Integrating Pavement Life-Cycle Cost Analysis and Life-Cycle Assessment for Multi-criteria Decision Making

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Outline

- The climate policy perspective
- LCCA and LCA
- Integrating LCCA and LCA
- Policy levers

The importance of transportation in climate policy making

- International: ~25% of GHG emissions
- California: ~40% of GHG emissions

- Transport policy typically focuses on:
  Vehicle efficiency, Alternative fuels, Travel Reduction

- Most work has focused on fuel consumption, for which short-term fuel demand elasticity has been low, and technologies have been relatively slow to make an impact

- The infrastructure supply-chain has also been shown to contribute significantly to emissions

Outline

- The climate policy perspective
    - Some completed transportation LCA work
    - Climate policy prioritization
- LCCA and LCA
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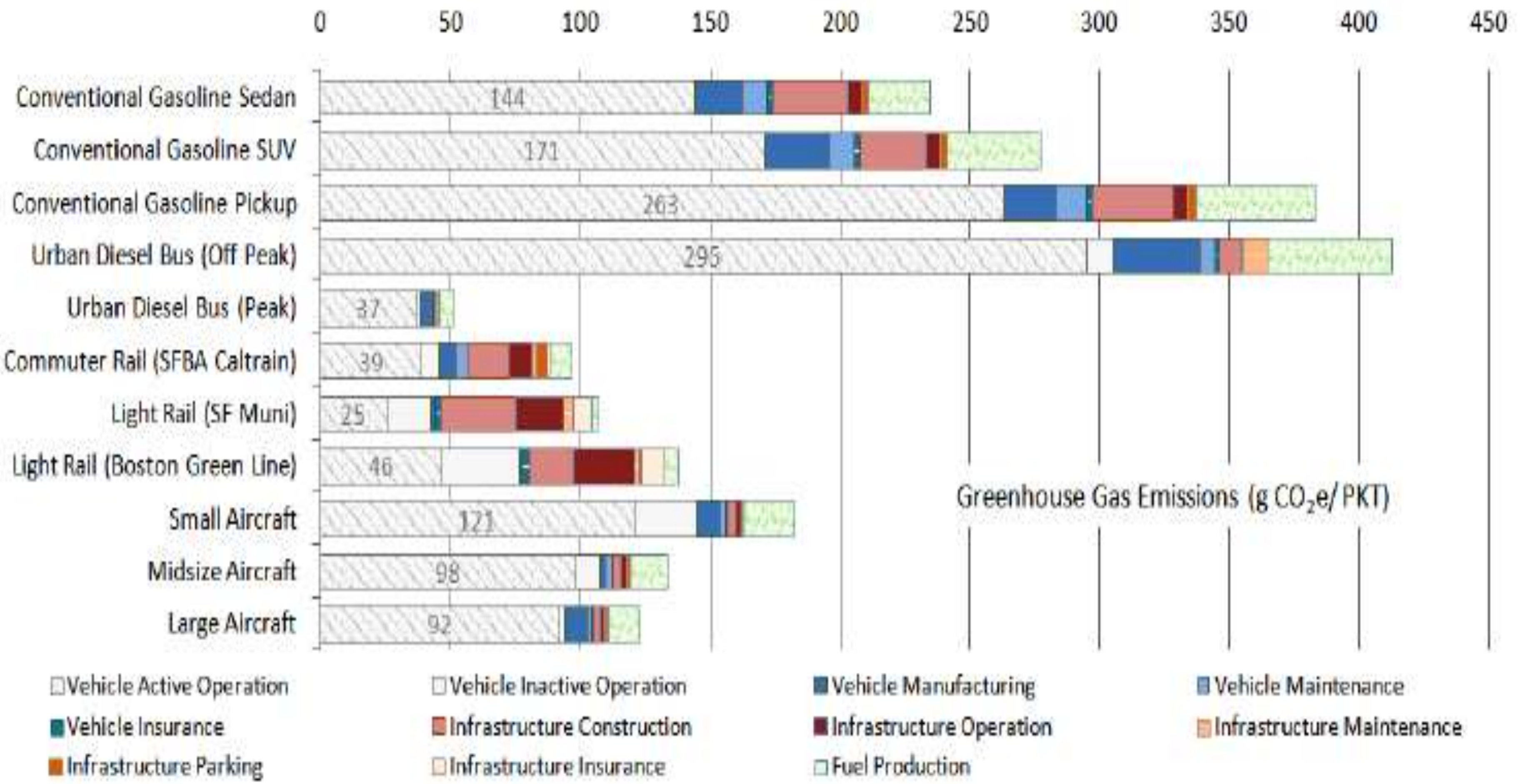
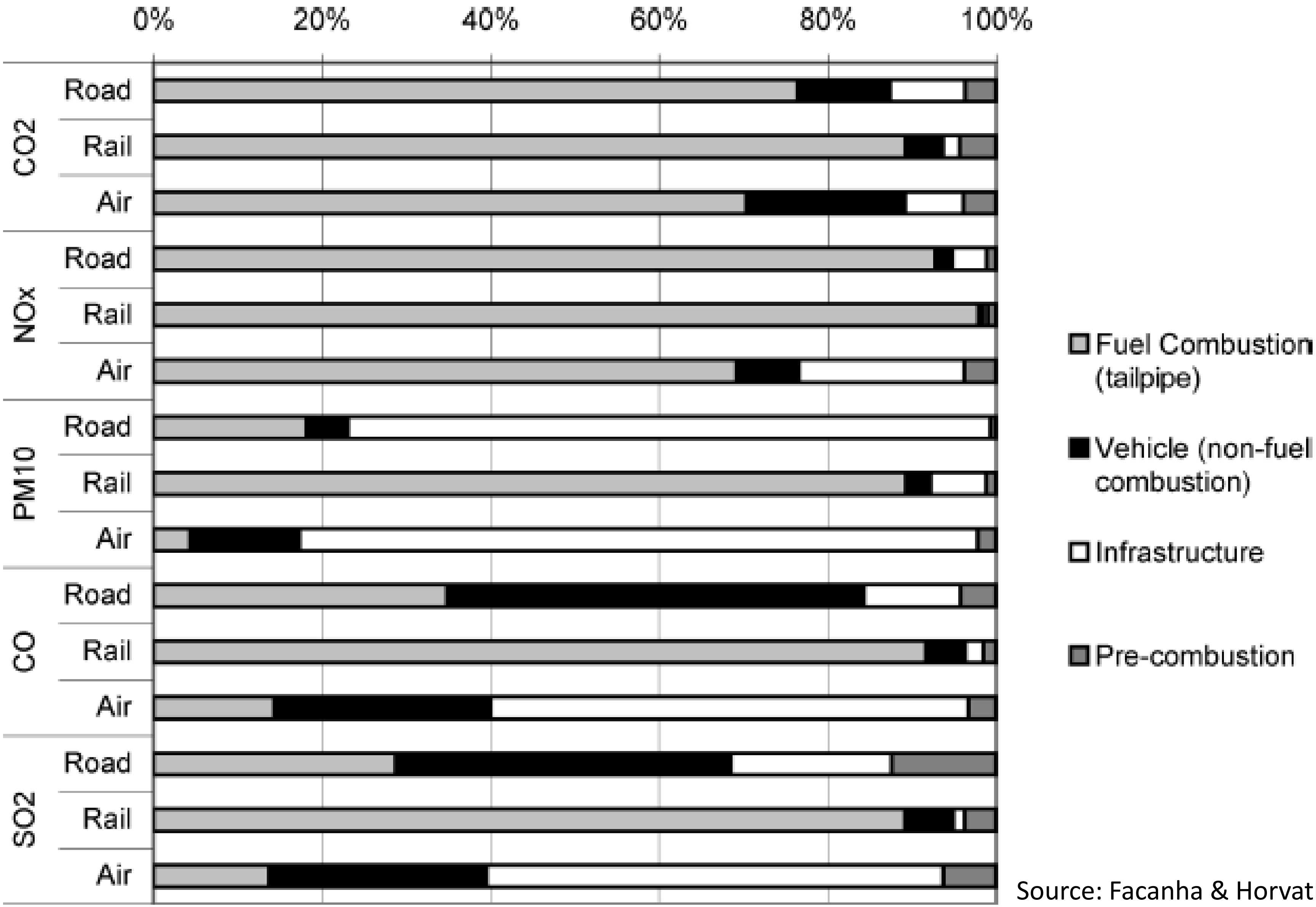
LCA for US passenger transportation



Source: Chester & Horvath (2009)

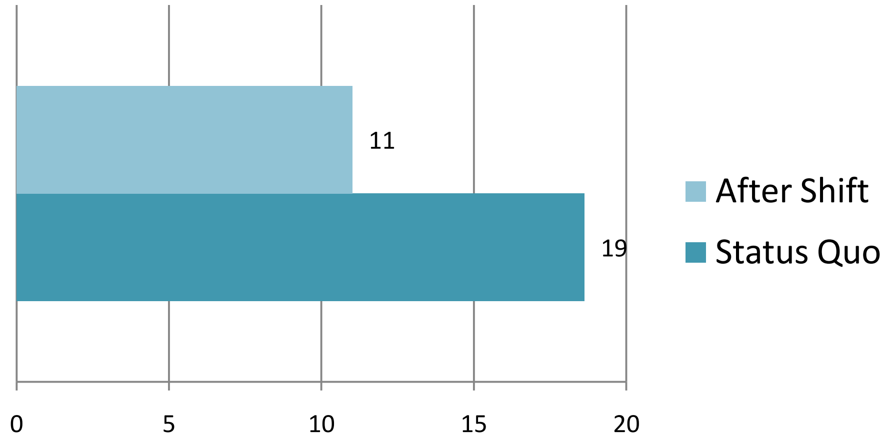
LCA for US freight transportation



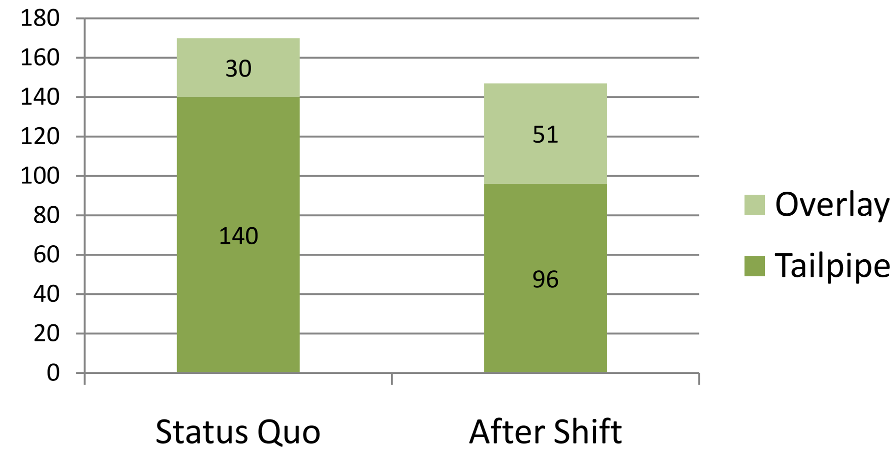
Source: Facanha & Horvath (2006)

Within-Vehicle Class Consolidation on SR-13

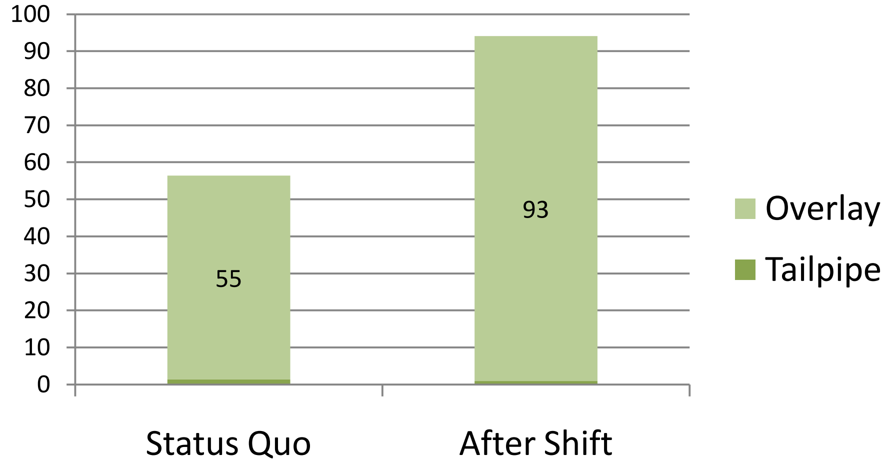
Years between overlays



GHG (10^3 kg CO_2 eq./yr)



SO_2 (kg/yr)



$PM_{2.5}$ (kg/yr)

Source: Sathaye, Horvath & Madanat (2010)

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Climate policy prioritization in California

- Total achievable GHG reductions

- Cost-effectiveness:
  - $ costs per GHG reductions

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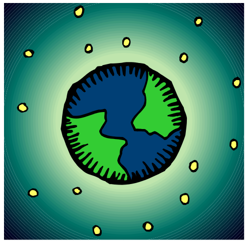
- LCCA  and LCA 
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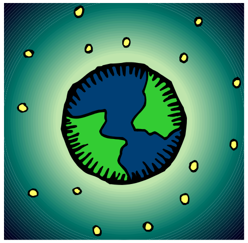
Life-Cycle Cost Analysis

- Agency costs
  - reconstruction
  - maintenance (e.g. overlays)
- Social costs
  - traffic delays
  - vehicle wear
  - accident costs
  - environmental costs
    - e.g. price per ton of carbon emissions

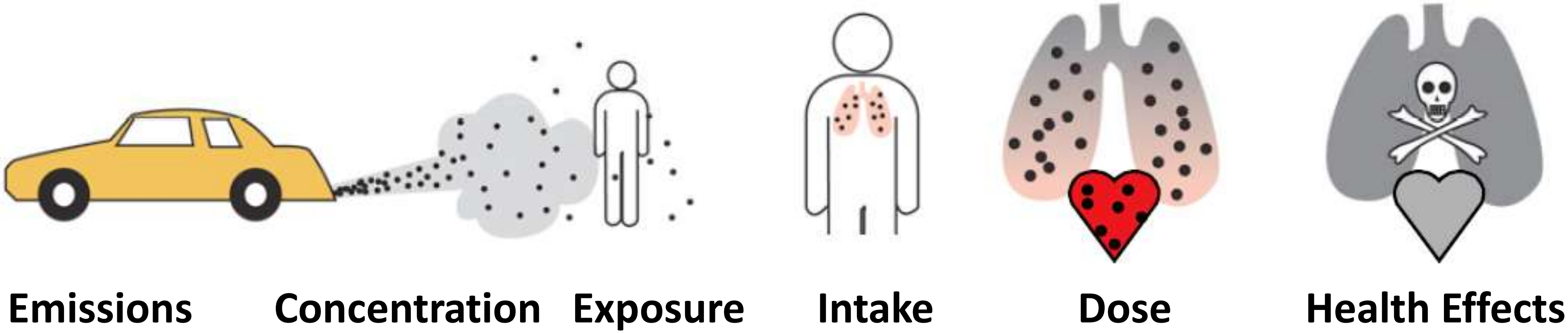
Optimization of costs

- objectives:
  - agency costs
  - user costs
  - user benefit
- constraints:
  - agency budget
  - minimum pavement condition

Life-Cycle Assessment



- Maintenance Supply Chain
- Fuel consumption resulting from roughness
- Delay



Source: Marshall (2005)

Quantifying environmental impacts

Table 2. Air Pollution Damages Costs by Impacted Region

Pollutant name	Average cost (2003 US$/t)			
	Urban	Urban fringe	Rural	Global
Particulate matter	6,144	2,750	800	—
Nitrogen oxides	156	65	19	—
Sulfur dioxides	170	88	21	—
Carbon monoxide	2	1	0	—
Lead	3,955	2,059	480	—
VOC	1,960	1,960	1,960	—
Carbon dioxide	—	—	—	21
Nitrous oxide	—	—	—	7,112
Methane	—	—	—	384

Source: Kendall, Keoleian & Helfand (2008)

Indexes

- Can provide a communicable framework (e.g. LEED)

- Life-cycle emissions vary by time and location
  - Deterioration is an uncertain process
  - Variability in fuel consumption across fleet
  - Traffic networks differ

- Equity Concerns

- Point systems oversimplify impacts
  - Higher ratings can result in higher impacts

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  - Multi-objective optimization
  - Question marks
- Policy levers

Multi-objective Optimization of costs and GHGs

- objectives:

  agency costs

  user costs

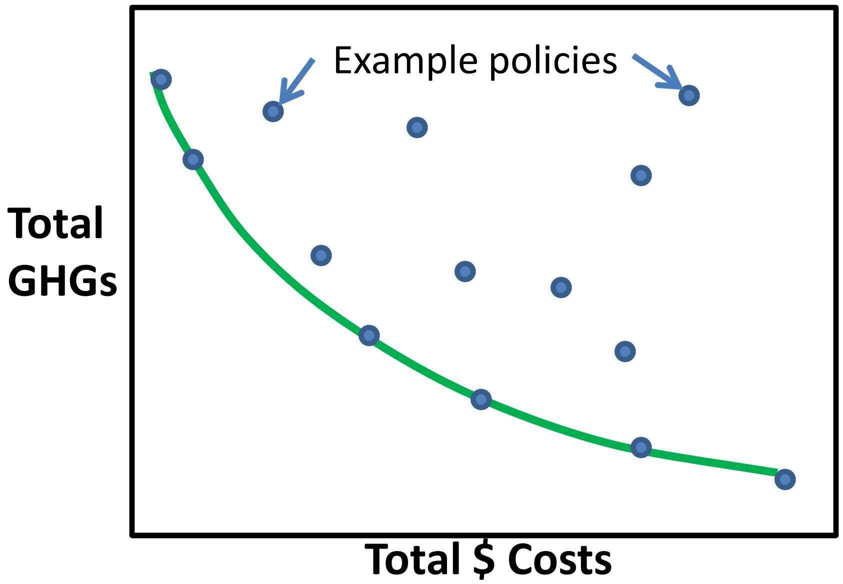
  user benefit

- constraints:

  agency budget

  GHG emissions

Using a Pareto optimal frontier



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Approach to pavement management systems

- Single-facility level vs. Network-level
  - Heterogeneity of LCA results suggest importance of budget allocation issues

Time horizon

- Discount rates
  - Investment, Opportunity Costs
  - Social discount rate (IPCC)
- Period
  - Pavement functional design life
  - Environmental regulatory objectives

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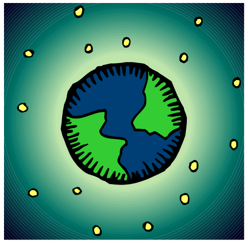
- LCCA  and LCA 
- Integrating LCCA and LCA
- Policy levels

What level of government for multi-criteria decision making?

- Pavement management is conducted at multiple levels
- Implementation of pollution policy was developed at the city, regional and state levels in the US
- Environmental policy is mandated at the state or federal level in many countries
- GHG policy is entering the international level
- Highlights the need for communication across government levels

Important Concepts

- Cost effectiveness and total GHG reductions
- No-regrets options

- Potential problems with blanket indexes
- Pareto optimal frontier for multi-criteria decision making

- Communication is necessary across multiple levels of government