Implementation of a Multiple-Objective Decision Analysis (MODA) Approach for Prioritization of Asset Investments for Caltrans

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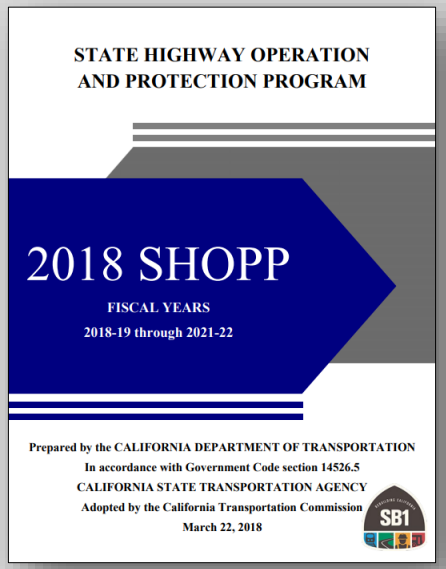
Motivation for Developing a Multi-Objective Decision Analysis (MODA) Framework

Project prioritization challenges in prior SHOPP cycles:

- Funding allocations made primarily by asset type (“silos”)
- Alignment to strategic objectives not well defined



- The purpose of the State Highway Operation and Protection Program (SHOPP) is to maintain and preserve the State Highway System (SHS) and its supporting infrastructure – a “fix-it-first” program.
- The current 2018 SHOPP represents a portfolio of projects valued at $18bil over 4 years.
- Projects in the SHOPP are limited to capital improvements relative to maintenance, safety, and rehabilitation –improvements that do not add capacity to the system.

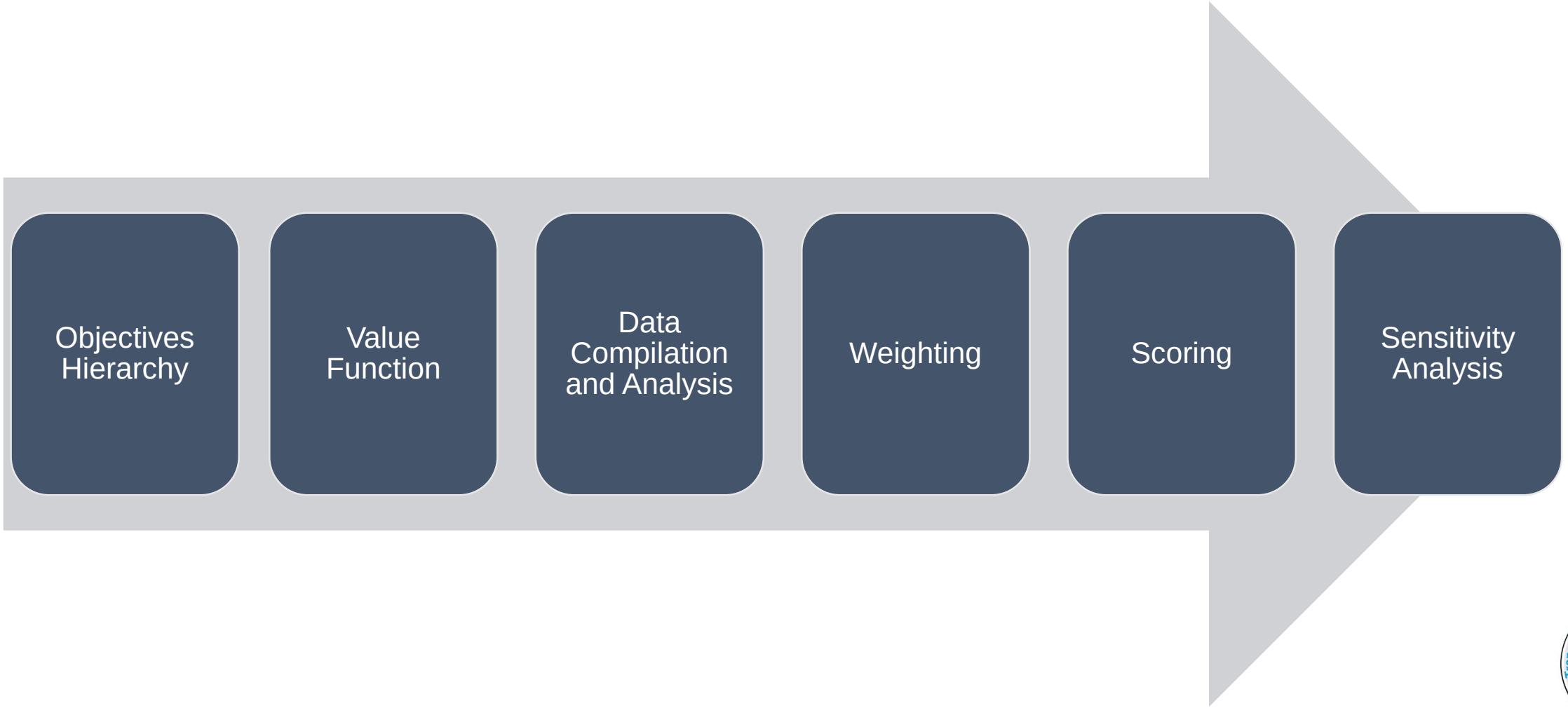
Initial Work by Caltrans

- **2014 SHOPP MODA Feasibility Assessment**
  - *"SHOPP Pilot Project Phase 1 – A Framework for Project Prioritization"* (June 2015) http://www.dot.ca.gov/assetmgmt/multi-objective.html
  - 2014 SHOPP project portfolio
  - Evaluated 172 projects valued at $2.7bil

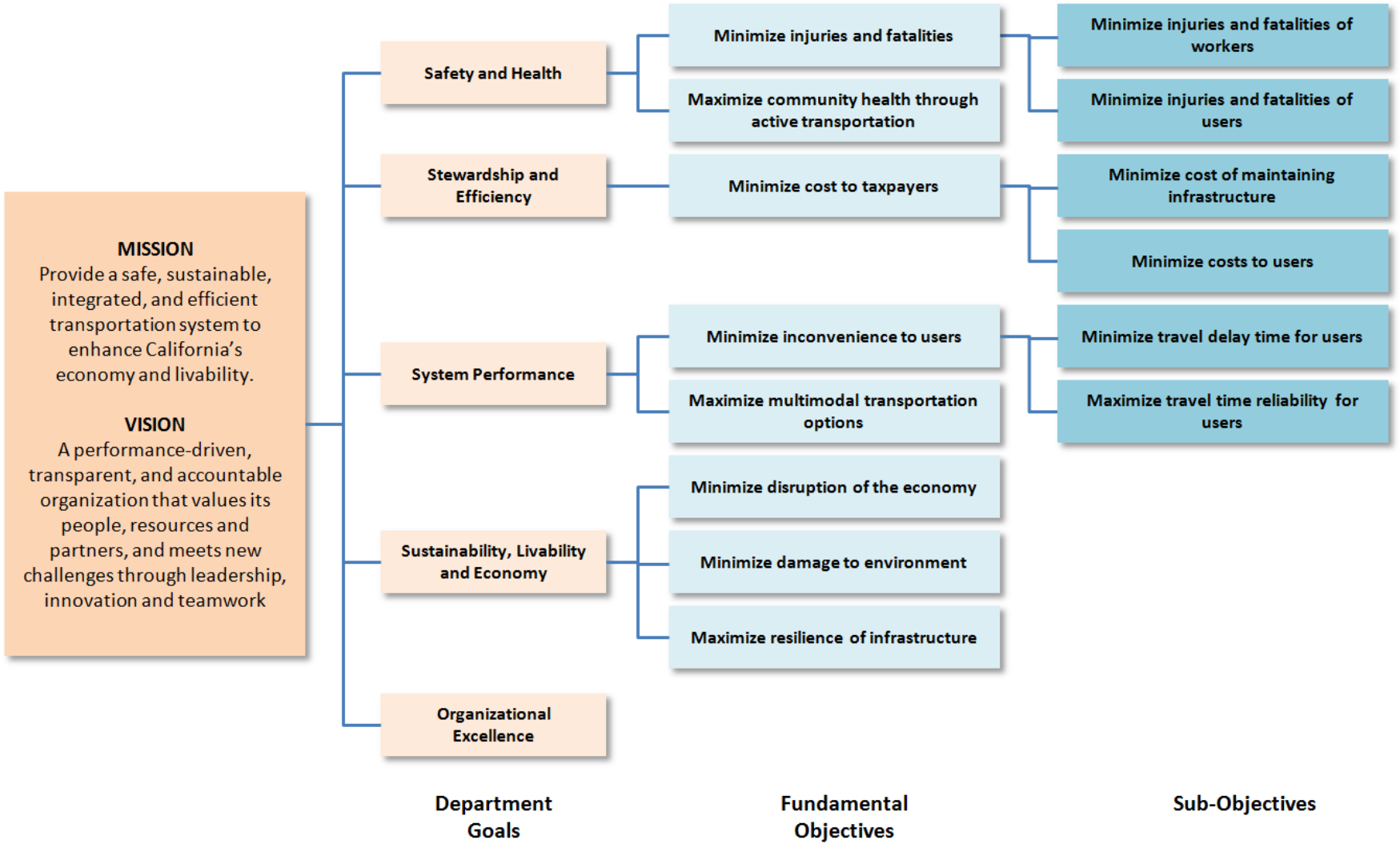
- **2016 SHOPP MODA Feasibility Assessment**
  - *"SHOPP Project Prioritization – Application of a Project Prioritization Framework to the 2016 SHOPP"* (March 2016) http://www.dot.ca.gov/assetmgmt/multi-objective.html
  - 2016 SHOPP project portfolio
  - Evaluated 384 projects valued at $4.6bil

- **2016 SHOPP Asset Management Pilot Program**
  - *"Project Prioritization Criteria for the SHOPP Asset Management Pilot Program"* (2016) http://www.dot.ca.gov/assetmgmt/ampp.html
  - 2016 SHOPP project portfolio
  - Evaluated 37 projects valued at $770mil
  - 9 projects valued at $100mil total were funded using this process

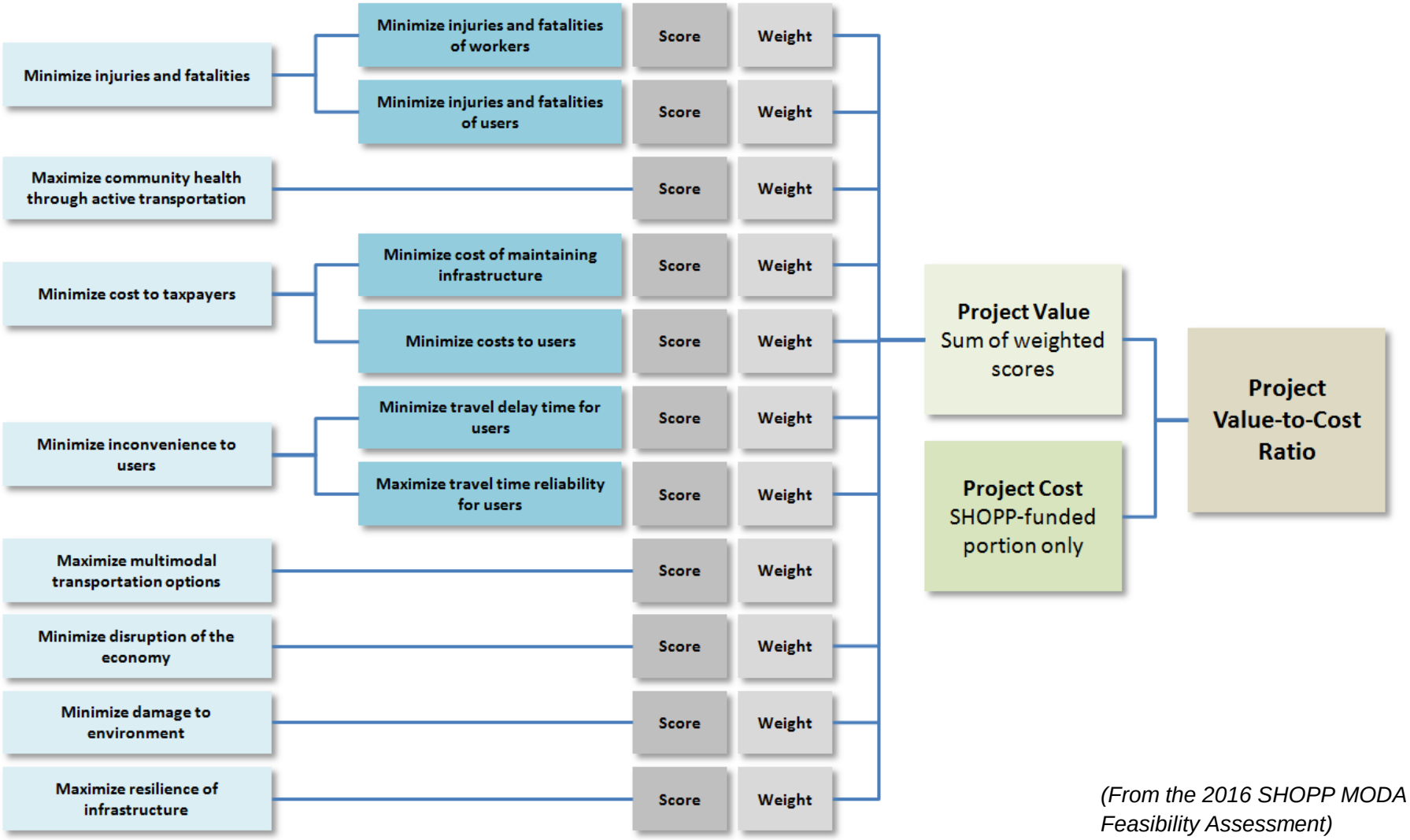
Framework for a MODA-Based Approach



Objectives Hierarchy



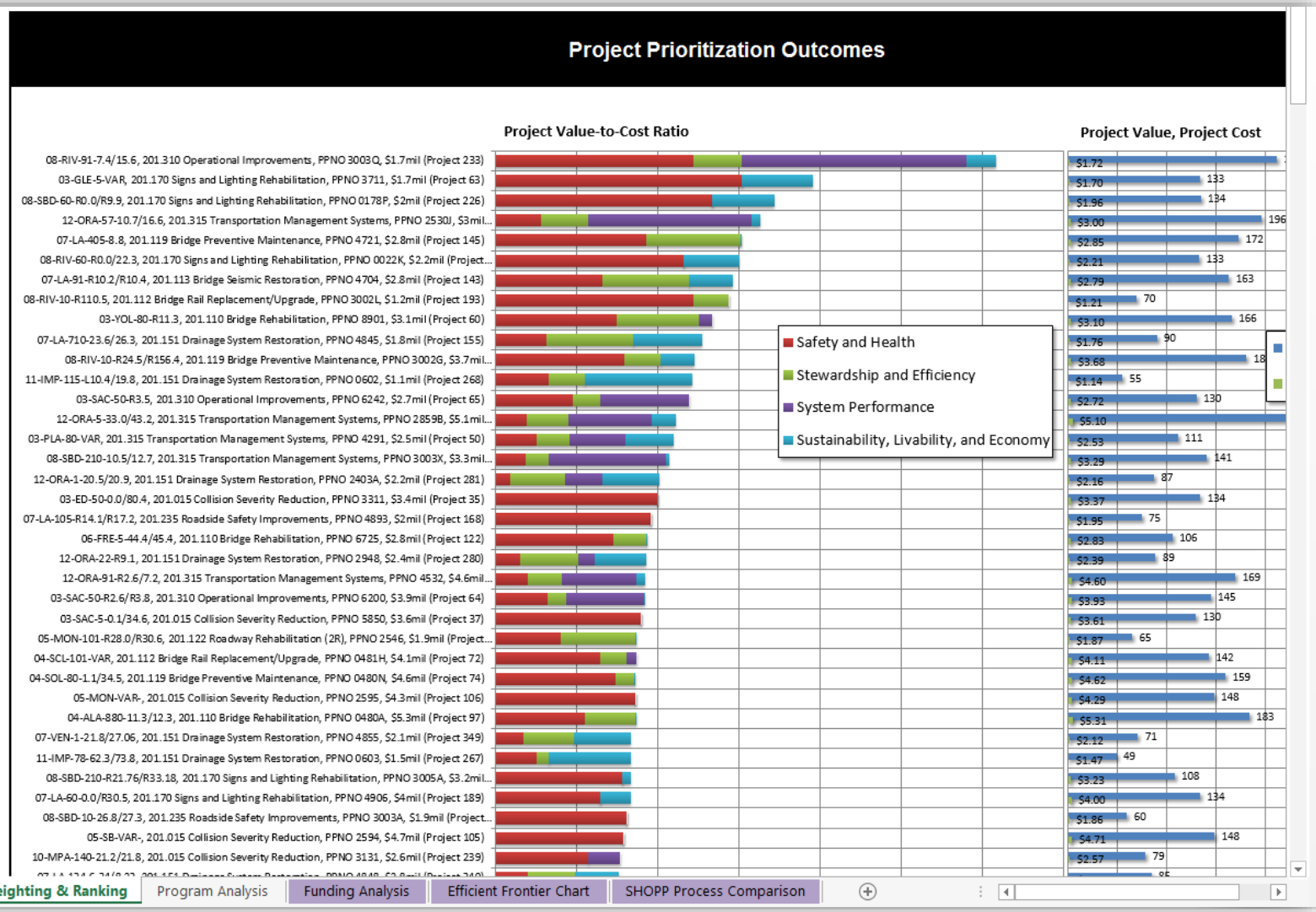
Value Function



(From the 2016 SHOPP MODA Feasibility Assessment)

Prototype Tool to Test MODA Framework

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



... (8) Complete Streets | (9) Freight | (10) GHG, Water Quality | (11) Resilience | Scoring | Weighting & Ranking | Program Analysis | Funding Analysis | Efficient Frontier Chart | SHOPP Process Comparison

Outcomes

MODA was shown to be effective to:

- Bring transparency to the SHOPP project prioritization process.
- Establish a logical, quantitative, and data-driven basis for decision-making.
- Provide a framework to communicate the alignment of project priorities with strategic objectives.
- Identify best projects based on calculated value and cost.

Review of Initial Work

- 3 MODA experts reviewed initial work
  - Arnold Barnett – MIT Sloan School of Management
  - Alexander Engau – University of Colorado Denver
  - Ralph Keeney – Duke University

> In conceptual terms, the Caltrans methodology … is excellent. It makes a full range of relevant considerations explicit, and it advances procedures to measure and quantify performance on all key dimensions. The methodology is logical, systematic, and fair.
>
> **— Arnold Barnett**

Review Findings

- MODA has great potential for Caltrans
- Need to revise value function
- Value function should predict monetized benefits
- Avoid categorical variables
- Issues with weighting goals
- Issues with normalizing scores
- Explore implementing an optimization approach

Revised Approach

Goals and Objectives

GOAL 1: SAFETY

- Annual Vehicle User Crash Savings
- Annual Non-Vehicle User Crash Savings

GOAL 2: HEALTH AND AIR QUALITY

- Annual Emissions Reduction Benefit
- Annual Active Transportation Health Benefit

GOAL 3: STEWARDSHIP AND EFFICIENCY

- Asset Preservation Benefit
- Annual Vehicle Detour Benefit

GOAL 4: SYSTEM PERFORMANCE AND ECONOMY

- Annual Fuel Savings Benefit
- Annual Travel Time Benefit
- Freight Corridor Benefit

GOAL 5: SUSTAINABILITY AND LIVABILITY

- Modal Improvement Benefit
- Water Quality Benefit
- Biological Benefit

Revised Approach Details

- Maintains continuity between previous iterations of the approach
- Utilizes techniques from Cal B/C, an internal benefit/cost analysis tool
- Each measure represents a monetized benefit
- Pitfalls avoided with this approach:
  - Need for categorical variables
  - Need for subjective scores
  - Need for scaling of benefits
  - Need for weights on the goals
- Exploring Data Envelopment Analysis (DEA) as optimization approach

Approach Example

- Example Project Activities
  - Rehabilitate pavement
  - Repair bridge
  - Construct storm drainage improvements
  - Construct ITS elements
  - Improve pedestrian, bicycle, and ADA facilities
- Example Project Characteristics
  - $31M
  - AADT = 25,300
  - 1.4 miles

Example- Results

Goal	Objective	Value	Note
Safety	Annual Vehicle Safety Savings	0	
	Annual Non-Vehicle Safety Savings	4,529	Reduces worker exposure hours
Air Quality and Health	Annual Emissions Reduction Benefit	9,074	Reduces fuel from VMT and IRI change
	Annual Health Activity Benefit	871	Improves bike/ped facilities
Stewardship and Efficiency	Asset Preservation Benefit	1,614,030	Improves bridge and pavement condition
	Annual Vehicle Detour Benefit	0	
System Performance and Economy	Annual Fuel Savings	42,033	Reduces fuel from VMT and IRI change
	Annual Travel Time Benefit	85,764	Reduces delay
	Annual Freight Corridor Benefit	0	
Sustainability and Livability	Annual Modal Improvement Benefit	4,529	Improves bike/ped facilities
	Annual Water Quality Benefit	0	
	Annual Biological Improvement Benefit	0	
	Total Project Value	**1,760,830**	

Next Steps

- Test the approach
- Review the results through a set of workshops
- Implement the approach statewide