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16. ABSTRACT

This report documents the analysis and prioritization of a portfolio of 384 newly proposed projects for the 2016 State Highway Operation and Protection Program (SHOPP), having a multi-year funding of approximately $4.6 billion. The project prioritization approach used in this analysis builds upon a methodology developed for the 2014 SHOPP, documented in the June 2015 report, "SHOPP Pilot Project Phase 1, A Framework for Project Prioritization." This prior work demonstrated the application and benefits of a Multi-Objective Decision Analysis (MODA) framework to aid decision-makers in identifying a project portfolio delivering the greatest value to stakeholders. The approach was shown to bring transparency to the project prioritization process, providing a quantitative basis for decision making and a mechanism to communicate the alignment of project priorities with strategic objectives.

A number of changes were made in the analysis methods, incorporating a broader range of transportation data and considers a broader range of factors in determining project value. The spreadsheet-based tool, initially developed for the 2014 SHOPP, was updated to include these improvements.

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SHOPP Project Prioritization

Application of a Project Prioritization Framework to the 2016 SHOPP

March 3, 2016

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1. Introduction

This report documents the analysis and prioritization of a portfolio of 384 newly proposed projects for the 2016 State Highway Operation and Protection Program (SHOPP), having a multi-year funding of approximately $4.6 million. The project prioritization approach used in this analysis builds upon a methodology developed for the 2014 SHOPP, documented in the June 2015 report, *"SHOPP Pilot Project Phase 1, A Framework for Project Prioritization."*[1] This prior work demonstrated the application and benefits of a Multi-Objective Decision Analysis (MODA) framework to aid decision-makers in identifying a project portfolio delivering the greatest value to stakeholders. The approach was shown to bring transparency to the project prioritization process, providing a quantitative basis for decision making and a mechanism to communicate the alignment of project priorities with strategic objectives. Furthermore, in contrast to past prioritization processes, the new approach breaks down funding "silos" by ranking projects based on objective, data-derived value and direct consideration of the project's cost.

A number of changes were made in the 2016 SHOPP analysis, based on experience from the prior 2014 SHOPP analysis and the more recent work through the 2016 SHOPP Asset Management Pilot Program[2]. Although still evolving, the calculation framework for the 2016 SHOPP incorporates more relevant transportation data and considers a broader range of factors in determining project value. The spreadsheet-based tool, initially developed for the 2014 SHOPP, was updated to include these improvements. New and revised report products have been added to more effectively present prioritization outcomes.

[1] http://www.dot.ca.gov/tam/shopp/index.html

[2] http://www.dot.ca.gov/tam/shopp/ampp.html

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2. The Decision Analysis Framework

Decision Analysis[3] encompasses the methods and tools to systematically consider key aspects of a decision-making problem, guides the selection of the best alternative, and establishes a logical and transparent framework that provides insight on how decisions are made. Decision analysis is a discipline that combines elements of operations research, management science, and systems analysis. The goal of the decision-making process is to provide the decision maker with a logical and defensible framework that can help articulate how choices and priorities were made. Project prioritization is a specific implementation of decision analysis based on the same fundamental principles. Where in decision analysis the goal is to determine the single best alternative, project prioritization aims to identify an optimized portfolio of projects from a pool of projects.

The decision analysis framework is comprised of an *Objectives Hierarchy*, a *Value Function* and its sub-models, and scoring and weighting procedures. Collectively, these components are used to calculate the *Project Value*. The *Project Value-to-Cost Ratio* is then used to determine its priority relative to other projects. The definitions of these terms and this calculation framework are described in this section.

2.1. Multi-Objective Decision Analysis for Project Prioritization

A Multi-Objective Decision Analysis (MODA) approach is implemented for the prioritization of SHOPP projects. Specifically, a Multi-Attribute Value Theory (MAVT) process, a sub-type of MODA, is used to carry out a number of key steps, as shown in Figure 2-1.

Figure 2-1- MODA/MAVT Process

In this process, an *Objectives Hierarchy* (Figure 2-2) is developed that ties the decision maker's high level goals to lower level criteria that can be measured. The objectives hierarchy provides a means to deconstruct organizational goals into *fundamental objectives*. *Weights* are determined for objectives, and a linear-additive, multi-attribute value function is then used to combine the products of the weighted values to determine the overall value that a project delivers. Portfolios of projects are analyzed for sensitivity to changes in the weighting assignment, which provides insight to the decision-making process.

[3] http://web.stanford.edu/class/cee115/wiki/uploads/Main/Schedule/OverviewDA.pdf

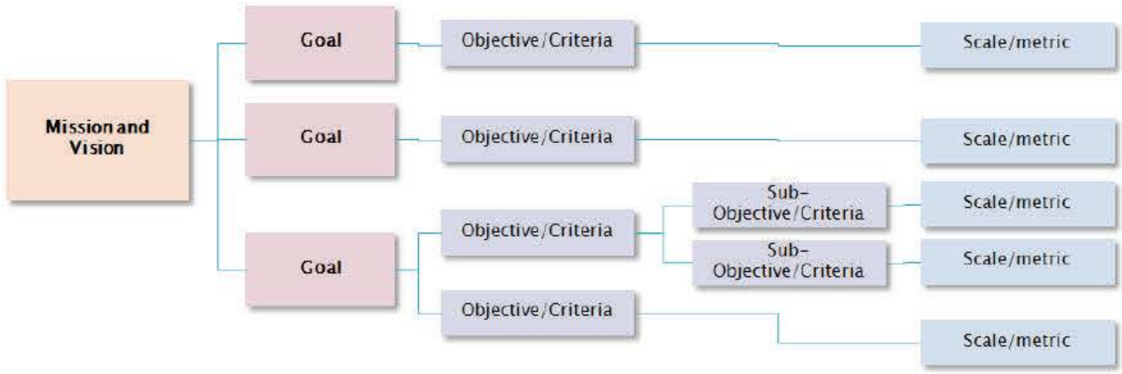

Figure 2-2 – General Framework for an Objectives Hierarchy

In the MAVT process, scores are assigned to the lowest level elements in the hierarchy. These scores are then aggregated using the weighting on each score and summing the components. This aggregation provides a structured framework to bring together different considerations and perspectives of the decision makers. Furthermore, these differences can then be isolated, analyzed, and more effectively communicated through this framework.

2.2. Objectives Hierarchy

The objectives hierarchy used in the 2016 SHOPP analysis is shown in Figure 2-3, representing the Department's fundamental objectives, sub-objectives, and the relationships to Department strategic goals. A few changes were made from the objectives hierarchy used in the prior 2014 SHOPP analysis. These include the addition of a health objective, the consolidation of sub-objectives relating to environmental impacts, and rewording of some of the objective titles.

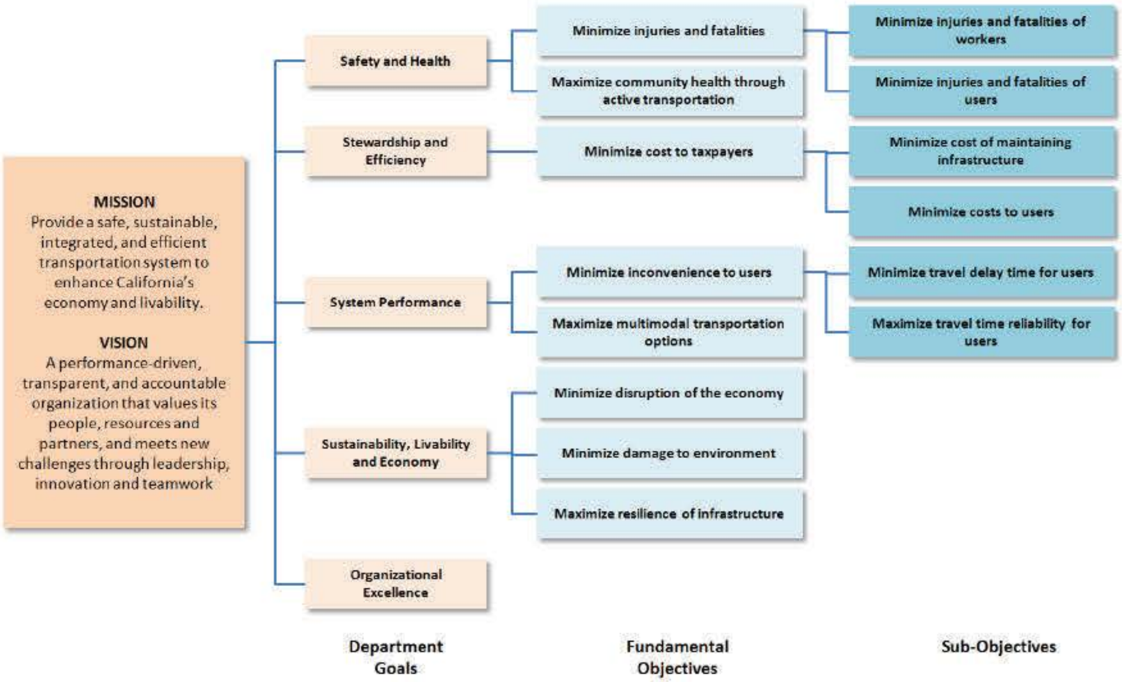

Figure 2-3 - Objectives Hierarchy

The overall objectives hierarchy, shown in Figure 2-3, shows the fundamental objectives and sub-objectives as well as their alignment to the Department's mission, vision, and goals. It is important to note that the Organizational Excellence Goal does not have any fundamental objectives. This omission was based on recommendations from decision analysis experts from the prior Phase 1 work, where it was observed that the Organizational Excellence Goal is "influenced more by the implications of the totality of Caltrans actions than by the selection of specific projects."[4]

2.2.1. Safety and Health Objectives

The Department's Safety and Health goal is stated as follows: "Provide a safe transportation system for workers and users and promote health through active transportation and reduced pollution in communities." A detailed diagram of the fundamental objectives, sub-objectives, benefit sub-models, and data sources is presented in Figure 2-4.

[4] *"SHOPP Pilot Project Phase 1, A Framework for Project Prioritization"* http://www.dot.ca.gov/tam/shopp/index.html

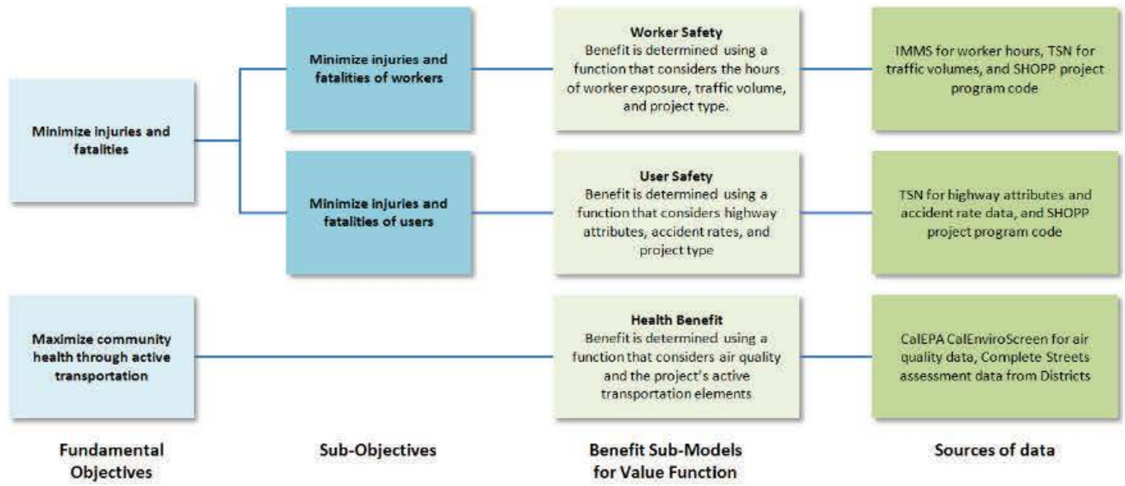

Figure 2-4 - Safety and Health Objectives

2.2.2. Stewardship and Efficiency Objectives

The Department's Stewardship and Efficiency goal is stated as follows: "Money counts. Responsibly manage California's transportation-related assets." A detailed diagram of the fundamental objectives, sub-objectives, benefit sub-models, and data sources is presented in Figure 2-5:

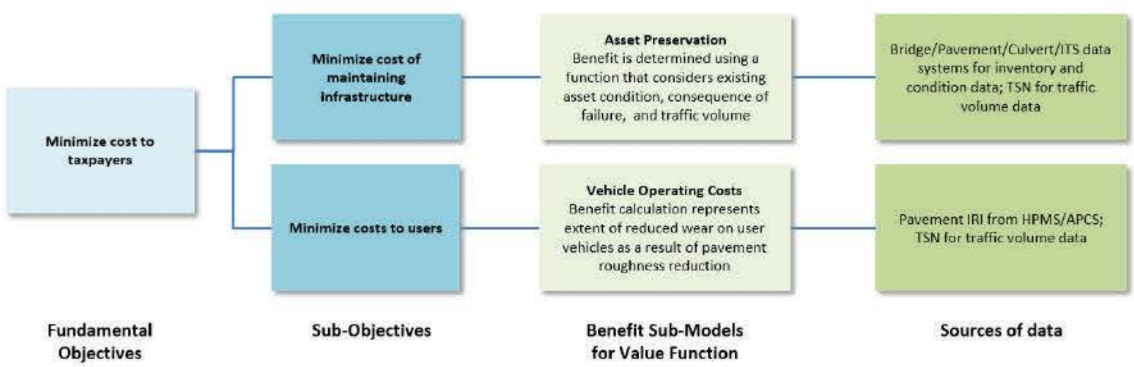

Figure 2-5 - Stewardship and Efficiency Objectives

2.2.3. System Performance Objectives

The Department's System Performance goal is stated as follows: "Utilize leadership, collaboration and strategic partnerships to develop an integrated transportation system that provides reliable and accessible mobility for travelers." A detailed diagram of the fundamental objectives, sub-objectives, benefit sub-models, and data sources is presented in Figure 2-6.

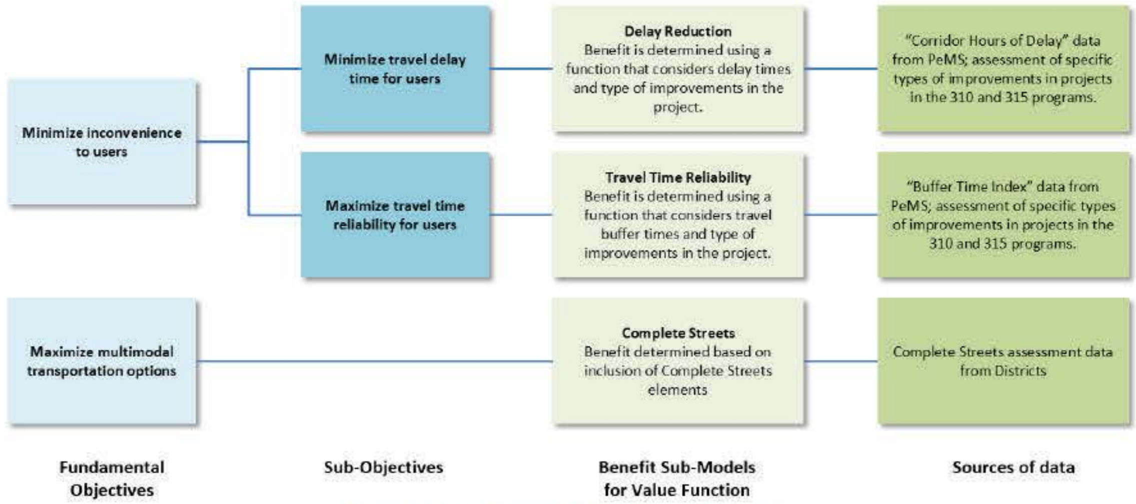

Figure 2-6 - System Performance Objectives

2.2.4. Sustainability, Livability and Economy Objectives

The Department's Sustainability, Livability and Economy goal is stated as follows: "Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl." A detailed diagram of the fundamental objectives, sub-objectives, benefit sub-models, and data sources is presented in Figure 2-7.

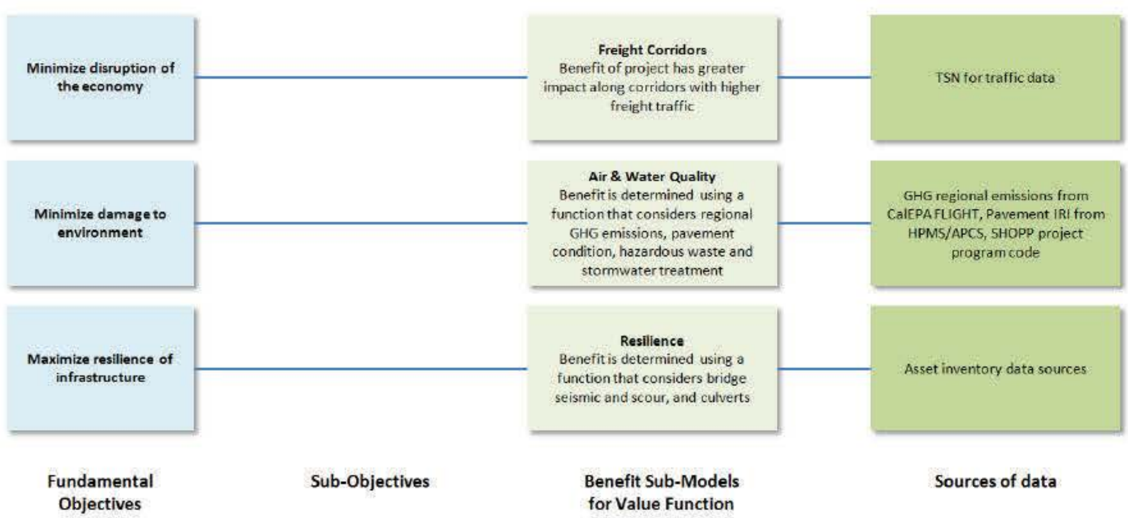

Figure 2-7 - Sustainability, Livability, and Economy Objectives

2.3. Calculation Framework

2.3.1. Value Function

A project's overall value, or benefit, is determined through the aggregation of benefits derived from benefit sub-models associated with each objective. This calculation is referred to as the *Value Function*. In the calculation framework, shown in Figure 2-8, each objective or sub-objective has a sub-model that is used to determine a score. Those scores are multiplied by a weight, and the sum of the weighted scores is added to produce the *Project Value*. The project value is divided by the project cost to produce the *Project Value-to-Cost Ratio*, the key metric used to in project prioritization.

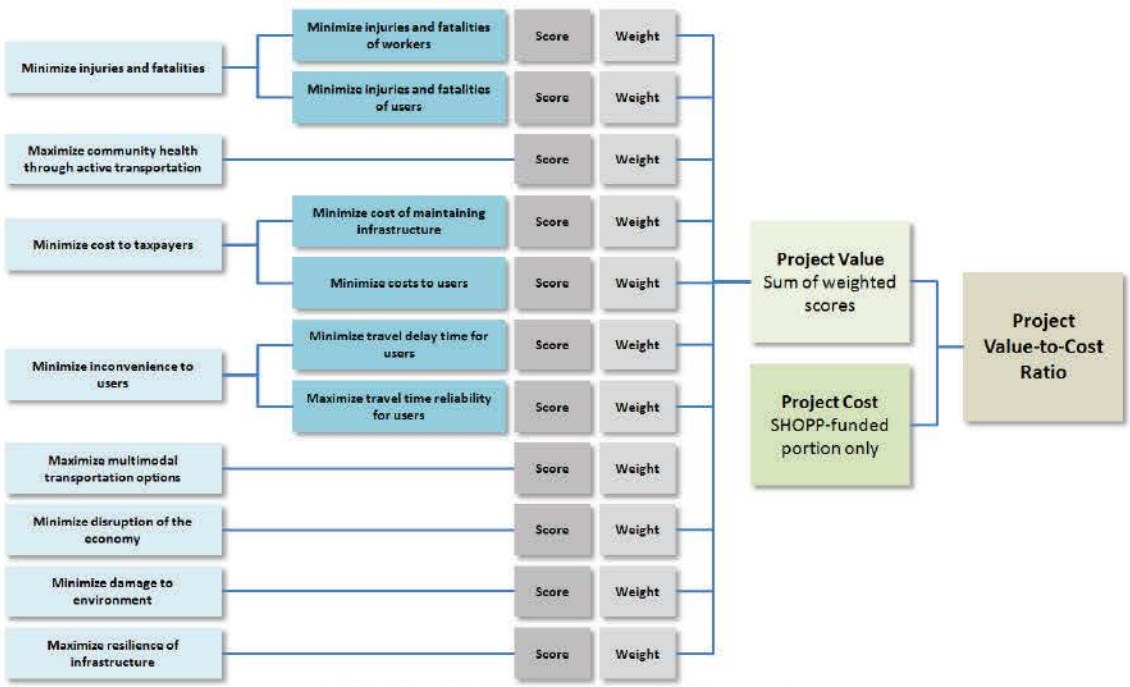

Figure 2-8 - Value Function Calculation Framework

The value function takes the generalized form:

$$Project\ Value = (Score_1)(Weight_1) + (Score_2)(Weight_2) + \dots + (Score_n)(Weight_n)$$

$$Project\ Value\ to\ Cost\ Ratio = \frac{Project\ Value}{Project\ Cost}$$

2.3.2. Scaling Project Value with Magnitude of Project Work

In all of the sub-model calculations, the value associated with each objective is determined on a 0-100 scale. As designed, the score is intended to reflect the magnitude of benefit from a particular work activity as it scales up or down depending on the size of the project. For example, one would need to differentiate the relative benefit from a five-mile pavement project compared to a 50-mile pavement project. In this example, the larger project might be expected to produce up to ten times the benefit.

In the earlier 2014 SHOPP project prioritization work, a *Project Magnitude Scaling Factor* ($SF_{project\ magnitude}$) was introduced into calculations in order to scale the relative benefit of a particular objective to the overall size of the project using the dollar worth of the asset as the basis. This approach considered the replacement cost of the primary infrastructure asset as a basis for scaling project values.

The 2016 SHOPP project prioritization approach retains a similar approach for one sub-model calculation, asset preservation under the Stewardship goal (see Appendix A.4 – Minimize Cost of Maintaining Transportation Infrastructure). In other sub-model calculations, scaling for project magnitude is accounted for less rigorously. Eliminating the Project Magnitude Scaling Factor was adopted in order to better align this prioritization approach with the concurrent 2016 SHOPP Asset Management Pilot Program[5]. Additional work is needed to determine how best to account for scaling of project value.

[5] http://www.dot.ca.gov/tam/shopp/ampp.html

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3. Analysis of the 2016 SHOPP Project Portfolio

3.1. Overview of the New 2016 SHOPP Projects

A total of 384 new projects are included in the 2016 SHOPP portfolio. The cumulative multi-year funding for these projects is estimated to be approximately $4.58 billion, using cost data at the time of this report preparation. Detailed breakdowns by project type, counts, and funding are presented in Table 3-1.

Table 3-1 – New 2016 SHOPP Projects

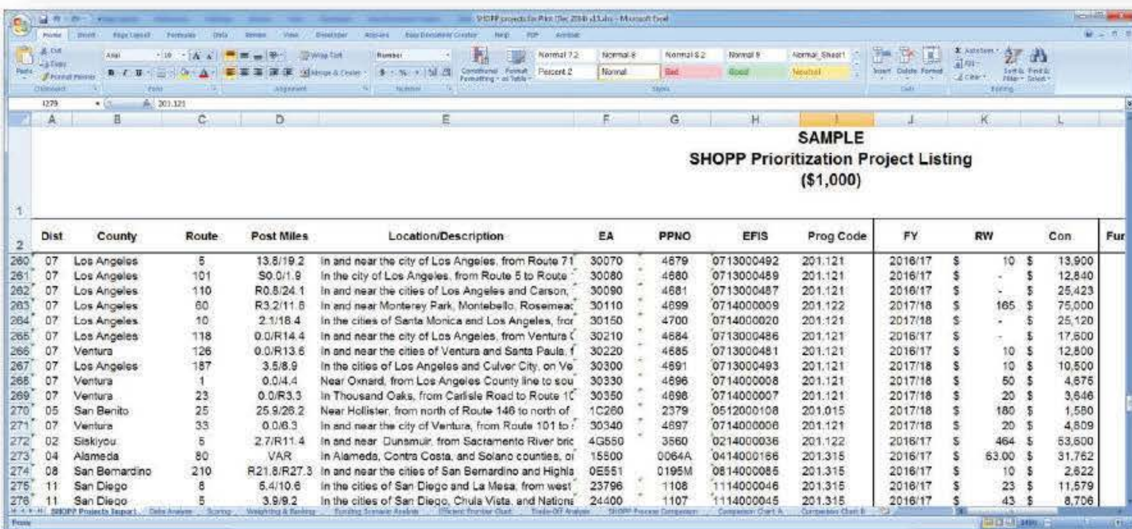
Program Code	Program Priority	Program	Count	Funding	Percent of Funds
201.130	1	201.130 Emergency Damage Repair	0	$0	0.0%
201.010	1	201.010 Safety Improvements	2	$107,008,000	2.3%
201.131	1	201.131 Permanent Restoration	0	$0	0.0%
201.361	1	201.361 ADA Access Improvements	22	$105,868,000	2.3%
201.378	1	201.378 ADA Pedestrian Infrastructure	9	$44,031,800	1.0%
201.235	1	201.235 Roadside Safety Improvements	59	$262,179,000	5.7%
201.119	1	201.119 Bridge Preventive Maintenance	13	$78,723,000	1.7%
201.321	1	201.321 Weigh Stations & WIM Facilities	7	$30,670,000	0.7%
201.015	2	201.015 Collision Severity Reduction	32	$296,647,000	6.5%
201.111	3	201.111 Bridge Scour Mitigation	2	$25,064,000	0.5%
201.113	4	201.113 Bridge Seismic Restoration	11	$95,096,000	2.1%
201.110	5	201.110 Bridge Rehabilitation	21	$300,261,000	6.6%
201.120	6	201.120 Roadway Rehabilitation (3R)	5	$304,150,000	6.6%
201.121	6	201.121 Roadway Preservation (CAPM)	41	$806,772,000	17.6%
201.122	6	201.122 Roadway Rehabilitation (2R)	19	$1,090,266,000	23.8%
201.151	7	201.151 Drainage System Restoration	30	$133,518,000	2.9%
201.112	8	201.112 Bridge Rail Replacement Upgrade	13	$119,496,000	2.6%
201.335	9	201.335 Stormwater	25	$188,218,000	4.1%
201.315	10	201.315 Transportation Management Systems	22	$237,185,000	5.2%
201.322	11	201.322 Trans Permit Requirements for Bridges	4	$60,008,000	1.3%
201.150	12	201.150 Roadway Protective Betterment	10	$40,483,000	0.9%
201.310	13	201.310 Operational Improvements	12	$108,309,000	2.4%
201.240	14	201.240 Roadside Protection and Restoration	4	$18,530,000	0.4%
201.250	15	201.250 Safety Roadside Rest Area Rehabilitatior	2	$22,000,000	0.5%
201.210	16	201.210 Roadside Rehabilitation	4	$9,022,000	0.2%
201.170	17	201.170 Signs and Lighting Rehabilitation	10	$37,961,000	0.8%
201.160	18	201.160 Relinquishments	0	$0	0.0%
201.325	19	201.325 Railroad at-grade Crossing	0	$0	0.0%
201.330	20	201.330 Hazardous Waste Mitigation	1	$5,074,000	0.1%
201.352	21	201.352 Maintenance Facilities	3	$21,992,000	0.5%
201.351	22	201.351 Equipment Facilities	1	$29,000,000	0.6%
201.353	23	201.353 Office Buildings	0	$0	0.0%
201.260	25	201.260 New Safety Roadside Rest Areas	0	$0	0.0%
Sub-Totals by Asset Type					
		Bridge	64	$678,648,000	15%
		Pavement	65	$2,201,188,000	48%
		Culvert	30	$133,518,000	3%
		TMS Elements	34	$345,494,000	8%
		Priority 1 (Safety, Mandates, excluding bridge)	99	$549,756,800	12%
		All Other Projects	92	$668,927,000	15%
Portfolio Summary					
		Total Number of Projects		384	
		Total Portfolio Funding		$4,577,531,800	
		Total Project Portfolio Value		32,953	

3.2. Analysis of the Portfolio

To arrive at a final prioritization, several major activities were carried out. This included the compilation of project-specific and regional transportation data, a geo-spatial analysis to associate regional data to specific projects, the calculation of project scores, and the weighting and ranking of projects.

3.2.1. Data Compilation and Geo-Spatial Analysis

Two primary sources of data are used by the tool – SHOPP project data and Caltrans GIS Library data. SHOPP project data was provided by the Division of Transportation Planning through the SHOPP Management Office. This data includes location information (i.e. district, county, route, and postmile limits), funding, program coding, and a brief project description. SHOPP Project data is imported into the spreadsheet tool (Figure 5.3). The format and structure of this worksheet is identical to the file generated by the SHOPP Management Office.



SAMPLE
SHOPP Prioritization Project Listing
($1,000)

	Dist	County	Route	Post Miles	Location/Description	EA	PPNO	EFIS	Prog Code	FY	RW	Con	Fur
260	07	Los Angeles	5	13.8/19.2	In and near the city of Los Angeles, from Route 71	30070	4679	0713000492	201.121	2016/17	$ 10	$ 13,900	
261	07	Los Angeles	101	S0.0/1.9	In the city of Los Angeles, from Route 5 to Route	30080	4680	0713000489	201.121	2016/17	$ -	$ 12,840	
262	07	Los Angeles	110	R0.8/24.1	In and near the cities of Los Angeles and Carson,	30090	4681	0713000487	201.121	2016/17	$ -	$ 25,423	
263	07	Los Angeles	60	R3.2/11.8	In and near Monterey Park, Montebello, Rosemea	30110	4699	0714000009	201.122	2017/18	$ 165	$ 75,000	
264	07	Los Angeles	10	2.1/18.4	In the cities of Santa Monica and Los Angeles, fror	30150	4700	0714000020	201.121	2017/18	$ -	$ 25,120	
265	07	Los Angeles	118	0.0/R14.4	In and near the city of Los Angeles, from Ventura (	30210	4684	0713000486	201.121	2016/17	$ -	$ 17,600	
266	07	Ventura	126	0.0/R13.6	In and near the cities of Ventura and Santa Paula, f	30220	4685	0713000481	201.121	2016/17	$ 10	$ 12,800	
267	07	Los Angeles	187	3.5/8.9	In the cities of Los Angeles and Culver City, on Ve	30300	4691	0713000493	201.121	2017/18	$ 10	$ 10,500	
268	07	Ventura	1	0.0/4.4	Near Oxnard, from Los Angeles County line to sou	30330	4696	0714000008	201.121	2017/18	$ 50	$ 4,675	
269	07	Ventura	23	0.0/R3.3	In Thousand Oaks, from Carlisle Road to Route 10	30350	4698	0714000007	201.121	2017/18	$ 20	$ 3,646	
270	05	San Benito	25	25.9/26.2	Near Hollister, from north of Route 146 to north of	1C260	2379	0512000108	201.015	2017/18	$ 180	$ 1,580	
271	07	Ventura	33	0.0/6.3	In and near the city of Ventura, from Route 101 to	30340	4697	0714000006	201.121	2017/18	$ 20	$ 4,809	
272	02	Siskiyou	5	2.7/R11.4	In and near Dunsmuir, from Sacramento River bric	4G550	3560	0214000036	201.122	2016/17	$ 464	$ 53,600	
273	04	Alameda	80	VAR	In Alameda, Contra Costa, and Solano counties, or	15500	0064A	0414000166	201.315	2016/17	$ 63.00	$ 31,762	
274	08	San Bernardino	210	R21.8/R27.3	In and near the cities of San Bernardino and Highla	0E551	0195M	0814000085	201.315	2016/17	$ 10	$ 2,622	
275	11	San Diego	8	6.4/10.6	In the cities of San Diego and La Mesa, from west	23796	1108	1114000046	201.315	2016/17	$ 23	$ 11,579	
276	11	San Diego	5	3.9/9.2	In the cities of San Diego, Chula Vista, and Nations	24400	1107	1114000045	201.315	2016/17	$ 43	$ 8,706	

Figure 3-1 - SHOPP Project Data Import

Department GIS data is obtained from the online Caltrans GIS Data Library, maintained by the Division of Research, Innovation, and System Information (DRISI). Key GIS data sets include Annual Average Daily Traffic (AADT), truck traffic, pavement International Roughness Index (IRI), locations of high traffic congestion (or "bottleneck") zones, bridges, and various other highway fixtures tied to the statewide Linear Reference System (LRS).

By combining the available SHOPP project data and the Caltrans GIS data through the LRS, a suite of data can be attributed to each SHOPP project for further analysis. The geospatial analysis that is required to extract this data is carried out in ESRI ArcGIS software (Figure 3-2).

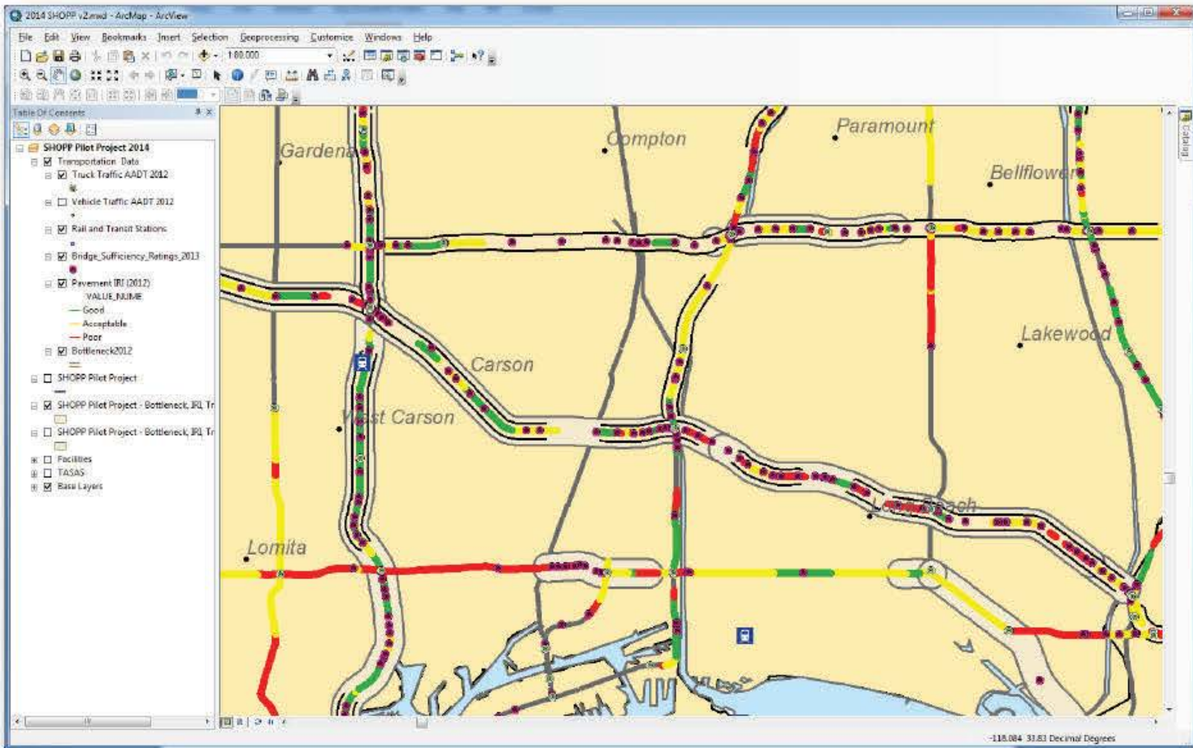


Figure 3-2 – Geo-Spatial Analysis of SHOPP Projects Implemented with Caltrans GIS Data

3.2.2. Project Scoring

For each of the 384 projects in the 2016 SHOPP, calculations were carried out using 11 benefit sub-models associated with the fundamental objectives and sub-objectives. Details of the calculations are documented in Appendix A of this report. The spreadsheet tool is configured with a separate tab for each of the 11 benefit sub-model calculations (Figure 3-3). Each benefit sub-model produces a single score per project, ranging 0 to 100.

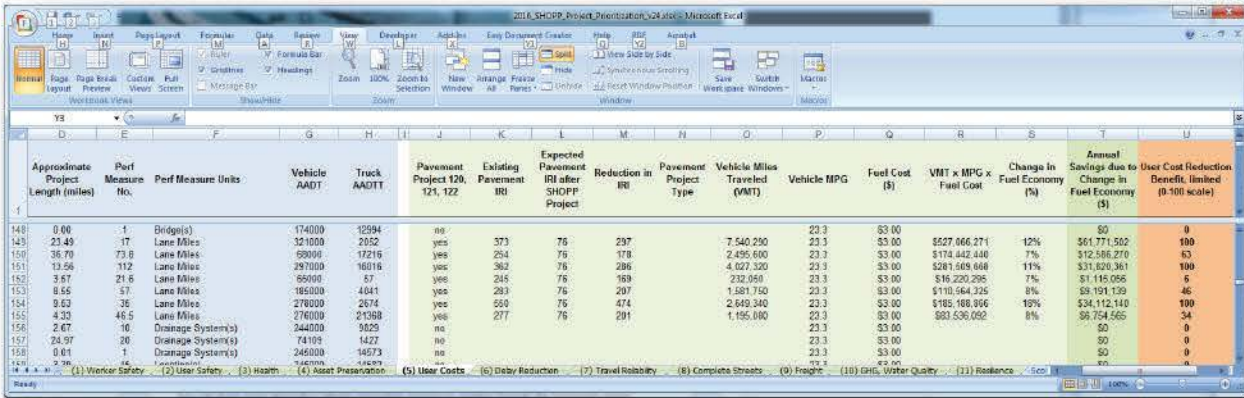


Figure 3-3 – Benefit Sub-Model Calculations in Spreadsheet Tool

The compilation of project scores is summarized on the *Scoring* worksheet (Figure 3-4), which captures the calculations and scores for all projects based on the benefit sub-models.

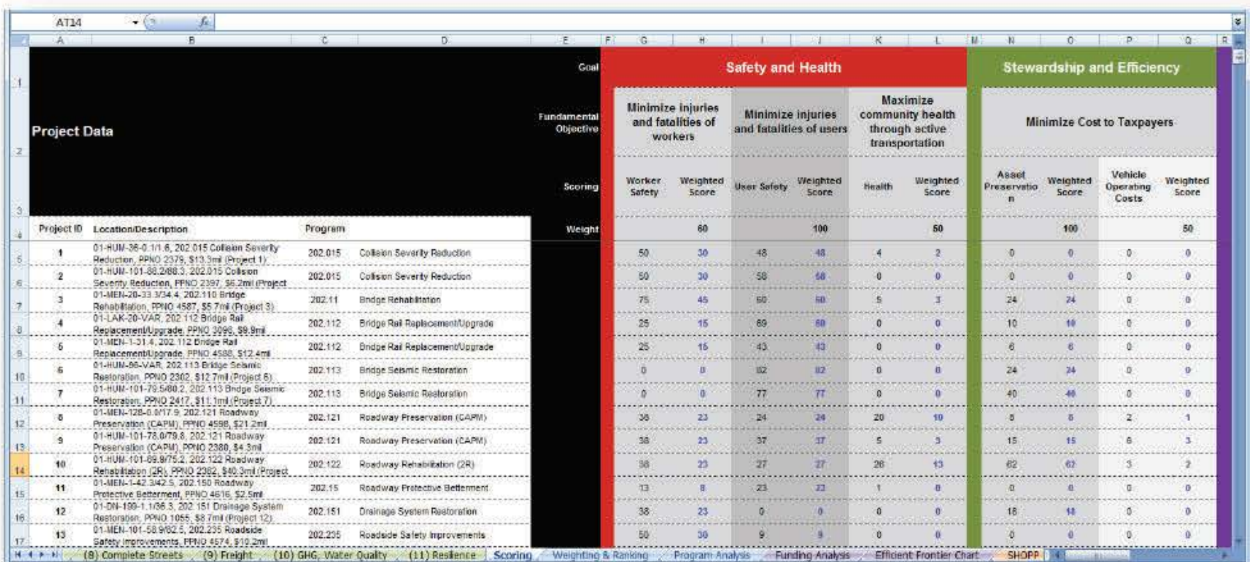


Figure 3-4 - Scoring Worksheet

The right-most columns in the *Scoring* worksheet (Figure 3-5) calculate and summarize the project scores as a product of the weighted sum of the scores from the sub-models. The resulting score, called the *Project Value*, is divided by the *Project Cost* to yield the *Project Value-to-Cost Ratio*. The *Project*

Value-to-Cost Ratio is used to rank projects in priority order and accounts for the broad range of project costs and scopes.

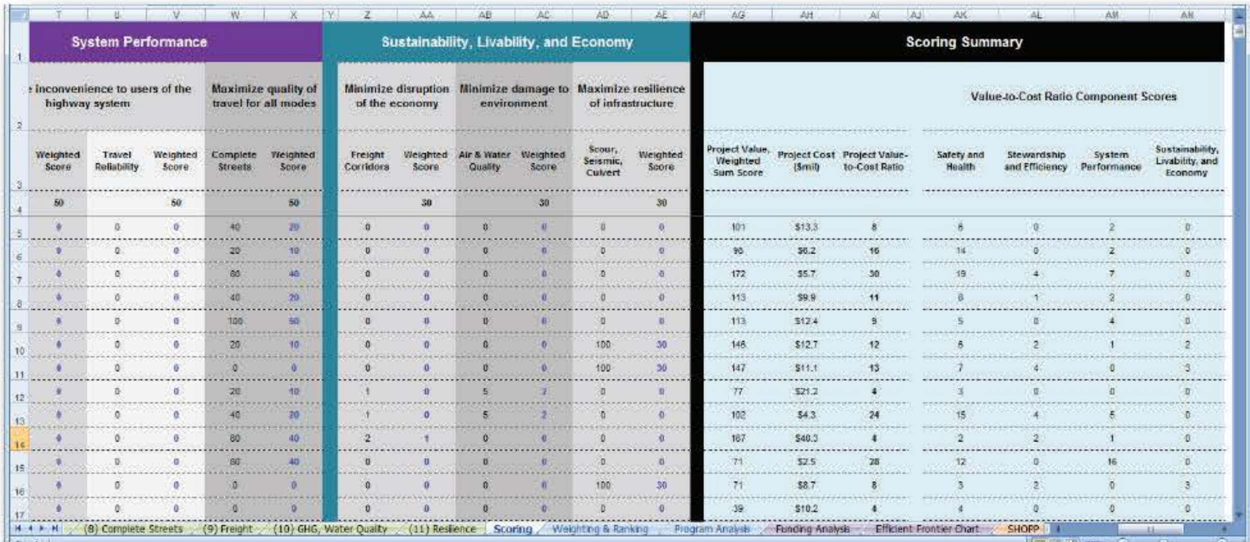


Figure 3-5 - Scoring Worksheet Summary

3.2.3. Weighting

In Section 2.3 the calculation of *Project Value* was described, where individual weights for each of the 11 benefit sub-models are applied as the sum of the weighted scores, as follows:

$$Project\ Value = (Score_1)(Weight_1) + (Score_2)(Weight_2) + \dots + (Score_n)(Weight_n)$$

The project prioritization tool incorporates a weight input and adjustment feature, as shown in Figure 3-6. Weights are entered as a numeric value on a 0 to 100 scale for each of the 11 benefit sub-models. The relative contributions of each sub-model score towards a goal are displayed by percentage. The relative contributions of each goal are also presented in the table.

Goal	Goal Weight (%)	Fundamental Objective	Sub-Objective	Benefit Sub-Model	Sub-Objective Weight (%)	Assigned Weight (0-100)
Safety and Health	35%	Minimize injuries and fatalities on the transportation system	Minimize injuries and fatalities of workers	(1) Worker Safety	29%	60
			Minimize injuries and fatalities of users	(2) User Safety	48%	100
		Maximize community health through active transportation		(3) Health	24%	50
Stewardship and Efficiency	25%	Minimize cost to taxpayers	Minimize cost of maintaining infrastructure	(4) Asset Preservation	67%	100
			Minimize costs to users	(5) Vehicle Operating Costs	33%	50
System Performance	25%	Minimize inconvenience	Minimize travel time for users	(6) Delay Reduction	33%	50
			Maximize travel time reliability for users	(7) Travel Reliability	33%	50
		Maximize multimodal transportation options		(8) Complete Streets	33%	50
Sustainability, Livability, and Economy	15%	Minimize disruption of the economy		(9) Freight Corridors	33%	30
		Minimize damage to environment		(10) GHG, Water Quality	33%	30
		Maximize resilience of infrastructure		(11) Scour, Seismic, Culvert	33%	30

Figure 3-6 - Setting Weights

Department-level goal weights were established through a management group process in January 2016, led by the State Asset Management Engineer and capturing input from the Executive Board members. Weights for each goal, expressed as a percentage of the total, were determined by asking Executive Board members to make to quantify the relative importance of one goal against others. These pair-wise comparisons were evaluated using an Analytic Hierarchy Process (AHP)[6], and the aggregation of the group's responses was used to develop the final goal weights.

[6] http://www.colorado.edu/geography/leyk/geog_5113/readings/saaty_2008.pdf

Since the 2016 SHOPP does not consider Organizational Excellence in the calculations, the percentage weights from the five goals were redistributed across four goals, rounding off to the nearest 5%. The final goal weights used for the 2016 SHOPP are presented in Table 3-2.

Table 3-2 - Goal Weights

Notes	Safety and Health	Stewardship and Efficiency	Sustainability, Livability, and Economy	System Performance	Organizational Excellence
Weights Resulting from Executive Board Process	32%	23%	15%	22%	8%
Weights Applied in the 2016 SHOPP Analysis	35%	25%	15%	25%	N/A

Note that the target goal weights shown in Figure 3-6 are consistent with the goal weights established those presented in Table 3-2.

3.2.4. Project Priorities

Once scores and weights are established for all projects, the project prioritization tool reports a ranked listing of projects in priority order, as shown in Figure 3-7.

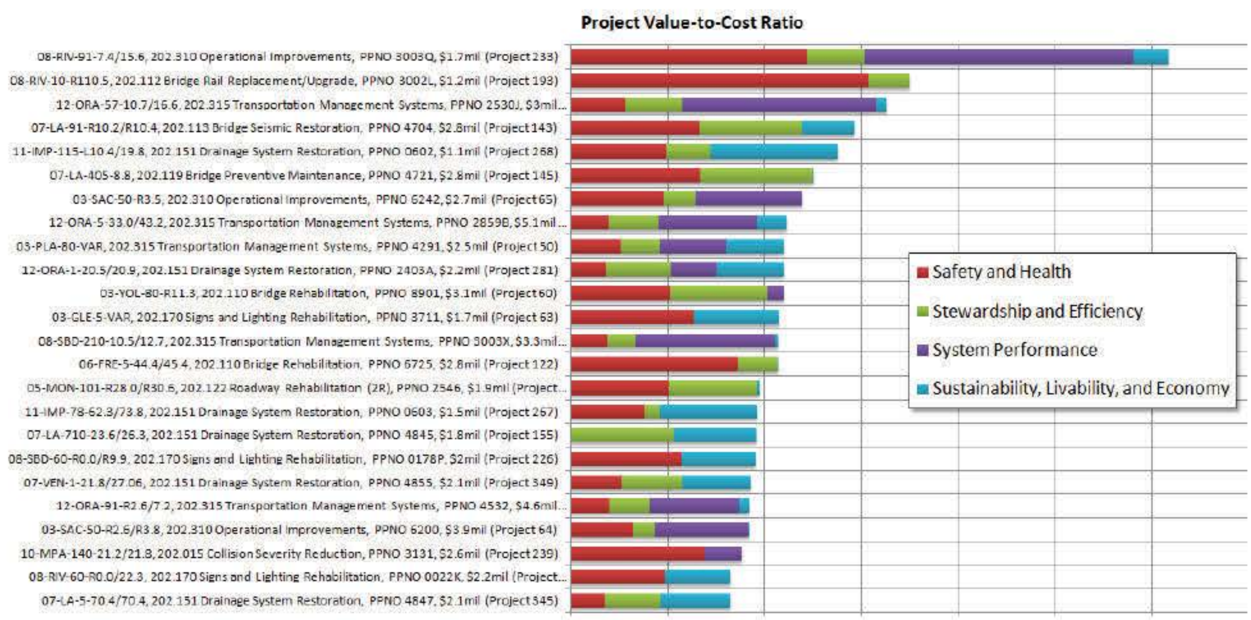


Figure 3-7 - Prioritization Outcomes

The relative contributions of each Department goal are represented as a proportion of the bars in the chart, symbolized using the color convention throughout the tool. The length of each bar represents the Project Value-to-Cost ratio. Projects that provide more value (i.e., higher ratio of score-to-cost) rank higher. Also, a notable feature in the tool is that the rank order of projects changes dynamically as the weights are adjusted.

The comprehensive list of the prioritization results for all 384 projects is included in tables in Appendix B. For each project the following data are presented:

- Weighted score resulting from each of the 11 benefit sub-model calculations
- The Project Value, a weighted sum of the 11 scores
- The Project Cost
- The Project Value-to-Cost Ratio
- The project's ID and description
- The overall priority ranking

Scores are graphically presented as data bars within the cells to help the reader identify scoring trends. Figure 3-8 shows an excerpt of the presentation of results from Appendix B.

Projects			Safety and Health			Stewardship and Efficiency		System Performance			Sustainability, Livability, and Economy			Scoring Summary		
			Minimize injuries and fatalities of workers	Minimize injuries and fatalities of users	Maximize health of California residents	Minimize Cost to Taxpayers		Minimize inconvenience to users of the highway system		Maximize quality of travel for all modes	Minimize disruption of the economy	Minimize damage to environment	Maximize equity and access to multimodal transportation systems			
Rank	ID	Description	Worker Safety	User Safety	Health	Asset Preservation	User Costs	Delay Reduction	System Reliability	Travel Quality	Freight Corridors	Air & Water Quality	Complete Streets	Project Value	Project Cost ($mil)	Project Value-to-Cost Ratio
1	233	08-RIV-91-7.4/15.6, 202.310 Operational Improvements, PPNO 3003O, $1.7mil (Project 233)	0	60	24	20	0	50	35	10	12	0	0	211	$1.7	**123**
2	63	03-GLE-5-VAR, 202.170 Signs and Lighting Rehabilitation, PPNO 3711, $1.7mil (Project 63)	60	43	0	0	0	0	0	0	30	0	0	133	$1.7	**78**
3	226	08-SBD-60-R0.0/R9.9, 202.170 Signs and Lighting Rehabilitation, PPNO 0178P, $2mil (Project 226)	60	44	0	0	0	0	0	0	30	0	0	134	$2.0	**69**
4	286	12-ORA-57-10.7/16.8, 202.315 Transportation Management Systems, PPNO 2530J, $3mil (Project 286)	0	25	9	36	0	50	50	20	6	0	0	196	$3.0	**65**
5	145	07-LA-405-8.8, 202.119 Bridge Preventive Maintenance, PPNO 4721, $2.8mil (Project 145)	30	76	0	67	0	0	0	0	0	0	0	172	$2.8	**61**
6	225	08-RIV-60-R0.0/22.3, 202.170 Signs and Lighting Rehabilitation, PPNO 0022K, $2.2mil (Project 225)	60	43	0	0	0	0	0	0	30	0	0	133	$2.2	**60**

Figure 3-8 - Summary of Scores and Ranking

3.3. Observations on Prioritization Outcomes

3.3.1. Ranking Summary

Prioritization outcomes are summarized in the context of SHOPP program categories and presented in Table 3-3 (by project counts) and Table 3-4 (by project funding) for each of the 33 SHOPP programs. For a given program (table row), the metrics are further parsed into 10% interval bins based on percent-rank. For example, in Table 3-3 one can see that 3 projects in the 201.235 Roadside Safety Improvements program ranked in the top 10% of all new 2016 SHOPP projects. Table 3-4 shows that those same 3 projects constitute $5.7 million of the total. Data bars are graphically displayed within each cell to draw attention to significant outcomes from the analysis.

In the lower section of each table, the same metrics are presented for programs grouped by the four primary asset classes – bridge, pavement, culverts, and transportation management system elements.

Table 3-3 – Ranking Summary by Program Count

				Percentile Ranking of Project Counts by Program Presents sub-totals of program counts broken down into 10% ranking bins									
Program	**Program Priority**	**Number of Projects**	**Total Program Funding ($mil)**	**0%-10% (Highest Priorities)**	**11%-20%**	**21%-30%**	**31%-40%**	**41%-50%**	**51%-60%**	**61%-70%**	**71%-80%**	**81%-90%**	**91%-100% (Lowest Priorities)**
201.130 Emergency Damage Repair	1	0	$0.0	0	0	0	0	0	0	0	0	0	0
201.010 Safety Improvements	1	2	$107.0	0	0	0	0	0	1	0	0	0	1
201.131 Permanent Restoration	1	0	$0.0	0	0	0	0	0	0	0	0	0	0
201.361 ADA Access Improvements	1	22	$105.9	0	0	1	2	3	2	4	0	5	5
201.378 ADA Pedestrian Infrastructure	1	9	$44.0	0	0	1	1	2	0	1	3	0	1
201.235 Roadside Safety Improvements	1	59	$262.2	3	10	15	6	8	6	4	2	3	2
201.119 Bridge Preventive Maintenance	1	13	$78.7	3	1	1	5	1	0	2	0	0	0
201.321 Weigh Stations & WIM Facilities	1	7	$30.7	0	0	0	0	1	3	1	2	0	0
201.015 Collision Severity Reduction	2	32	$296.6	5	6	4	3	6	0	2	2	1	3
201.111 Bridge Scour Mitigation	3	2	$25.1	0	0	0	0	0	1	1	0	0	0
201.113 Bridge Seismic Restoration	4	11	$95.1	1	4	1	1	3	0	1	0	0	0
201.110 Bridge Rehabilitation	5	21	$300.3	3	2	2	2	3	3	3	2	0	1
201.120 Roadway Rehabilitation (3R)	6	5	$304.2	0	0	0	0	0	0	3	0	1	1
201.121 Roadway Preservation (CAPM)	6	41	$806.8	0	2	1	2	3	7	5	13	7	1
201.122 Roadway Rehabilitation (2R)	6	19	$1,090.3	1	0	0	0	0	0	0	8	6	4
201.151 Drainage System Restoration	7	30	$133.5	8	3	4	6	3	3	3	0	0	0
201.112 Bridge Rail Replacement Upgrade	8	13	$119.5	2	2	1	3	1	2	0	1	1	0
201.335 Stormwater	9	25	$188.2	0	0	0	0	0	3	2	1	8	11
201.315 Transportation Management Systems	10	22	$237.2	5	2	3	3	1	2	4	0	2	0
201.322 Trans Permit Requirements for Bridges	11	4	$60.0	0	0	0	0	0	0	0	0	2	2
201.150 Roadway Protective Betterment	12	10	$40.5	0	1	0	3	0	4	1	0	1	0
201.310 Operational Improvements	13	12	$108.3	3	2	2	1	2	0	1	1	0	0
201.240 Roadside Protection and Restoration	14	4	$18.5	0	0	0	0	0	0	0	0	0	4
201.250 Safety Roadside Rest Area Rehabilitatic	15	2	$22.0	0	0	0	0	0	0	0	0	1	1
201.210 Roadside Rehabilitation	16	4	$9.0	0	1	2	0	1	0	0	0	0	0
201.170 Signs and Lighting Rehabilitation	17	10	$38.0	5	2	1	0	0	2	0	0	0	0
201.160 Relinquishments	18	0	$0.0	0	0	0	0	0	0	0	0	0	0
201.325 Railroad at-grade Crossing	19	0	$0.0	0	0	0	0	0	0	0	0	0	0
201.330 Hazardous Waste Mitigation	20	1	$5.1	0	0	0	0	0	0	0	1	0	0
201.352 Maintenance Facilities	21	3	$22.0	0	0	0	0	0	0	0	2	1	0
201.351 Equipment Facilities	22	1	$29.0	0	0	0	0	0	0	0	0	0	1
201.353 Office Buildings	23	0	$0.0	0	0	0	0	0	0	0	0	0	0
201.260 New Safety Roadside Rest Areas	25	0	$0.0	0	0	0	0	0	0	0	0	0	0
Summary by Asset Type													
Bridge		64	$678.6	9	9	5	11	8	6	7	3	3	3
Pavement		65	$2,201.2	1	2	1	2	3	7	8	21	14	6
Culvert		30	$133.5	8	3	4	6	3	3	3	0	0	0
TMS Elements		34	$345.5	8	4	5	4	3	2	5	1	2	0

Table 3-4 – Ranking Summary by Program Funding

Program	Program Priority	Number of Projects	Total Program Funding ($mil)	Percentile Ranking of Project Funding ($mil) by Program Presents sub-totals of program funds broken down into 10% ranking bins 0%-10% (Highest Priorities)	11%-20%	21%-30%	31%-40%	41%-50%	51%-60%	61%-70%	71%-80%	81%-90%	91%-100% (Lowest Priorities)
201.130 Emergency Damage Repair	1	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
201.010 Safety Improvements	1	2	$107.0	$0.0	$0.0	$0.0	$0.0	$0.0	$5.3	$0.0	$0.0	$0.0	$101.7
201.131 Permanent Restoration	1	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
201.361 ADA Access Improvements	1	22	$105.9	$0.0	$0.0	$3.6	$5.0	$9.9	$6.8	$22.0	$0.0	$27.6	$31.0
201.378 ADA Pedestrian Infrastructure	1	9	$44.0	$0.0	$0.0	$3.2	$1.9	$6.5	$0.0	$10.5	$18.9	$0.0	$3.0
201.235 Roadside Safety Improvements	1	59	$262.2	$5.7	$27.1	$54.5	$22.7	$40.2	$39.9	$32.2	$9.2	$16.3	$14.2
201.119 Bridge Preventive Maintenance	1	13	$78.7	$11.1	$3.7	$3.6	$34.5	$5.3	$0.0	$20.5	$0.0	$0.0	$0.0
201.321 Weigh Stations & WIM Facilities	1	7	$30.7	$0.0	$0.0	$0.0	$0.0	$2.3	$10.3	$5.5	$12.5	$0.0	$0.0
201.015 Collision Severity Reduction	2	32	$296.6	$18.5	$25.6	$23.4	$16.9	$49.0	$0.0	$36.3	$43.3	$9.4	$74.1
201.111 Bridge Scour Mitigation	3	2	$25.1	$0.0	$0.0	$0.0	$0.0	$0.0	$11.4	$13.7	$0.0	$0.0	$0.0
201.113 Bridge Seismic Restoration	4	11	$95.1	$2.8	$25.8	$4.7	$11.1	$36.6	$0.0	$14.2	$0.0	$0.0	$0.0
201.110 Bridge Rehabilitation	5	21	$300.3	$11.2	$15.5	$16.8	$17.6	$18.6	$32.4	$40.0	$22.3	$0.0	$125.9
201.120 Roadway Rehabilitation (3R)	6	5	$304.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$54.4	$0.0	$74.8	$175.0
201.121 Roadway Preservation (CAPM)	6	41	$806.8	$0.0	$13.5	$4.8	$23.2	$44.8	$79.3	$100.8	$332.6	$148.4	$59.5
201.122 Roadway Rehabilitation (2R)	6	19	$1,090.3	$1.9	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$239.4	$388.6	$460.5
201.151 Drainage System Restoration	7	30	$133.5	$15.9	$11.8	$20.1	$30.0	$14.6	$18.4	$22.7	$0.0	$0.0	$0.0
201.112 Bridge Rail Replacement Upgrade	8	13	$119.5	$5.3	$12.8	$6.2	$18.6	$8.8	$22.3	$0.0	$21.8	$23.6	$0.0
201.335 Stormwater	9	25	$188.2	$0.0	$0.0	$0.0	$0.0	$0.0	$10.9	$8.1	$1.7	$52.5	$115.0
201.315 Transportation Management Systems	10	22	$237.2	$18.5	$10.7	$19.1	$25.7	$4.2	$26.8	$66.6	$0.0	$65.6	$0.0
201.322 Trans Permit Requirements for Bridges	11	4	$60.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$27.2	$32.8
201.150 Roadway Protective Betterment	12	10	$40.5	$0.0	$2.5	$0.0	$7.5	$0.0	$13.7	$4.3	$0.0	$12.5	$0.0
201.310 Operational Improvements	13	12	$108.3	$8.4	$15.6	$18.2	$8.7	$20.2	$0.0	$10.0	$27.2	$0.0	$0.0
201.240 Roadside Protection and Restoration	14	4	$18.5	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$18.5
201.250 Safety Roadside Rest Area Rehabilitatic	15	2	$22.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$11.0	$11.0
201.210 Roadside Rehabilitation	16	4	$9.0	$0.0	$1.6	$5.0	$0.0	$2.5	$0.0	$0.0	$0.0	$0.0	$0.0
201.170 Signs and Lighting Rehabilitation	17	10	$38.0	$13.1	$10.3	$3.4	$0.0	$0.0	$11.2	$0.0	$0.0	$0.0	$0.0
201.160 Relinquishments	18	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
201.325 Railroad at-grade Crossing	19	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
201.330 Hazardous Waste Mitigation	20	1	$5.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$5.1	$0.0	$0.0
201.352 Maintenance Facilities	21	3	$22.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$13.9	$8.1	$0.0
201.351 Equipment Facilities	22	1	$29.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$29.0
201.353 Office Buildings	23	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
201.260 New Safety Roadside Rest Areas	25	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Summary by Asset Type													
Bridge		64	$678.6	$30.5	$57.7	$31.2	$81.9	$69.4	$66.0	$88.4	$44.1	$50.8	$158.6
Pavement		65	$2,201.2	$1.9	$13.5	$4.8	$23.2	$44.8	$79.3	$155.1	$572.0	$611.7	$694.9
Culvert		30	$133.5	$15.9	$11.8	$20.1	$30.0	$14.6	$18.4	$22.7	$0.0	$0.0	$0.0
TMS Elements		34	$345.5	$26.9	$26.3	$37.3	$34.4	$24.3	$26.8	$76.6	$27.2	$65.6	$0.0

3.3.2. Observations

The breakdown of priorities by program count and funding into percent-rank groupings highlighted some trends and biases in the methodology. Combined with the detailed scoring results presented in Appendix B, the following notable observations can be made:

- The strong emphasis on the weight for the Safety goal (35%) had a significant influence on the ranking outcome. Upper ranked projects had a significant portion of their scores attributable to Safety, as can be seen in the project-level scores in Appendix B.
- Pavement projects were predominantly ranked in the lower half of all projects, primarily due to high project costs. It appears that the scoring models may not adequately scale upwards with the magnitude of the project in the same way it does for other types of asset preservation projects.
- A reliance on program codes (rather than specific details of the work) as basis for some scoring appears to bias certain programs. While this approach was a necessity due to the lack of sufficient project-level information, the apparent bias boosted some programs while penalizing others. For example, Scoring under the System Performance goal was only carried out for those

projects in the 201.310 (Operational Improvements) and 201.315 (Transportation Management Systems) programs.

- Projects in 201.240 (Roadside Protection and Restoration) program scored low or did not score at all, as benefits from these projects were not considered in many of the calculations that relied on program codes as a filter.
- A couple of projects at the bottom rank could not be scored due to the lack of specific location information. These were typically described as having "various" locations. As these projects could not be processed in the geo-spatial analysis stage, key data parameters could not be extracted to support scoring.
- Project location information influenced scoring. Some projects with discreet locations (e.g. traffic camera installation locations along a corridor) were described by the full postmile extent, while other projects with similar work were described by specific locations. The geo-spatial analysis used the "footprint" of the project (either a collection of points or a bounded line) to associate other types of data to a project (e.g. traffic volume). The inconsistency in handling project limits, in some instances, may have introduced a bias in the scoring.

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4. Limitations of the Analysis and Method

4.1. Data Availability and Accuracy

As with the 2014 SHOPP analysis framework, a data-driven approach was carried over in the development of the 2016 SHOPP analysis framework. This was an intentional design decision to eliminate subjectivity from the scoring process to the extent possible. The data sets used were typically in the form of spreadsheets, databases, and the Department's geospatial data libraries.

Although the combination of data sets provided a sound basis to carry out many of the calculations, a number of errors, omissions, and misrepresentations were likely introduced into the project prioritization outcomes. For example, project specific data from Project Initiation Documents (PIDs) were not used, as the files were in a format (i.e. scanned PDF files) that could not be systematically parsed. In the geo-spatial analysis, the project's spatial limits, defined by begin and end postmiles, were used in many calculations to infer key parameters, such as traffic volumes, roadway attributes, and regional air quality metrics. Some projects cited limits encompassing broad regions where key parameters varied widely, while other projects cited specific spot locations where more representative key parameters could be assigned. These data-related issues could be reasonably addressed in the future with more time and a carefully constructed process to parse data from PIDs at the time of submission.

4.2. Over-Simplification of Complex Correlations

The project prioritization framework likely over-simplifies many complex correlations. In some instances the simplifications were applied due to the lack of availability of data. For example, program codes were used in many calculations as a proxy to infer benefit provided by a particular type of project. In other instances the simplifications were necessary in order to reduce the complexity of a more rigorous benefit calculation based on multiple factors. The approach applied to scaling project value to the size of the project, in particular, is a key issue that warrants more study. The choices made in the calculation framework likely have an impact on the overall determination of project value and rankings. However, the specific influence of these tradeoffs on the resulting project priorities was not studied.

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5. Recommendations

Recommendations for the future SHOPP development process are as follows:

- Engage experts in the field of decision analysis and project prioritization to review the work carried out to date on the 2014 and 2016 SHOPP prioritization efforts and guide the development of an improved framework for the 2018 SHOPP process.
- Develop and implement web-based tools and business processes to more effectively capture SHOPP project-specific data necessary to drive the prioritization process.
- Using the spreadsheet-based prioritization tool as an example prototype, develop an operational web-based tool (or extend functionality in existing SHOPP tools) that facilitates the calculation of values and project prioritization.
- Identify changes in the SHOPP programming workflow, such that project prioritization occurs earlier in the planning phases, prior to PID development.

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Appendix A – Description of Calculations

This appendix documents the calculations used for the benefit sub-models in determining Project Value. The calculations used in the 2016 SHOPP analysis differ from those applied in the 2014 SHOPP analysis. As part of the Department's ongoing asset management implementation, a new Asset Management Pilot Program[7] was initiated as part of the 2016 SHOPP. Through efforts led by the State Asset Management Engineer, project nominations were reviewed by Strategic Plan goal teams that evaluated the projects' contributions toward each of the department's five strategic goals relative to the proposed cost of the projects. These calculation methods employed by the goal teams were used directly or adapted, where feasible, in the 2016 SHOPP prioritization described in this report.

A.1 – Minimize Injuries and Fatalities of Workers

Step 1 – Estimate the Hours of Worker Exposure within Project Limits

For the projects in the 235 Roadside Safety Improvements program, actual annual worker hours were compiled from Caltrans' Integrated Maintenance Management System (IMMS)[8] using a 3-year average. IMMS captures the detailed time charges by Caltrans staff for maintenance work performed on roadway elements by postmile. This level of data compilation was not practical to carry out for non-235 projects due to the time required to query data from the system. As an alternative, a statewide annual average was calculated on a per-mile basis using data on worker hours associated with all highway maintenance activities. The result of both approaches was the number of Caltrans worker hours associated within a project's limit.

An analysis of the project worker hours showed a large variation. A percentile-based analysis was used to categorize worker hours into three broad exposure categories, as presented in Table A-1.

Table A-1 – Worker Exposure Category

Percentile	Hours	Exposure
33%	1,074	Low
67%	10,944	Medium
100%	2,379,464	High

Step 2 – Obtain Annual Average Daily Traffic (AADT)

The maximum *Annual Average Daily Traffic (AADT)* within the project limits is obtained from Transportation System Network (TSN) data sources.

[7] http://www.dot.ca.gov/tam/shopp/ampp.html
[8] http://www.dot.ca.gov/hq/maint/imms/

Step 3 – Calculate the Project Location Risk Score

A metric representing the degree of worker exposure was created, called the *Project Location Risk Score (S_{PL})*. This score uses a combination of the number of hours of worker exposure and traffic volume to assign a relative 0-100 score, as shown in Table A-2. Projects with higher traffic volumes and worker activity are more likely to have a higher risk.

Table A-2 – Project Location Risk Score

		AADT Range		
	(max)	no limit	75000	15000
Exposure	(min)	75000	15000	0
High		100	75	50
Medium		75	50	25
Low		50	25	5

All projects in the 235 program receive a score of 100, regardless of traffic volume and/or worker exposure.

Step 4 – Determine the Worker Safety Program Factor

The *Worker Safety Program Factor (F_{WS})* is determined by the SHOPP program code, as presented inTable A-1. These factors were assigned by subject matter experts based on judgment, and represent the degree to which some project types contribute to worker safety more than others.

Table A-3 – Worker Safety Program Factor

Program Code	Priority	Program	Worker Safety Factor
201.130	1	Emergency Damage Repair	1
201.010	1	Safety Improvements	1
201.131	1	Permanent Restoration	0.5
201.361	1	ADA Access Improvements	0
201.378	1	ADA Pedestrian Infrastructure	0
201.235	1	Roadside Safety Improvements	1
201.119	1	Bridge Preventive Maintenance	1
201.321	1	Weigh Stations & WIM Facilities	0
201.015	2	Collision Severity Reduction	1
201.111	3	Bridge Scour Mitigation	0
201.113	4	Bridge Seismic Restoration	0
201.110	5	Bridge Rehabilitation	1
201.120	6	Roadway Rehabilitation (3R)	1
201.121	6	Roadway Preservation (CAPM)	0.5
201.122	6	Roadway Rehabilitation (2R)	0.5
201.151	7	Drainage System Restoration	0.5
201.112	8	Bridge Rail Replacement/Upgrade	1

Program Code	Priority	Program	Worker Safety Factor
201.335	9	Stormwater	0
201.315	10	Transportation Management Systems	0
201.322	11	Trans Permit Requirements for Bridges	0
201.150	12	Roadway Protective Betterment	0.5
201.310	13	Operational Improvements	0
201.240	14	Roadside Protection and Restoration	0
201.250	15	Safety Roadside Rest Area Rehabilitation	0
201.210	16	Roadside Rehabilitation	1
201.170	17	Signs and Lighting Rehabilitation	1
201.160	18	Relinquishments	0
201.325	19	Railroad at-grade Crossing	0
201.330	20	Hazardous Waste Mitigation	0
201.352	21	Maintenance Facilities	1
201.351	22	Equipment Facilities	1
201.353	23	Office Buildings	1
201.260	25	New Safety Roadside Rest Areas	0

Step 5 – Calculate the Worker Safety Benefit Score

The *Worker Safety Benefit Score (B_{WS})* is calculated using the *Project Location Risk Score (S_{PL})* and the *Worker Safety Program Factor (F_{WS})* as follows:

$$B_{WS} = (F_{WS}) \times (S_{PL})$$

The resulting benefit score ranges from 0-100.

A.2 – Minimize Injuries and Fatalities of Users

Step 1 – Calculate the Project Location Risk Score

A metric representing the degree to which some projects are more susceptible to accidents than others is defined, called the *Project Location Risk Score (S_{PL})*. This score uses a combination of as-built highway features and type. Values associated with the various types of features were determined based on consultation with subject matter experts. The list of attributes is as follows:

- Functional Class
- Total Lanes
- Divided or Undivided
- Access Control
- Terrain (i.e., rolling, flat, mountainous)
- Rural or Urban
- Median Type
- Pavement Surface

For each project, the as-built attributes are used to assign a score on a 0-100 scale, as shown in Table A-4. A weighted sum is then calculated from these scores. Weights are assigned to the features based on judgments by subject matter experts.

Table A-4 – Highway Attribute Scoring

Highway Group		Score
R	Independent Alignment - Right	10
L	Independent Alignment - Left	10
D	Divided Highway	60
U	Undivided Highway	90
X	Unconstructed Highway	10
	Group Weight	90

Population Code		Score
B	Urban	90
R	Rural	50
U	Urbanized	70
	Group Weight	100

Functional Class		Score
0	None	20
1	Principle Arterial w/ C/L Principle Arterial	90
2	Principle Arterial w/ C/L Minor Arterial	85
3	Principle Arterial Non-Connecting Link	80
4	Minor Arterial	40
5	Major Collector	50
6	Minor Collector	30
7	Local	20
	Group Weight	90

Access Control		Score
C	Conventional	80
E	Expressway	70
F	Freeway	50
S	One-Way City Street	60
	Group Weight	100

Terrain		Score
F	Flat	20
R	Rolling	30
M	Mountainous	50
	Group Weight	20

Pavement Surface Type		Score
B	Bridge Deck	50
C	Concrete	50
H	Base & Surface >7" Thick	20
M	Base & Surface <7" Thick	20
O	Oiled Earth - Gravel	80
P	Bridge Deck	50
E	Earth	90
F	Undetermined	70
G	Bridge Deck (All Not Codes B or P)	40
	Group Weight	80

Median Type		Score
A	Cable Barrier	70
B	Cable Barrier w/ Glare Screen	70
C	Metal Beam Barrier	30
D	Metal Beam Barrier w/ Glare Screen	20
E	Concrete Barrier	60
F	Concrete Barrier w/ Glare Screen	60
G	Bridge Barrier Railing	30
H	Chain Link Fence	20
J	Guardrail in Median Both Roadway	40
K	Guardrail in Median Left Roadway	40
L	Guardrail in Median Right Roadway	30
M	Two-Way, One Lane Road	80
N	Thrie Beam Barrier	60
P	Thrie Beam Barrier w/ Glare Screen	55
Q	Conc. Barrier, Both Ways Inside Both Shoulders	45
R	Conc. Barrier, Left Rdwy Median Shoulder Area	60
S	Conc. Barrier, Right Rdwy Median Shoulder Area	50
X	External Barriers on Median Type = C or E	60
Y	Other Not Included Above	60
Z	No Barriers	90
	Group Weight	20

Step 2 – Determine the Accident Rate Score

Based on accident data extracted from TASAS over the past 12-month period, an *Accident Rate Score (S_{AR})* is calculated. The calculation of this score takes the accident rate within the project's limits, normalizes it by percent-rank for all projects under consideration, and multiplies the result by 100.

Step 3 – Determine the User Safety Program Factor

The *User Safety Program Factor (F_{US})* is determined by the SHOPP program code, as presented inTable A-1. These factors were derived with input from subject matter experts based on judgment, and represent the degree to which some project types contribute to worker safety.

Table A-5 – User Safety Program Factor

Program Code	Priority	Program	Worker Safety Factor
201.130	1	Emergency Damage Repair	1
201.010	1	Safety Improvements	1
201.131	1	Permanent Restoration	0.5
201.361	1	ADA Access Improvements	0.2
201.378	1	ADA Pedestrian Infrastructure	0.4
201.235	1	Roadside Safety Improvements	0.2
201.119	1	Bridge Preventive Maintenance	1
201.321	1	Weigh Stations & WIM Facilities	0.5
201.015	2	Collision Severity Reduction	1
201.111	3	Bridge Scour Mitigation	1
201.113	4	Bridge Seismic Restoration	1
201.110	5	Bridge Rehabilitation	1
201.120	6	Roadway Rehabilitation (3R)	1
201.121	6	Roadway Preservation (CAPM)	0.5
201.122	6	Roadway Rehabilitation (2R)	0.5
201.151	7	Drainage System Restoration	0
201.112	8	Bridge Rail Replacement/Upgrade	1
201.335	9	Stormwater	0
201.315	10	Transportation Management Systems	0.3
201.322	11	Trans Permit Requirements for Bridges	0
201.150	12	Roadway Protective Betterment	0.5
201.310	13	Operational Improvements	0.7
201.240	14	Roadside Protection and Restoration	0
201.250	15	Safety Roadside Rest Area Rehabilitation	0.4
201.210	16	Roadside Rehabilitation	0
201.170	17	Signs and Lighting Rehabilitation	0.5
201.160	18	Relinquishments	0
201.325	19	Railroad at-grade Crossing	1
201.330	20	Hazardous Waste Mitigation	0
201.352	21	Maintenance Facilities	0
201.351	22	Equipment Facilities	0
201.353	23	Office Buildings	0
201.260	25	New Safety Roadside Rest Areas	0.7

Step 4 – Calculate the User Safety Benefit Score

The *User Safety Benefit Score (B_{US})* is calculated using the *Project Location Risk Score (S_{PL})*, the *Accident Rate Score (S_{AR})*, and the *User Safety Program Factor (F_{US})* as follows:

$$B_{WS} = (F_{WS}) \times 0.5(S_{PL} + S_{AR})$$

The resulting benefit score ranges from 0-100.

A.3 – Maximize Community Health through Active Transportation

Step 1 – Determine the Air Quality at the Project Site

The existing air quality in the region of the proposed project is determined by county-wide maximum ozone levels, measured in parts-per-million (ppm). The source for ozone data is the *CalEnviroScreen Version 2.0* website[9], developed by the Office of Environmental Health Hazard Assessment (OEHHA), on behalf of the California Environmental Protection Agency (CalEPA). The data is made available through their website as an ArcGIS point shapefile. Data points are aggregated by county within ArcGIS, and the resulting maximum ozone levels are associated to SHOPP projects.

Ozone measures are assigned to one of three categories (i.e. *high, medium, low*) based on the criteria presented in Table A-6.

Table A-6 – Ozone level category

Ozone Measure (ppm)	Air Quality
0.60-0.30	Poor
0.29-0.10	Fair
0.09-0	Good

Step 2 – Determine the Number of Active Transportation Elements

An assessment of all new 2016 SHOPP projects was carried out by the Districts that prepared the PID submittals. District project leads were asked to respond "yes" or "no" to indicate the presence of one or more active transportation elements in the project. These elements are as follows:

- New Pedestrian Facility
- Upgraded Pedestrian Facility
- New Bicycle Facility
- Upgraded Bicycle Facility
- Transit

Step 3 – Determine the Health Benefit Score

The *Active Transportation Score (S_{AT})* is determined from the air quality category and the number of active transportation elements, using the matrix presented in Table A-7.

[9] http://oehha.ca.gov/ej/ces2.html

Table A-7 – Active Transportation Score

Air Quality	Active Transportation Elements					
	5	4	3	2	1	0
Poor	100	90	80	70	60	0
Fair	80	70	60	50	40	0
Good	60	50	40	30	20	0

Step 4 – Calculate the Project Area Factor

The *Project Area Factor (F_{PA})* serves as a proxy for the extent to which the active transportation elements impacts users. Larger projects that incorporate elements are expected to have a more significant impact to the community – e.g. a 100 mile pavement project that adds an element is likely to provide more benefit than a 1 mile pavement project that incorporates the same element. F_{PA} is calculated as follows:

$$F_{PA} = \text{(Project length) / (Max project length of all SHOPP projects)}$$

A maximum project length of 10 miles is used in the F_{PA} calculation. The resulting factor is limited to a maximum value of 1.0.

Step 5 – Calculate the Health Benefit Score

The *Health Benefit Score (B_{HB})* is determined as follows:

$$B_{HB} = F_{PA} \times S_{AT}$$

A.4 – Minimize Cost of Maintaining Transportation Infrastructure

Step 1 – Calculate the Condition Benefit Factor

The *Condition Benefit Factor (F_{CB})* is determined from the pre-project condition of the asset and the type of work performed, either preservation or rehab/replacement. F_{CB} values range from 1 to 10, and are determined by the matrix presented in Table A-8. Pre-project condition data is obtained from Department sources for bridge, pavement, culvert, and traffic management systems asset inventories.

Table A-8 – Condition Benefit Factor Matrix

Pre-Project Condition	Proposed Project Type	
	Preservation	Rehab/Replacement
Good	5	1
Fair	8	5
Poor	2	10

Step 2 – Determine Quantities and Unit Costs for Project Activities

For each project, the quantity and corresponding unit cost is determined for the activity, based on values presented in Table A-9.

Table A-9 –Unit Costs by Asset Type

Activity Category	Activity Detail	Unit Cost of Activity including support	Units
Bridge	Bridge Preservation	$400	Sq Ft
	Bridge Replacement	$1,000	Sq Ft
	Bridge Rail	$2,000	LF
	Bridge Widening	$1,000	Sq Ft
	Pedestrian Overcrossing	$1,000	Sq Ft
Culvert	Replace Culverts	$2,000	LF
	Fish Passage	$2,000	LF
Facilities	Maintenance Building	$425	Sq Ft
	Equipment Shop	$350	Sq Ft
	Lab	$550	Sq Ft
	TMC	$500	Sq Ft
	Office Buildings	--	Sq Ft
Pavement	Pavement Rehab/Replace	$895,000	lane mile
	Pavement Overlay (CAPM)	$309,000	lane mile
	Median Island Paving	$11	SF
	Shoulder	$25	SF
Roadside	Erosion Control	$20,000	Acre
	Guard Rail	$39	LF
	HMA dike	$6	LF
	Luminaires/Lighting	$13,000	EA
	Maintenance Vehicle Pullouts	$25,000	EA
	Planting and Irrigation	$110,000	Acre

Activity Category	Activity Detail	Unit Cost of Activity including support	Units
	Rest Stop (Solar)	$4,030,000	EA
	Retaining Wall	$325	LF
	Roadside Paving	$25	SF
	Rock Slope Protection	$40,000	EA
	R/W Fencing	$90	LF
	Sideslopes	--	
	Vegetation Control (guardrail)	--	
	Wetlands	--	
Safety	Median Barrier	$350	LF
	Rumble Strips		
Streets	ADA Curb Ramps	$15,000	EA
	Bike Lanes	$25	SF
	Curb and Gutter	$77	LF
	Curb Extensions and PPB	$39,000	EA
	Driveways	$150	LF
	Intersection improvements	--	
	Multi-use Path	$25	SF
	Pedestrian Signals (APS, PCT, PHB)	$7,500	Each
	Sidewalks	$150	LF
	Transit (Bus stations)	$13,000	Each
	Utility undergrounding		
Traffic	Blank-out / Radar Sped Signs	$25,000	EA
	Census Station	$20,000	EA
	Changeable Message Sign	$327,320	EA
	CCTV	$93,000	EA
	Fiber Optic Communications	$59	LF
	Loop Detection Station (16 Loop VDS)	$1,000	per # loops
	Ramp Meter	$182,280	EA
	Railroad Crossing Arms	--	
	Roundabout	--	
	Traffic Signals	$462,280	EA
	Video Detection	$72,000	EA

Step 3 – Calculate the Condition Benefit Score

The *Condition Benefit Score (S_{CB})* is calculated as the product of the *Condition Benefit Factor (F_{CB})*, the activity quantity, and the activity unit cost. The resulting metric is expressed as an integer value in multiples of $1x10^6$, as follows:

$$S_{CB} = F_{CB} \text{ x (activity quantity) x (activity unit cost) / } (1x10^6)$$

Step 4 – Calculate the Consequence Factor

The *Consequence Factor (F_C)* is determined by the type of project and asset using Table A-10.

Table A-10 – Consequence of Conditional Failure

System Impact	Asset/Activity	Factor
Potential highway closure or long detour (>20 mi) over an extended period of time (>5 days)	• Bridge rehabilitation/replacement of poor condition bridge that carries highway traffic. • Scour mitigation of scour critical bridges. • Bridge seismic - Tier 1 seismic bridge • Culvert rehabilitation/replacement of poor condition culvert • Facilities - fire, life and safety projects	2
Short term closure or short term partial highway lane capacity loss	• Pavement – Rehabilitation of poor condition pavement (2R,3R) only. • Bridge seismic - Tier 2 or higher seismic bridge needs	1.5
Failure of asset does not significantly impact highway capacity	• All other assets/activities	1

Step 5 – Determine the Traffic Volume and Freight Score

The *Traffic Volume and Freight Score (S_{TF})* is determined from the maximum *Annual Average Daily Traffic (AADT)* and *Annual Average Daily Truck Traffic (AADTT)*. Table A-11 is used to determine S_{TF}. The higher of either the AADT or AADTT based score is used.

Table A-11 – Matrix for Traffic Volume and Freight Score

AADT	AADTT	Score
200000	14000	100
130000	12000	90
75000	10000	80
35000	8000	70
25000	6000	60
15000	4000	50
7500	2000	40
5000	1000	30
2500	500	20
0	0	10

Step 6 – Calculate the Stewardship Benefit Score

The *Stewardship Benefit Score (B_{SB})* is calculated as a constructed metric using the *Consequence Factor (F_C)*, the *Condition Benefit Score (S_{CB})*, and the *Traffic Volume and Freight Score (S_{TF})* as follows:

$$B_{SB} = F_C * (0.7\ S_{CB} + 0.3\ S_{TF})$$

The results are normalized to a 0-100 score.

A.5 – Minimize Costs to Users

Users of the highway system are subject to significant vehicle operating costs, including fuel and oil consumption, tire wear, repair and maintenance, and depreciation. These costs are largely dependent on the vehicle class and are influenced by vehicle technology, pavement-surface type, pavement condition, roadway geometrics, environment, speed of operation, and other factors. SHOPP projects have the capacity to reduce vehicle operating costs in a number of ways – reducing pavement roughness, reducing travel-time delay, etc. However, for purposes of the SHOPP Pilot Project, the benefit sub-model used is built upon the reduction in pavement roughness and the related improvements in fuel economy.

A study conducted through the National Cooperative Highway Research Program (NCHRP), titled "NCHRP 720: Estimating the Effects of Pavement Condition on Vehicle Operating Cost,"[10] described three primary areas of vehicle operating costs tied to pavement roughness: fuel efficiency, tire wear, and vehicle repair and maintenance. Numerous models have been proposed by researchers to quantify these costs. Overall, there is general consensus that fuel consumption related to pavement roughness is the largest component of cost. The study suggests that the change in fuel consumption can be as much as 12% for an IRI reduction from 6 m/km (380 in/mi) to 1 m/km (63.4 in/mi) for some vehicle classes. Additionally, for newly rehabilitated pavements, a Federal Highway Administration (FHWA) study showed that "85 percent of the test sections had an IRI value of less than 1.2 m/km (76 in/mi)" after overlay.[11]

Step 1 – Calculate the Annual Vehicle Miles Traveled (VMT_{365})

For each project, an annual VMT within the limits of the project is calculated as follows:

$$VMT_{365} = [\text{AADT vehicles/day}] \times [\text{Project Length, L miles}] \times [\text{365 days/year}]$$

Step 2 – Calculate Annual Average Fuel Cost

For each project, the annual average fuel cost for all vehicle types attributed to the limits of the SHOPP project is estimated as follows:

$$\text{Fuel Cost} = \text{VMT (miles)} \times (\text{23.3 miles/gallon})^{12} \times (\$3.00/\text{gallon})^{13}$$

[10] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_720.pdf

[11] FHWA Tech Brief, "Reducing Roughness in Rehabilitated Asphalt Concrete (AC) Pavements," PUBLICATION NO. FHWA-RD-98-149
http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/98149/98149.pdf

[12] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

[13] http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sca_a.htm

Step 3 – Calculate the Percent Reduction in Fuel Consumption

Determine the percent reduction in fuel consumption using the maximum IRI value within the limits of the SHOPP project and the assumption that any pavement work will result in an IRI of 76 inches/mile or less following the construction/maintenance work.

$$Percent\ reduction\ in\ fuel\ consumption = 2.4\ \cdot IRI \cdot \left(\frac{1\ m/km}{63.4\ in/mi}\right) - 2.4$$

Note: Although not used in this calculation sub-model, the percent reduction in fuel mileage is commensurate with the percent reduction in greenhouse gas (GHG) emissions. The rate of CO2 emissions can be calculated based on fuel consumption, per the Environmental Protection Agency[14] and US Department of Transportation studies.[15] These studies established the initial National Program fuel economy standards for model years 2012-2016 and a common conversion factor of 8.887×10^{-3} metric tons CO2/gallon of gasoline. Using the 2012 US DOT reported vehicle fleet average of 23.3 mpg,[16] the estimated GHG emissions within the limits of a project can be calculated as follows:

Existing GHG emissions = VMT_{365} x 1/(23.3 mpg) x (8.887×10^{-3} metric tons CO2/gallon)

Step 4 – Calculate the Total Reduction in Fuel Costs

Multiply the percent reduction in fuel consumption by the existing fuel consumption cost to get the overall reduction in fuel consumption cost.

Total reduction fuel consumption cost = (% reduction) x (existing fuel consumption cost)

Step 5 – Calculate the User Cost Reduction Benefit Score

The *User Cost Reduction Benefit Score (B_{UC})* is calculated by taking the maximum value for the reduction in fuel consumption cost for all SHOPP projects under consideration and normalizing on a scale of 0-100, as follows:

B_{UC} = (Total reduction fuel cost) / (Max reduction in fuel cost)

An upper limit value for the max reduction in fuel cost of $20mil is used in this calculation.

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14 http://www.epa.gov/cleanenergy/energy-resources/refs.html

15 http://www.gpo.gov/fdsys/pkg/FR-2010-05-07/pdf/2010-8159.pdf

16 http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

A.6 – Minimize Travel Delay Time for Users

Users of the highway system can benefit from travel delay reductions. Two categories of SHOPP projects specifically address this – Program 201.310 Operational Improvements and 201.315 Transportation Management Systems. The benefit sub-model adopted for the SHOPP Pilot Project uses these program codes in combination with traffic volumes to determine an overall score.

Step 1 – Assign Activity Value to Projects

For projects in the 201.310 Operational Improvements and 201.315 Transportation Management Systems programs, an assessment of the *Delay Reduction Activity Value* is determined using criteria presented in Table A-12.

Table A-12 – Delay Reduction Activity Value

Activity Value	Activity Type
High	High volume relief (Hard shoulder running, switchable lanes)
	Auxiliary lanes
	Ramp metering
	Signal timing upgrades
	Connected or integrated corridor systems
	Connection or intersection improvements
	Managed Lanes
	Upgrade, replace, or add new detection (part of a TMS system, completing a system)
Medium	Support incident response (CCTV, associated communications, TMC upgrades)
	Roundabouts
	Strategies supporting bus or rail usage
	Strategies supporting active transportation (bike & ped)
	Improve communication / Fiber replacement
	CMS or EMS signs
Low	Turn lane reconfigurations
	Park and ride facilities

Step 2 – Determine Corridor Hours of Delay at 35 mph

For each project, determine the *Corridor Hours of Delay at 35 mph*. This metric is available through the *Caltrans Performance Measurement System (PeMS).*[17]

Step 3 – Calculate the Delay Reduction Benefit Score

The *Delay Reduction Benefit Score* (B_{DR}) is determined using Table A-13.

[17] http://pems.dot.ca.gov/

Table A-13 – Delay Reduction Benefit Score

	Corridor Hours of Delay at 35mph		
	> 100,000 hrs	10,000 - 100,000 hrs	< 10,000 hrs
High Value Activity	100	80	30
Medium Value Activity	70	50	20
Low Value Activity	20	20	10

A.7 – Maximize Travel Time Reliability for Users

Users of the highway system can benefit from the reduction in uncertainties in travel time estimates. Two SHOPP programs specifically address this – 201.310 Operational Improvements and 201.315 Transportation Management Systems. The benefit sub-model adopted for the SHOPP Pilot Project uses these program codes in combination with traffic volumes to determine an overall score.

Step 1 – Assign Activity Value to Projects

For projects in the 201.310 Operational Improvements or 201.315 Transportation Management Systems programs, an assessment of the *System Reliability Activity Value* is determined using the criteria presented in Table A-14.

Table A-14 – System Reliability Activity Value

Activity Value	Activity Type
High	Auxiliary lanes
	Support incident response (CCTV, associated communications, TMC upgrades)
	High volume relief (Hard shoulder running, switchable lanes)
	Connected or integrated corridor systems
	Connection reconfigurations
	Signal timing upgrades
	Ramp metering
Medium	Upgrade, replace, or add new detection (part of a TMS system, completing a system)
	CMS or EMS signs
	Improve communication / Fiber replacement
	Safety improvements
Low	Park and ride facilities
	Managed Lanes
	Turn lanes
	Rural roundabouts

Step 2 – Determine Corridor Buffer Time Index

For each project, determine the *Corridor Buffer Time Index*. The Buffer Time Index (BTI) expresses the amount of extra "buffer" time needed to be on-time 95 percent of the time.[18] This metric is available through the *Caltrans Performance Measurement System (PeMS).*[19]

Step 3 – Calculate the Travel Time Reliability Benefit Score

The *Travel Time Reliability Benefit Score (B_{TT})* is determined using Table A-15.

[18] http://www.ops.fhwa.dot.gov/congestion_report_04/appendix_C.htm

[19] http://pems.dot.ca.gov/

Table A-15 – System Reliability Benefit Score

	Corridor Hours of Delay at 35mph		
	> 100,000 hrs	10,000 - 100,000 hrs	< 10,000 hrs
High Value Activity	100	70	30
Medium Value Activity	70	50	20
Low Value Activity	30	20	10

A.8 – Maximize multimodal transportation options

Step 1 – Determine the Modal Improvement Score

The *Modal Improvement Benefit Score* (B_{MI}) is determined from an assessment of the project in addressing goals of the *Complete Streets*[20] program. District Project Managers were asked to review their projects and indicate the inclusion of the following elements:

- New Pedestrian Facility
- Upgraded Pedestrian Facility
- New Bicycle Facility
- Upgraded Bicycle Facility
- Transit

20 points were added to the score for the occurrence of each element, with a maximum score of 100 for a given project.

[20] http://www.dot.ca.gov/hq/tpp/offices/ocp/complete_streets.html

A.9 – Minimize Disruption of the Economy

Step 1 – Determine the Maximum AADTT within the Project Limits

The volume of truck traffic on the State Highway System serves as a reasonable proxy to identify freight corridors that support elevated economic activity. These corridors can be identified based on the Annual Average Daily Truck Traffic (AADTT)[21].

Step 2 – Calculate the Annual Vehicle Miles Traveled (VMT_{365}) for Trucks

For each project, an annual truck VMT within the limits of the project is calculated as follows:

$$VMT_{365} = [AADTT\ vehicles/day] \times [Project\ Length,\ L\ miles] \times [365\ days/year]$$

Step 3 – Determine the Freight Impact Program Factor

The *Freight Impact Program Factor* (F_{FI}) is determined by the SHOPP program code, as presented in Table A-16. This factor is either a 0 or 1 and indicates if the type of project has the potential to impact freight traffic.

Table A-16 – Freight Impact Program Factor

Program Code	Priority	Program	Worker Safety Factor
201.130	1	Emergency Damage Repair	0
201.010	1	Safety Improvements	0
201.131	1	Permanent Restoration	0
201.361	1	ADA Access Improvements	0
201.378	1	ADA Pedestrian Infrastructure	0
201.235	1	Roadside Safety Improvements	0
201.119	1	Bridge Preventive Maintenance	1
201.321	1	Weigh Stations & WIM Facilities	1
201.015	2	Collision Severity Reduction	0
201.111	3	Bridge Scour Mitigation	0
201.113	4	Bridge Seismic Restoration	0
201.110	5	Bridge Rehabilitation	1
201.120	6	Roadway Rehabilitation (3R)	1
201.121	6	Roadway Preservation (CAPM)	1
201.122	6	Roadway Rehabilitation (2R)	1
201.151	7	Drainage System Restoration	0
201.112	8	Bridge Rail Replacement/Upgrade	0

Program Code	Priority	Program	Worker Safety Factor
201.335	9	Stormwater	0
201.315	10	Transportation Management Systems	1
201.322	11	Trans Permit Requirements for Bridges	1
201.150	12	Roadway Protective Betterment	0
201.310	13	Operational Improvements	1
201.240	14	Roadside Protection and Restoration	0
201.250	15	Safety Roadside Rest Area Rehabilitation	0
201.210	16	Roadside Rehabilitation	0
201.170	17	Signs and Lighting Rehabilitation	1
201.160	18	Relinquishments	0
201.325	19	Railroad at-grade Crossing	0
201.330	20	Hazardous Waste Mitigation	0
201.352	21	Maintenance Facilities	0
201.351	22	Equipment Facilities	0
201.353	23	Office Buildings	0
201.260	25	New Safety Roadside Rest Areas	1

[21] http://traffic-counts.dot.ca.gov/

Step 4 – Calculate the Freight Corridor Benefit

The *Freight Corridor Benefit Score* (B_{FC}) is calculated as follows:

$$B_{FC} = (F_{FI}) \times (VMT_{365})$$

The resulting score is normalized on a 0-100 scale. A limiting maximum value for VMT of 200,000 vehicle-miles per year is applied.

A.10 – Minimize Damage to Environment

Minimizing damage to the environment is achieved through reducing adverse changes to the physical conditions within the area affected by the project, including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance. Two components of environmental impacts are addressed: (1) the reduction of greenhouse gas emissions, and (2) impacts on water quality.

Step 1 – Calculate County-Level GHG Emissions

The *Facility Level Information on Greenhouse Gases Tool (FLIGHT)*[22] reports greenhouse gas data reported to Environmental Protection Agency (EPA) by large emitters, facilities that inject CO2 underground, and suppliers of products that result in GHG emissions when used in the United States. Using this data resource, annual county-level totals can be calculated. Annual *Vehicle Miles of Travel (VMT)* is published by Caltrans through the "California Public Road Data" report[23]. Using an EPA default rate of 423 grams of CO2 per VMT for a passenger car[24], county-level GHG emissions due to vehicle traffic can be approximated.

Step 2 – Calculate the GHG Emissions Score

The sum of GHG emissions from facilities and vehicles by county is associated to each project. Pavement projects where the existing IRI exceeds 255 inches per mile are considered most effective in reducing GHG emissions while improving the asset condition at optimum cost. For pavement projects where IRI>255, a *GHG Emissions Score (S_{GE})* is determined based on county-level GHG emissions relative to 10 million metric tons. The calculation is as follows:

$$S_{GE} = (\text{GHG emissions at project location}) / (\text{10 mil metric tons}) * 100$$

S_{GE} is limited to a maximum score of 100.

Step 3 – Calculate the Water Quality Score

SHOPP projects in the programs for Stormwater (201.335) and Hazardous Waste Mitigation (201.330) are assigned a *Water Quality Score (S_{WC})*. Stormwater projects are quantified by the area of land treated, in units of acres.

S_{WC} is calculated based on a combination of 330 and 335 projects. The first component, S_{WC1}, is determined from the area of land treated, in units of acres, relative to 30 acres. The calculation is as follows:

[22] http://ghgdata.epa.gov/ghgp/main.do

[23] http://www.dot.ca.gov/hq/tsip/hpms/hpmslibrary/prd/2013prd/2013PRD-revised.pdf

[24] https://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/ghg_handbook/chapter05.cfm

$$S_{WC1} = (area\ of\ land\ treated) / (30\ acres) * 100$$

A second component, S_{WC2}, is determined by the number of locations on a 0-100 scale for Waste Mitigation projects. The number of locations for a given project relative to the maximum for any SHOPP project determines the score.

$$S_{WC2} = (number\ of\ locations) / (max\ locations) * 100$$

S_{WC} used in subsequent calculations is the maximum of either S_{WC1} or S_{WC2}.

Step 4 – Determine the Air & Water Quality Benefit Score

The *Air & Water Quality Benefit Score* (B_{AW}) is determined by the maximum of either the *GHG Emissions Score* (S_{GE}) or the *Water Quality Score* (S_{WC}).

A.11 – Maximize Resilience of Infrastructure

Step 1 – Calculate the Infrastructure Resilience Score

The *Infrastructure Resilience Score (S_{IR})* is determined by the project type. Projects that address bridge seismic, bridge scour, or culverts are assigned a score of 100.

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Appendix B – 2016 SHOPP Project Scores and Priorities

This appendix presents the complete list of new 2016 SHOPP projects and the results of the scoring and prioritization analysis.

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