

Monte Carlo Sensitivity Analysis:

Uncertainty exists in every cost-benefit analysis. To account for the uncertainty in our cost and benefit projections, we conducted a Monte Carlo sensitivity analysis. A Monte Carlo sensitivity analysis randomly generates variables based on the conditions we establish. It essentially simulates the highway improvement project's costs and benefits. It recreates the scenario 1000 times using random variables and provides a range of likely values for the costs and benefits in each year of a project's life.

The first step in our analysis was to create random variables for both the no-build scenario and for the scenario where Bayfield County uses a BUILD grant to improve Highway A and Highway N. Below is a table of the variables defined, their mean, their standard deviation (if applicable), and what type of distribution was used in the Monte Carlo simulation.

Table 1: No-Build Scenario Variables			
Variable	Mean	Standard Deviation	Distribution [range]
Winter maintenance costs	\$5,159/mile	\$761/mile	Uniform [\$4000, \$6070]
Number of trucks	44 trucks/day	9.6 trucks	Uniform [-5%, +5%]
Routine (summer) maintenance	\$5,000/mile	n/a	Uniform [-10%, + 10%]

Table 2: Build Scenario Variables			
Variable	Mean	Standard Deviation	Distribution [range]
Winter maintenance costs	\$4,127/mile	\$609/mile	Uniform [\$3200, \$4800]
Road Quality	n/a	n/a	Uniform [mean, +10%]
Number of trucks	44 trucks/day	9.6 trucks	Uniform [-5%, +5%]
Routine (summer) maintenance	\$5,000	n/a	Uniform [-5%, +5%]
Construction for 3-year period	\$837,424/year/mile	n/a	Uniform [-5%, +5%]
Travel time based on # of	\$3,765/mile	n/a	Uniform [-10%, +10%]

vehicles per day			
Logging bids	\$1,228,130.40*15%	+5%	Normal [min 10%, max 20%]

Our Monte Carlo analysis took the following steps:

1. Calculate cost by calculating the sum of all cost variables and discounting them for each year at a rate of 7%.

- i. Calculate PV of cost for no-build, discounted

$$\sum_{t=1}^{26} \frac{(\text{summer status quo maintenance}_t + \text{winter status quo maintenance}_t)}{(1 + 0.07)^t}$$

- ii. Calculate PV of cost for BUILD scenario, discounted

$$\sum_{t=1}^{26} \frac{(\text{summer BUILD maintenance}_t + \text{winter BUILD maintenance}_t + \text{construction}_t)}{(1 + 0.07)^t}$$

- iii. Take the difference between the cost of no-build scenario and the cost of no-build

$$\sum_{t=1}^{26} \frac{(\text{summer status quo maintenance}_t + \text{winter status quo maintenance}_t)}{(1 + 0.07)^t} -$$

$$\sum_{t=1}^{26} \frac{(\text{summer BUILD maintenance}_t + \text{winter BUILD maintenance}_t + \text{construction}_t)}{(1 + 0.07)^t}$$

2. Calculate benefits by calculating the sum of all benefits variables and discounting them for each year at a rate of 7%.

- i. Calculate PV of benefits for no-build, discounted

$$\sum_{t=1}^{26} \frac{(\text{timber status quo revenue}_t)}{(1 + 0.07)^t}$$

- ii. Calculate PV of benefits for BUILD scenario, discounted

$$\sum_{t=1}^{26} \frac{(\text{timber BUILD revenue}_t + \text{time savings}_t)}{(1 + 0.07)^t}$$

- iii. Take the difference between the benefits of BUILD scenario and the benefits of no-build

$$\sum_{t=1}^{26} \frac{(\text{timber status quo revenue}_t)}{(1 + 0.07)^t} - \sum_{t=1}^{26} \frac{(\text{timber BUILD revenue}_t + \text{time savings}_t)}{(1 + 0.07)^t}$$

3. Calculate the residual value of the project using a linear decay function.
4. Present the net costs and net benefits.

Results

Costs

No Build: The present value of the cost of maintenance for the project route under the no-build scenario is estimated to be \$1.14 million (plus or minus \$169,000, with 95% certainty). This value reflects twenty years of routine maintenance, including annual plowing, regular crack-sealing, and occasionally resurfacing.

Reconstruction: The present value of the cost of maintenance for the project route under the build scenario, in which Highway A is reconstructed is estimated to be \$653,000 (plus or minus \$158,000, with 95% certainty). This value reflects a stronger road that needs routine maintenance less often as well as more asphalt that can be recycled (“scrapped”) when the road needs to be resurfaced.

The present value of the entire build scenario, including the cost of construction, is estimated to be \$22.6 million (plus or minus \$2.5 million, with 95% certainty). This reflects the present value of construction between 2023 and 2025.

Cost Category	No-Build Scenario			Build Scenario			Cost Savings
	Mean	Min	Max	Mean	Min	Max	
Motor Vehicle Accidents	\$3.9	\$3.1	\$4.8	\$2	\$1.4	\$2.6	\$1.9
Maintenance	\$1.1	\$0.97	\$1.3	\$0.66	\$0.48	\$0.83	\$0.49
Project Cost				\$22	\$19.8	\$24.2	-\$22
Total Costs							-\$19.6

Benefits

Timber The present value of the increase in timber revenues is estimated to be \$4.33 million (plus or minus \$1.24 million, with 95% certainty). These revenues are roughly equally split between Bayfield County and the federal government. Timber revenues from county forests along Highway A are expected to rise by \$2.14 million. Timber revenues from the Chequamegon-Nicolet National Forest are expected to rise by \$2.18 million.

Safety Benefits: The present value of the decrease in car crashes is estimated to be \$1.75 million, representing a decline from a cost to society of \$3.9 million under the no-build scenario to nearly \$2 million with a reconstructed road. This reflects a decrease in crashes from an average of five per year, to an average of one.

Job Benefits: The present value of the increase in jobs is estimated to be \$2.9 million (plus or minus \$190,000, with 95% certainty). This reflects an increase of 13 jobs, on average in the region.

Travel Time Benefits: The present value of travel time savings is an average of \$305,000 (plus or minus \$25,000, with 95% certainty). This reflects a time savings of approximately 3 seconds for each driver per trip.

Table 4: Benefits (in millions)

Benefit Category	No-Build Scenario			Build Scenario			Benefits Improvements
	<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>Min</i>	<i>Max</i>	
County Revenue from Timber Sales	\$12.5	\$10.3	\$15.3	\$14.3	\$11.6	\$17.2	\$1.7
Federal Revenue from Timber Sales	\$15	\$10.9	\$19.2	\$17.4	\$12.1	\$22.9	\$2.4
Travel Time Savings				\$0.30	\$0.28	\$0.33	\$.177
Added Employment				\$2.85	\$.23	\$5.11	\$2.85
Total Benefits (Monte Carlo-adjusted)	\$23.5	\$21.2	\$34.5	\$32.9	\$24	\$45.4	\$7.4