the benefit cost by less than 0.1.

Table 3: Summary of Costs

Costs	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Capital Investment Costs	$663	$622	$574
Operation and Maintenance Costs	($57)	($46)	($35)
Residudal Costs[6]	($82)	($34)	($11)
Total Costs	$525	$542	$528

Table 4 presents the benefit-cost ratio, which consists of discounted benefits divided by the total discounted costs, at both three and seven percent discount rates.

Table 4: Benefit-Cost Ratio

	3% discount rate	7% discount rate
Benefit-Cost Ratio	3.1	1.7

Summary of Economic Impacts

All economic impacts in this study are described using the measures of jobs, income, value added, and output, defined as follows:

- **Jobs** includes both part- and full-time positions.
- **Income** includes total compensation for work, including gross wages, salaries, proprietor income, employer provided benefits and taxes paid to governments on behalf of employees.
- **Value Added** consists of compensation of employees, taxes paid on production and imports, and gross operating surplus. It equals the difference between an industry's gross business output and the cost of purchased goods and services. Value added for companies across industries and across the U.S. is a measure of Gross Domestic Product (GDP).
- **Business Sales**, also known as output or business revenue, is equivalent to value added plus the cost of purchased goods and services.

[6] The useful life of a facility describes the number of years after which a facility is considered to be obsolete and in need of replacement. TREDIS uses information on the useful life of project investment categories to determine the residual value of those investments at the end of the analysis period. At the completion of construction, investments begin depreciating at a rate tied to the useful life factor.

Table 5 shows the total economic impacts by period, including the construction phase and period after construction when the travel efficiencies will be realized by households and businesses. Because VIA and TREDIS produce "job-year" estimates, the job results are shown as average annuals.

Table 5: Economic impacts by major category

Impact	Jobs*	Income	GRP	Business Sales
Construction (2020-2025)	1,402	$446	$658	$1,238
2025 – 2030	130	$37	$49	$92
2030 – 2040	230	$164	$228	$447
2040 – 2050	313	$296	$425	$888
Total Economic Impact	**n/a**	**$943**	**$1,360**	**$2,665**

**Note: Jobs represent average annual estimates for each period.*

2. Detailed Economic Impacts

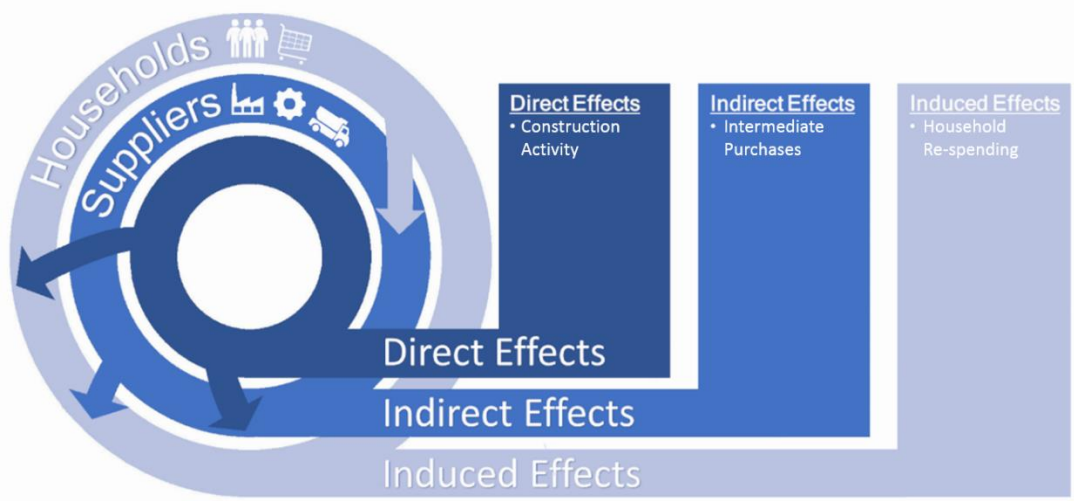
Economic Impact Methodology

The VIA Toolkit and TREDIS calculate the economic impacts for both the construction phase and operations phase of transportation projects. The underlying economic impacts are derived from the initial capital cost expenditures phase, long-term operations and maintenance, and the long-term transportation efficiencies due to freight logistics improvements. The results presented here are the total economic impacts, which are comprised of direct, indirect and induced impacts:

- **Direct** impacts represent the initial economic activity and transactions that are supported by the construction and operations and maintenance activity of the I-10 Broadway Curve Improvements. These direct impacts in turn stimulate additional demand for local goods and services due to indirect and induced effects—sometimes called "multiplier" or "spinoff" effects.
- **Indirect** impacts represent the additional economic activity associated with business-to-business purchase of goods and services, or supplier impacts. In this case, construction companies purchasing steel and concrete from local suppliers. Each supplier has a portion of its revenue supported by this project and will also use that revenue to pay workers as well as their own supply chain.
- **Induced** impacts are the additional household spending from worker income on items such housing, retail purchases, and services. Those expenditures support jobs in associated industries, whose workers then spend their salaries in Maricopa County.

These economic impacts represent the "total impact" inclusive of all multiplier effects: direct, indirect, and induced, as shown in Figure 1.

Figure 1: Components of Total Economic Impacts Due to the I-10 Broadway Curve improvements

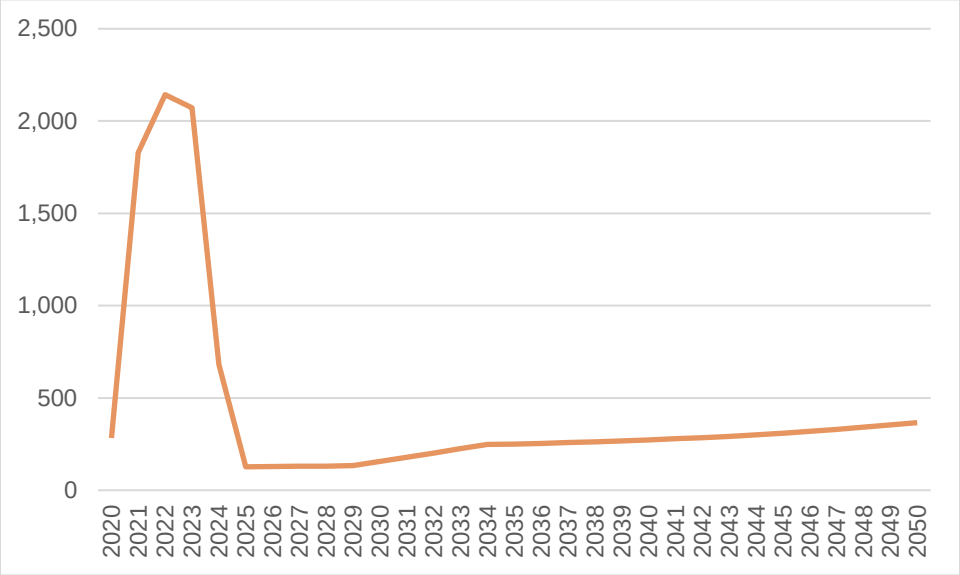


The total economic impacts for the construction and operations phase of the I-10 Broadway Curve project are presented below in terms of jobs, GRP, income and output. Unlike BCA, the dollar concepts in an economic impact analysis are not discounted, and all dollar concepts for the economic impact analysis are in fixed 2020 dollars. The following subsections provide additional detail for each impact category.

Jobs

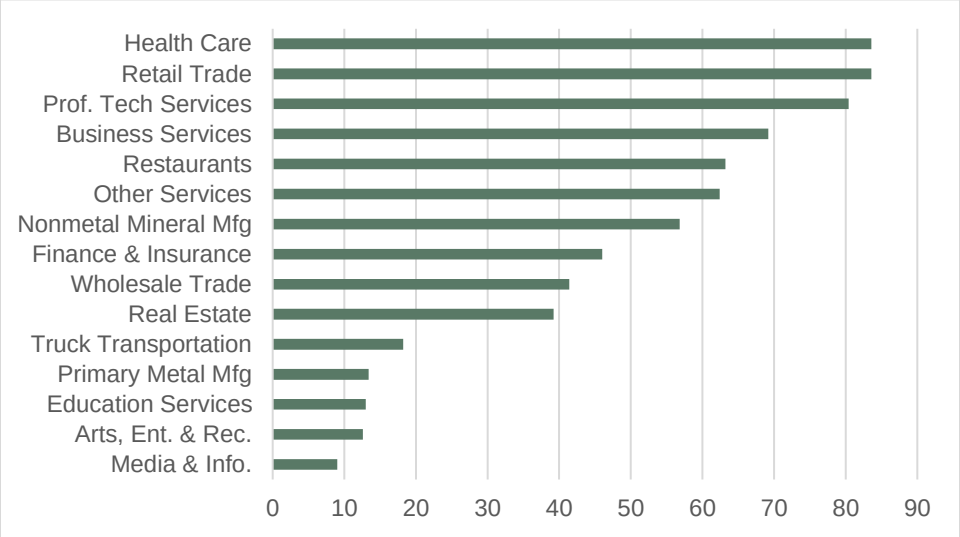
The job estimates include both part- and full-time positions. During the construction phase, it is estimated that there will be an average of 1,400 net new construction jobs from 2020 through 2025. Following the construction phase, there will be an annual average of 250 net new jobs created (versus the no-build scenario) from the long-term operations and maintenance expenditures, additional household expenditures due to new income to the region, increased sales from local suppliers, and the transportation efficiencies that provide local businesses with improved access and reduced costs.

Figure 2: Total Jobs by year



The top 15 industries in terms of business sales during the construction phase (excluding construction) are presented in Figure 3. The top five during this period are sectors that are more heavily weighted towards the income effects from the growth in household expenditures. These sectors are primarily related to personal services including retail, health care, and restaurants. Growth in wholesale trade, warehousing, and nonmetal mineral manufacturing will be a result of direct construction expenditures and the local supply chain supporting the I-10 Broadway Curve project.

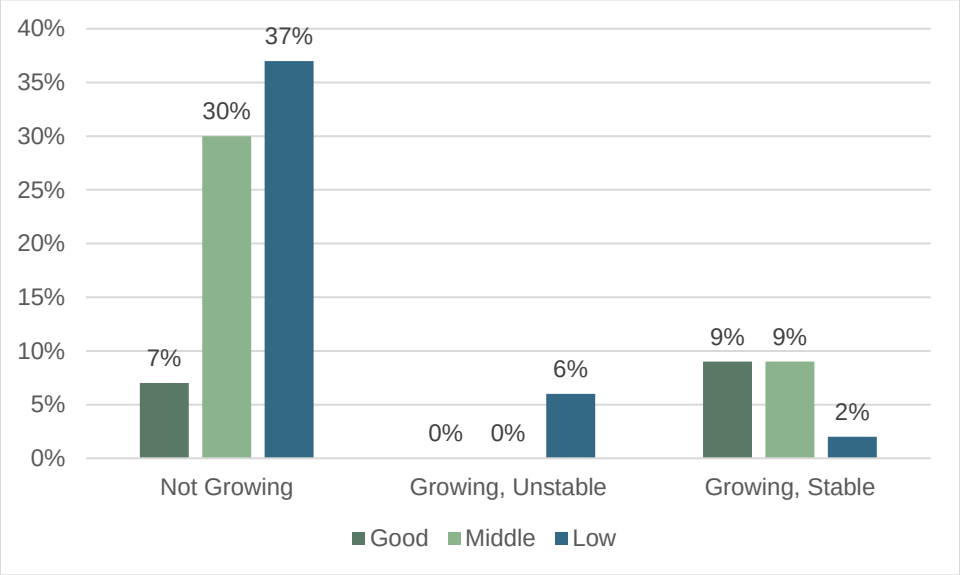
Figure 3: Construction Phase Top 15 Industries by Average Job Growth (Excluding Construction)



As part of the VIA Toolkit development, the team implemented the Quality Jobs analysis for the I-10 Broadway Curve analysis. The Quality Jobs methodology starts with occupation data to create a comprehensive national list of "quality job" rankings, correcting for any regional wage and education and skill requirement premiums. The approach determines the quality of jobs based the following dimensions: estimated future job growth, future openings, and wage levels.[7] As shown in Figure 4, the Quality Jobs analysis found that 18 percent of the long-term jobs created from the project are either middle to good income jobs that are forecasted to remain stable with positive growth. Another 37% were middle to good income jobs that are not growing. The largest category, however, was low paying jobs in sectors with little to no projected growth. These were primarily low wage jobs in retail, restaurants, and private education services.

[7] The complete methodology: EBP Memoranda, "Quality Jobs Analysis and Methodology for TREDIS / VIA" April 2020

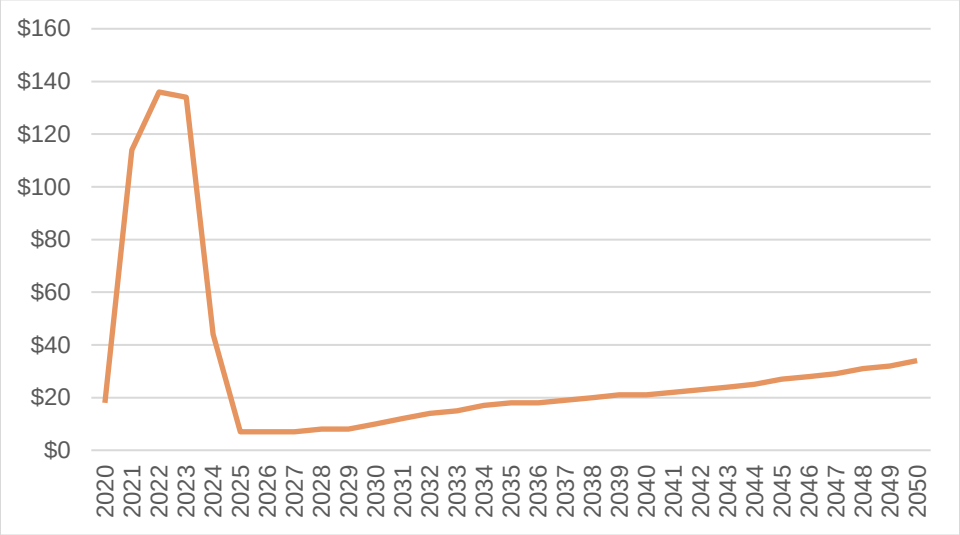
Figure 4: Quality Jobs



Incomes

Income covers total compensation for work, including gross wages, salaries, proprietor income, employer provided benefits, and taxes paid to governments on behalf of employees. As shown in Figure 5, the income impacts follow the same trends as job growth and business sales. Total income during the construction phase is estimated to be $446 million, of which the construction industry represents 47 percent, with the remainder being income created from suppliers and new household expenditures. This means that the construction activity will double the circulation of new income to the region during the construction phase. The long-term income impact represents 53 percent of the total project related income generation over the thirty years, and therefore the transportation impacts provide more economic growth for the region than the initial construction activity itself.

Figure 5: Total Income by Year in Millions of Dollars



Gross Regional Product (GRP) and Output

Gross Regional Product (GRP), or "value added," consists of compensation of employees, taxes paid on production and imports, and gross operating surplus. On the other hand, business sales, or "output," is a measure of gross business sales and incorporates the value of intermediate goods and services used in production, resulting in a higher measure than GRP. As shown in Table 6, the construction phase of the I-10 Broadway Curve, which includes engineering and design, creates $658 million in net new economic activity for Maricopa County. The analysis projects that local business sales will grow by $1.2 billion from 2020 through 2025.

Table 6: GRP and Business Sales by Impact Period in Millions of Dollars

Impact Period	GRP	Business Sales
Construction (2020-2025)	$658	$1,238
2025 – 2030	$49	$92
2030 – 2040	$228	$447
2040 – 2050	$425	$888
Total Economic Impact	**$1,360**	**$2,665**

The initial capital investment of $663 million during the construction phase results in $1.2 billion in net new sales for the county, representing a multiplier effect of 1.8. It is estimated that just over $500 million of the construction activity will be met by local firms. Additional economic

activity during construction phase will come from suppliers and additional household expenditures due to the increase of income flowing through the region. Figure 6 presents the top 15 industries, excluding construction, in terms of business sales during the construction phase.

Figure 6: Construction Phase Top 15 Industries by Business Sales Growth (Excluding Construction)

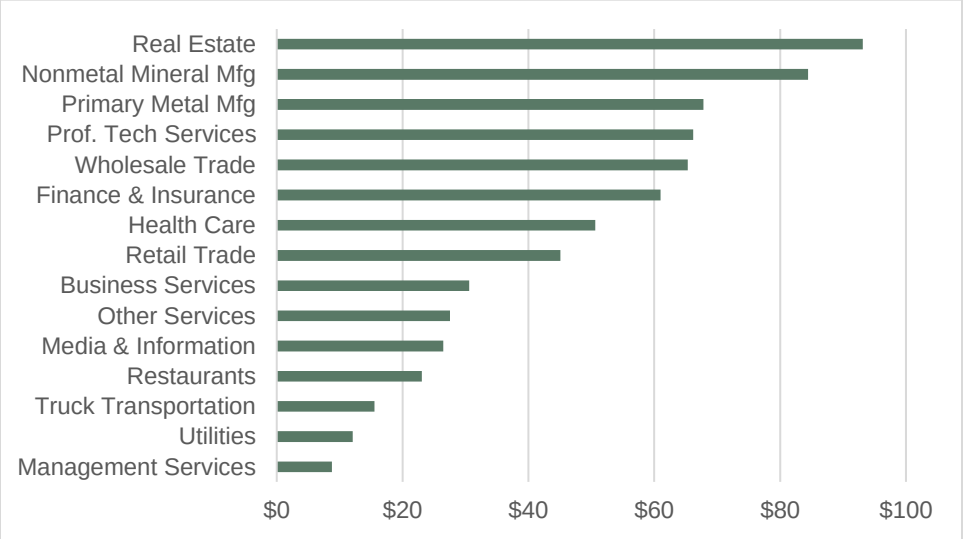
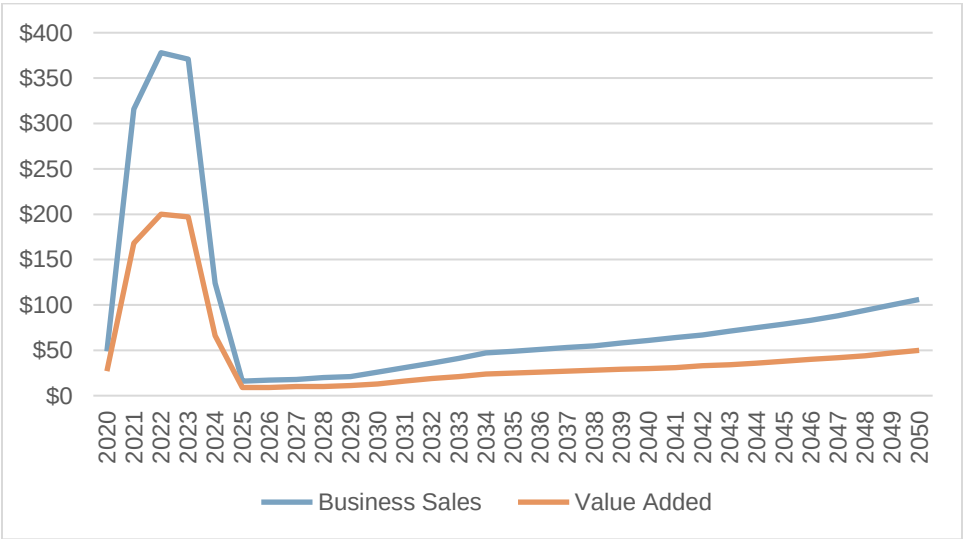


Figure 7 shows the initial surge of economic activity in 2020 through 2025 due to the $663 million construction investment. Following the reconstruction and expansion of the I-10 Broadway Curve, the time savings and roadway efficiencies continue to grow through 2050. During the period from 2025 through 2050, the average annual growth in local business sales in Maricopa County is $55 million. The top five industries growing as a result of these new efficiencies and net new income to the region are other services (maintenance and personal services), nonmetal mineral manufacturing, retail trade, finance and insurance, and wholesale trade.

Figure 7: GRP and Business Sales by Year in Millions of Dollars



3. Estimation of Benefits and Costs

Project Costs

Costs associated with the I-10 Broadway Curve Improvements include capital, operations, and maintenance.

- Capital costs, provided by MAG, include design, property acquisition, and roadway construction, and are incurred over the period of 2020 through 2025.
- For this analysis, operations and maintenance costs were modeled as the incremental change from the no-build, where, without this project, this segment of I-10 would have similar annual operations and maintenance costs.[8] The incremental operations and maintenance costs were focused on the five new lane miles (140 existing vs 145 proposed lane miles), and the operations and maintenance costs would phase in 20% each year for the first five years, since the roadway surface would be new. MAG provided the per lane mile operations and maintenance costs of $64,830.

It is assumed the I-10 Broadway Curve will have a useful life exceeding 25 years. Therefore, the residual cost calculation captures and monetizes the longer useful life exceeding the analysis period. The major costs are reported in Table 7 as undiscounted dollars and at three and seven percent discount rates.

Table 7: Summary of Costs (in millions)

Costs	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Capital Investment Costs	$663	$622	$574
Operation and Maintenance Costs	($57)	($46)	($35)
Residudal Costs[9]	($82)	($34)	($11)
Total Costs	$525	$542	$528

[8] At some point, annual operations and maintenance costs would increase, and require more substantive maintenance as the interstate reached the end of its useful life.

[9] The useful life of a facility describes the number of years after which a facility is considered to be obsolete and in need of replacement. TREDIS uses information on the useful life of project investment categories to determine the residual value of those investments at the end of the analysis period. At the completion of construction, investments begin depreciating at a rate tied to the useful life factor.

Travel Time and Reliability Savings

Travel time and reliability savings are calculated based on changes in Vehicle Hours Traveled (VHT) between the base and project scenarios, as projected by the MAG regional travel demand model. Over the 25-year analysis period, road users are projected to experience an average annual time savings of 2.5 million hours due to speed improvements and capacity enhancements. **Table 7**Table 8 shows the total and average annual VHT savings over the analysis period by mode.

Table 8: Vehicle Hours Traveled Savings in Millions, 2025-2050

	Business & Light Commercial Vehicles	Passenger Car - Personal & Commute	Truck - Tractor Trailer	Truck - Medium Duty	Passenger Car HOV - Personal & Commute	Total
Total VHT Savings	8.3	-47.0	-4.5	-9.3	-8.5	-61.0
Average Annual VHT Savings	0.3	-1.9	-0.2	-0.4	-0.3	-2.4

As shown in Table 9 and Table **10**, these projections are converted to monetary values based on per-hour value of time factors, and vehicle occupancies for each mode-purpose combination. The value of business-related travel time includes wages and benefits, and for truck drivers is estimated based on costs by industry sector. Commuter time is attributable to the value of wages only. Personal time is valued at half of the average wage rate. The car-business value of time and occupancy assumptions were applied for the commercial vehicle mode.

Table 9: Value of Time by Mode and Purpose

Mode/Purpose	Value (2020 $ per person-hour)[10]
Truck – Tractor Trailer	$32.97
Truck - Light / Medium	$25.30
Car – Business	$37.10
Car – Personal	$12.74
Car – Commute	$25.47

[10] 2020 U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 31.

Table 10: Crew, Passenger, and Freight Vehicle Loading Factors

Mode/Purpose	Passenger/ Crew per Vehicle[11]	Passenger HOV*	US Freight Tons Per Vehicle[12]
Truck – Tractor Trailer	1	n/a	17.5
Truck – Light / Medium Duty	1	n/a	4.15
Car – Business*	1.0	n/a	0
Car – Personal*	1.45	2.13	0
Car – Commute*	1.1	2.28	0

**Note: Provided by MAG's travel model.*

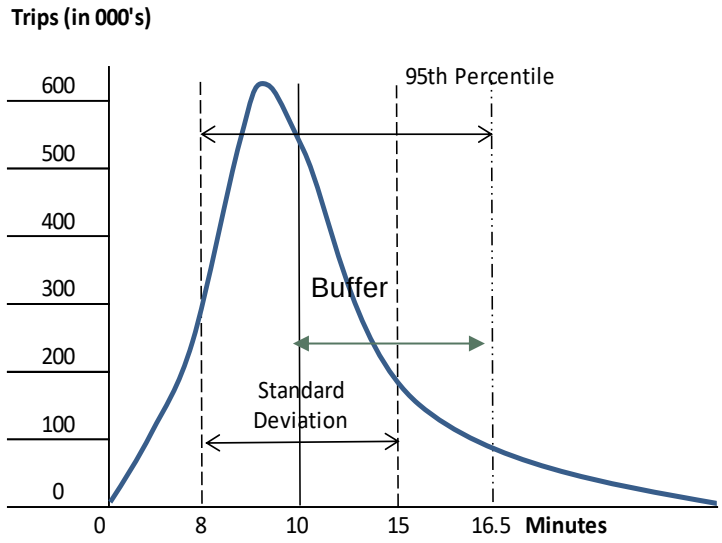
In addition to travel time and reliability savings for people and businesses, reduction in truck VHT produces savings in logistics and freight costs, defined as the cost born by shippers and receivers of freight associated with opportunity cost of freight in transit (e.g., inventory and safety stock costs), as well as the time savings related to faster, more reliable deliveries. The value of time savings for freight commodity shipments are calculated using per ton-hour cost factors using a customized regional commodity profile based on the FHWA Freight Analysis Framework (FAF). This cost measures the value of recurring delay to shippers and receivers of freight based on commodity specific factors such as spoilage, just-in-time supply chain importance, and warehouse and facility worker time.

This analysis also factored in time spent dealing with unreliable trips. Reliability is measured in terms of the buffer time, which is the amount of extra time above the average travel time that must be added to the average travel time for a trip to arrive on time 95 percent of the time. Figure 8 presents a stylized depiction of how buffer time is calculated for a trip with an average travel time of 10 minutes. If only accounting for uncongested travel time and average delay, a traveler will only arrive on time 50 percent of the time. If a system is relatively reliable a traveler will only need to leave a few minutes early, but if travel times fluctuate significantly buffer time could be a significant portion of average travel time. We value buffer time at the same rate as travel time except for freight. For trucks, the value of travel time reliability includes both driver and vehicle time, as well as the inventory value of freight for shippers and receivers of goods by commodity type and whether the goods being transported are inputs or outputs from affected industry sectors.

[11] 2020 U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 32.

[12] 2002 Vehicle Travel Information System (VTRIS) average estimates of truck share and mean gross vehicle weight for straight trucks and tractor + single trailer trucks nationally, as summarized in FAF2 Freight Traffic Analysis. Chapter 3: Development of Truck Payload Equivalency Factors. Table 3.1: Results of Vehicle Weight Validation. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c3_payload.htm

Figure 8: Buffer Time to Ensure 95% On-time Arrival



Source: EBP-US

Overall, as shown in Table 11, undiscounted time-related benefits (personal, business, reliability, and freight) are valued at more than $3.2 billion for the analysis period, or $1.9 billion discounted at three percent.

Table 11: Value of Time & Reliability Savings in Millions, 2025-2050

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Business Time and Reliability Costs	$1,596	$914	$480
Value of Personal Time and Reliability	$1,482	$906	$514
Logistics/Freight Costs	$171	$100	$54
Total Time-Related Benefits	**$3,249**	**$1,920**	**$1,048**

Vehicle Operating Cost Savings

The regional travel demand model estimates an 0.25% increase in vehicle miles traveled (VMT) as a result of the project, leading to a slight increase in costs to users in the form of vehicle operating costs. Over the analysis period, improvements to the I-10 Broadway Curve will

increase VMT by 3.8 billion, or an average of 151 million more miles driven each year. Most of the increased VMT accrue to personal vehicle travelers followed by business and light duty commercial vehicles.

Table 12: Increases in Vehicle Miles Traveled in Millions, 2025-2050

	Business & Light Commercial Vehicles	Passenger Car - Personal & Commute	Truck - Tractor Trailer	Truck - Medium Duty	Passenger Car HOV - Personal & Commute	Total
Total VMT	1,461	1,853	31	134	299	**3,777**
Average Annual VMT	58.5	74.1	1.2	5.3	11.9	**151.1**

The increase in VMT for this project makes economic sense as the I-10 Broadway Curve users will realize an increase in travel efficiency and speeds on this segment of I-10 resulting in more miles driven. The additional VMT over the no-build will result in an increase in costs from more expenditures on fuel and maintenance and repair of private vehicles.

The per-mile operating costs for cars and trucks are shown in Table 13. Fuel costs and per-mile operating costs are estimated separately (as speed and congestion effects fuel consumption) and aggregated together for the results.

The fuel consumption forecast by mode was updated using the Energy Information Administration's (EIA) "Annual Energy Outlook 2020." TREDIS interpolates the fuel consumption between the 2025 and 2040 forecast years, and while the point estimates for each mode are important the growth rate and change overtime are crucial since this analysis uses the same fuel consumption parameters for the no-build and build scenario. The forecast suggests an annual increase of fleetwide fuel efficiency gains of 1.4 percent for cars, 0.6 percent for light duty trucks and 1.1 percent for tractor trailers.

Gasoline and diesel fuel prices are a snapshot of data available from the Automobile Association of America (AAA) in the United States. All U.S. fuel prices include federal and state taxes and are assigned to the modes by the states used in the study region definition in TREDIS. Default tax rates do not include local or county taxes or other non-standard sources. They are based on data from the U.S. Energy Information Administration, updated as of January 2020, with fuel prices of $2.64 per gallon for gasoline and $3.08 per gallon for diesel.

Table 13: Per-Mile Vehicle Operating Costs and Fuel Consumption[13]

Mode	Value (2020 $ per mile)[14]	Free Flow Fuel Consumption 2025 - Gallons Per Mile	Free Flow Fuel Consumption 2040 - Gallons Per Mile
All Cars	$0.17	0.04	0.03
Business & Light Duty Commercial	$0.17	0.07	0.06
Truck - Medium Duty	$0.32	0.13	0.11
Truck - Tractor Trailer	$0.59	0.04	0.03

In total, discounted vehicle operating costs increased by $467 million due to the increase in VMT for all modes.

Table 14: Savings in Vehicle Operating Costs in Millions of Dollars, 2025-2050

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Vehicle Operating Costs (incl fuel)	-$783	-$467	-$258

Safety Benefits

Safety benefits consist of monetized savings associated with reductions in the number of crashes occurring each year. These safety benefits were assessed based on analysis of the Arizona Department of Transportation's (ADOT) existing conditions analysis and future years were modeled based on the expected crash rates for the improved facility.[15] With MAG's assistance the project team assembled other related information from engineering design reports that estimated the build and no-build safety effects along a similar future horizon in order to estimate safety effects from the proposed project. Those design reports explicitly included many sections of the I-10 project in question, and the project team matched similar designs described in the reports to fill in information about any missing sections. Where multiple future build scenarios were available, the average was selected for the benefit-cost analysis. The

[13] Fuel Consumption from EIA "Annual Energy Outlook 2020" Table 7

[14] Sources: For passenger cars, the AAA's 2018 Your Driving Cost, combining an average of SUVs, minivans, and small, medium and large cars; For trucks, American Trucking Research Institute's (ATRI) 2018 Operational Costs of Trucking report. Costs include truck and trailer leases and purchase payments, repair and maintenance, insurance, permits and licenses, and tires. Costs for labor, fuel and tolls are included separately. US DOT Guidance recommends these sources. Other sources like Federal GSA rate only cover business travel for government owned vehicles and personal vehicles for "on the clock travel".

[15] Memo: US 219 Corridor Study, Garrett County, 2045 No Build and 2045 Build Safety Analysis. MDOT SHA, 2020.

matching build and no-build crash rates by severity were applied to the existing conditions assessment to estimate future crashes in the different scenarios. Because of the improved geometry of the new alignment, crash rates for all types are expected to be lower on the improved segment.

Table 15 shows the estimated number of crashes expected under the build and no-build scenario by severity based on the safety analysis for the I-10 Broadway Curve. The crash rates and therefore the number of crashes are estimated to decline despite the rise in VMT and speeds under the build scenario.

Table 15: Projected 2040 Crashes for Build and No-Build Scenarios

	Estimated Total Crashes			
	Fatal (K)/ Incapacitating (A)	Non-Incapacitating (B)	Possible Injury (C)	Property Damage Only (O)
No-Build	3	23	227	286
Build	2	20	182	233

As shown in Table 16, reduction in total expected crashes are translated into monetary savings using the crash valuation factors from 2020 U.S. DOT BCA Guidance.

Table 16: Monetized Value per Crash by KABCO Level[16]

KABCO Level	Monetized Value per Crash ($2020)
K	$9,991,332
A	$477,815
B	$130,095
C	$66,505
O	$3,330

Table 17 presents the discounted safety benefits, which are projected to total over $248 million at three percent.

Table 17: Value of Safety Benefits in Millions of Dollars, 2025-2050

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Safety	$469	$248	$115

[16] U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs 2020. Guidance provides values in 2018 dollars, which were converted to 2020 dollars.

Environmental Sustainability

Environmental sustainability benefits in TREDIS are derived from reductions in emissions, including volatile organic compounds (VOC), nitrogen oxides (NOx), sulfur dioxide (SOx), and particulate matter (PM), that occur because of reduced vehicle operations. Emissions generated on a per mile basis are calculated by TREDIS using information from the U.S. EPA Office of Transportation and Air Quality as shown in Table 18. Emissions values (Table 19) are based on per-ton valuations for type of emissions as outlined in the 2020 U.S. DOT BCA Guidance.

Table 18: Emissions Generated on a Per Mile Basis[17]

	10^{-6} U.S. Short Tons per VMT			
Mode	**VOCs**	**NOx**	**SOx**	**PM**
Passenger Car	0.140	0.219	0.002	0.010
Truck - Medium Duty	0.175	1.646	0.009	0.077
Truck – Tractor Trailer	0.480	5.836	0.016	0.173

Table 19: Value per U.S. Short Ton of Criteria Pollutant Emissions[18]

Value per metric ton	VOCs	NOx	SOx	PM
2018 $	$2,100	$8,600	$50,100	$387,300

As described earlier, MAG has a regional emissions model calibrated specifically to Maricopa County which can provide more detailed and refined emissions estimates than the default emissions calculations in TREDIS. The TREDIS default emissions estimates are presented in Table 20 as a sensitivity analysis to demonstrate the potential magnitude these impacts could have on the BCA.

This sensitivity analysis found that an increase in VMT between the project build and no-build scenario will likely result in an increase in transportation related emissions and represent "disbenefits" or costs to society. If these emissions costs are included in the benefit-cost analysis, the benefit cost ratio at three percent would drop slightly from 3.1 to 3.0.

[17] Based on DOE's AFLEET 2018 model. AFLEET 2018 provides state specific emissions rates that are collapsed to national rates using registration data for each state as reported in Federal Highway Statistics 2017. AFLEET values are based on the most recent version of EPA MOVES and analysis prepared boy DOE. For cars and light trucks, fleet composition and emissions are assessed using, survival rates and mileage-based exposure factors used by NHTSA in rulemaking documents and sales volumes from Ward's Automotive handbook. For medium-duty trucks, the average MY2018 vehicle is assessed based on its expected emissions after 5 years of use. For heavy-duty trucks and buses, the average MY2018 vehicles is assessed based on its expected emissions after 10 years of use. These timeframes represent roughly the average age of vehicles in these classes.

[18] U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs 2020, page 33.

Table 20: Default Environmental Benefit Estimates in Millions of Dollars, 2025-2050

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	7% discount rate (in $millions)
Environmental	-$94	-$58	-$33

Benefit-Cost Ratio and Total User Benefits

Table 21 shows the benefit-cost ratio at the three and seven percent discount rates, which consist of discounted benefits divided by the total discounted costs. As described earlier, these results do not include environmental benefits which would reduce the benefit-cost ratio to 3.0 using a three percent discount rate and 1.6 using a seven percent discount rate.

Table 21: Benefit-Cost Ratio

	3% discount rate	7% discount rate
Benefit-Cost Ratio	3.1	1.7

The overall benefits categories are shown in Table 22, with a description of the driving factors for the estimate.

Table 22: Total Travel Benefits Relative to the No-Build Alternative 2025 to 2050

Benefit	Undiscounted (in $millions)	3% discount rate (in $millions)	Driving Factor
Business Time and Reliability Costs	$1,596	$914	Decrease in medium duty and tractor trailer VHT
Value of Personal Time and Reliability	$1,482	$906	VHT decrease for personal and commuting trips
Logistics/Freight Costs	$171	$100	Decrease in medium duty and tractor trailer VHT
Vehicle Operating Costs	-$783	-$467	Increase in VMT for autos and trucks
Safety	$469	$248	Improved safety and design standards
Environmental[19]	n/a	n/a	Default estimates excluded, but can impact the BCR from 0.1 to 0.2
Total Benefits	$2,935	$1,701	

[19] The VIA Tool Kit and TREDIS can estimate the environmental benefits using national level parameters. Since MAG has more sophisticated localized modeling available, the environmental benefits were excluded. If included, the default environmental analysis was negligible impacting the benefit cost by 0.11.

As noted previously, minor adjustments to the assumptions and parameters in this analysis can impact the results. Table 23 presents a list of sensitivity factors could shift the overall results.

Table 23: Risk and Sensitivity Factors

Risk and Sensitivity Factors	Descriptions
Capital Costs	The I-10 Broadway Curve has not completed the full design phase, therefore capital costs and the construction schedule can change. Potentially changing the upfront capital costs or sending these costs later into the future will drastically change the results. Moving costs further into the future will result in lower discounted costs and potentially higher benefit cost ratio.
Operations and Maintenance Costs	Maintenance costs can increase if an additional patching cycle is needed in future years beyond what was captured in this analysis.
New Development and Induced Traffic	Additional development may occur along the corridor once the project is complete. Typically, with new large transportation investments, nearby parcels will become more attractive for development. This can have a positive impact on the local economy and induce additional travel resulting in larger economic impacts. The tradeoff is that the safety analysis completed for this study shows that additional traffic would reduce the safety benefits of this project.

4. Travel Demand Data

The benefit-cost analysis was conducted over a 25-year time horizon, in accordance with the anticipated roadway lifecycle and U.S. DOT BCA Guidance. Twenty-five years is the projected lifespan of the road segment before repaving is required. The benefit-cost analysis is based on modeled traffic volumes in the region and existing and modeled crash rates as well as projected capital, operations, and maintenance costs. The following sections describe the methodology used for each of these processes in detail.

Travel Patterns

Travel patterns, including vehicle miles traveled (VMT), vehicle hours traveled (VHT), trips, and occupancy were estimated using MAG's regional travel demand model. The following modes were analyzed:

- light duty commercial vehicles
- passenger cars
- trucks – medium duty
- trucks – tractor trailers

Passenger cars were divided between personal, business, and commute trip purposes and occupancy levels. The travel model projects an increase in vehicular traffic over time in both the no-build (without the improvements to the I-10 Broadway Curve) and build (with the improvements to the I-10 Broadway Curve) scenarios. The analysis assumes that in a given year, there are almost the same number of trips in the no-build and build scenarios. That is, the new I-10 Broadway Curve segment does induce additional trips to be made, however, these induced trips represent an increase of less than 0.001%.

The travel demand data was presented by time of day, trip purpose, and in passenger car cases by occupancy level (LOV and HOV). The table below shows how the MAG travel demand model mode information was reconciled with the TREDIS modes to meet trip purpose and occupancy designations. Time of day estimates (morning, mid-day, evening, and night-time) were aggregated to daily estimates and annualized using a factor of 336 days. This annualization factor was calculated using MAG's factor of 0.92 for converting average daily traffic (ADT) to annual average daily traffic (AADT) and then applying to 365 days.

Table 24: TDM modes, trip purpose, and TREDIS mode designations

	Trip Purpose			
TDM Mode Name	**Business**	**Personal**	**Commute**	**TREDIS Mode**
hbwlov			x	passenger car
nhwlov	X			passenger car
aoplov		x		passenger car
hbwhov			x	passenger car HOV
nhwhov	X			passenger car HOV
aophov		x		passenger car HOV
Medium Duty Trucks	X			custom mode
Heavy Duty Trucks	X			Tractor Trailer Truck
Light Duty Trucks	X			custom mode

The travel demand model estimated more vehicle miles traveled in the build scenario compared to the no-build scenario, which increases vehicle operating cost. The travel data for the no-build scenario and the build scenario are shown in Table 25 and Table **26** for the years 2025 and 2040. Annual estimates between these points were linearly interpolated and extrapolated through the project horizon of 2050. The analysis assumes improvements to the I-10 Broadway Curve will improve flow and average speeds, resulting in VHT savings.

Table 25: Travel Demand Data for 2025 in Millions

2025	Vehicle Trips	VMT	VHT
no-build			
Passenger Car - Commute	849	11,195	342
Passenger Car - Personal	3,730	22,258	706
Passenger Car - HOV Commute	43	887	26
Passenger Car - HOV Personal	94	1,384	40
Light Duty Truck and Business	827	8,053	226
Medium Duty Truck	154	2,898	74
Tractor Trailer Truck	44	1,453	30
Build			
Passenger Car - Commute	849	11,218	341
Passenger Car - Personal	3,730	22,291	705
Passenger Car - HOV Commute	43	886	26
Passenger Car - HOV Personal	94	1,385	39
Light Duty Truck and Business	827	8,095	226
Medium Duty Truck	154	2,904	73
Tractor Trailer Truck	44	1,452	30

Table 26: Travel Demand Data for 2040 in Millions

2040	Vehicle Trips	VMT	VHT
no-build			
Passenger Car - Commute	1,051	14,292	456
Passenger Car - Personal	4,586	28,134	925
Passenger Car - HOV Commute	53	1,117	34
Passenger Car - HOV Personal	114	1,710	51
Light Duty Truck and Business	1,024	10,389	302
Medium Duty Truck	191	4,073	106
Tractor Trailer Truck	55	2,192	46
Build			
Passenger Car - Commute	1,051	14,326	455
Passenger Car - Personal	4,586	28,173	924
Passenger Car - HOV Commute	53	1,122	34
Passenger Car - HOV Personal	114	1,718	51
Light Duty Truck and Business	1,024	10,448	302
Medium Duty Truck	191	4,078	106
Tractor Trailer Truck	55	2,193	46