National Enhanced Elevation Assessment (NEEA)

Part 3: The Cost-Benefit Analysis Process

The US Geological Survey's extremely successful 3D Elevation Program (3DEP) is based on the National Enhanced Elevation Assessment (NEEA) for which I served as Dewberry's project manager. In Part 1 of this series, I summarized the USGS/Dewberry planning that went into the NEEA, and in Part 2, I summarized the steps we went through to document and validate DEM user requirements and benefits.

Master Geodatabase

All of the DEM user requirements and benefits were entered by Dewberry into a master geodatabase for 104 Functional Activities (FA's) from federal agencies, 329 FA's from states and U.S. territories, 144 FA's from local and tribal governments within each state, and 25 FA's from other organizations (not-for-profit and private companies). When populated, the geodatabase included over 100,000 polygons, each linked to user elevation data requirements and benefits for 602 FA's within 27 major business uses.

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Dewberry aggregated and analyzed all elevation data requirements and benefits for each FA and Business Use. Each FA was summarized for its *mission-critical* elevation data requirements by Quality Level and update frequency; and its tangible and intangible benefits to include annual dollar benefits for use in the Cost-Benefit Analyses (CBA). For about half of the FA's, users reported major dollar benefits but could not quantify those benefits, and many of the other benefits appeared to be ultra-conservative, i.e., financial benefits were understated for reasons explained in Appendix E of the NEEA report. Although Dewberry also estimated higher *potential benefits* documented in **Table 1**, the CBA and Return on Investment (ROI) calculations were performed only with the most *conservative benefits* as validated for each of the 602 FA's.

As shown at **Table 1**, the *conservative benefits* total $1.4 billion/year and the *potential benefits* total $13.3 billion/year. However, not all of these benefits would be achieved if users received poorer Quality Level data or update frequencies than optimally required for each FA. **Table 1** compares the conservatively-estimated benefits that seemed to be understated, with potential future benefits that are much higher but may still be understated. **Table 1**, sorted by conservative benefits, contrasts *conservative benefits* and *potential benefits.* State requirements and benefits vary widely in terms of data quality and benefits. For example, four states specified requirements for QL1 LiDAR and other states specified QL2 or QL3 LiDAR. In addition, North Carolina reported significantly higher benefits for coastal flood risk management than did other coastal states, and some states significantly underestimated or were unable to assign any benefits at all for flood risk management.

Estimated Costs per Square Mile

For the 48 conterminous states, USGS provided average cost estimates by Quality Level from its Geospatial Products and Services Contract (GPSC2) contractors for Quality Levels 1 through 4. These estimates, in 2011 dollars, are in column B in **Table 2** below. Columns C and D include the 15 percent estimated costs of QA/QC to include the survey of QA/QC checkpoints. Column E

Table 1. Estimated Annual Dollar Benefits, by Business Use, from Enhanced Elevation Data

BU#	Business Use (BU) Name	Enhanced Elevation Data Annual Benefits	
		Conservative Benefits	Potential Benefits
14	Flood Risk Management	$440.853M	$787.886M
21	Infrastructure and Construction Management	$246.311M	$974.643M
1	Natural Resources Conservation	$169.037M	$337.164M
8	Agriculture and Precision Farming	$122.330M	$2,011.330M
2	Water Supply and Quality	$85.659M	$156.583M
16	Wildfire Management, Planning and Response	$84.250M	$166.950M
9	Geologic Resource Assessment and Hazard Mitigation	$54.235M	$1,069.235M
5	Forest Resources Management	$43.949M	$61.655M
3	River and Stream Resource Management	$39.564M	$86.632M
20	Aviation Navigation and Safety	$35.000M	$56.000M
4	Coastal Zone Management	$23.785M	$41.740M
17	Homeland Security, Law Enforcement, Disaster Response	$10.444M	$126.544M
11	Renewable Energy Resources	$10.050M	$100.050M
12	Oil and Gas Resources	$10.000M	$100.000M
22	Urban and Regional Planning	$7.415M	$68.744M
15	Sea Level Rise and Subsidence	$5.800M	$21.660M
10	Resource Mining	$1.686M	$4.864M
7	Wildlife and Habitat Management	$1.510M	$4.020M
13	Cultural Resources Preservation and Management	$0.800M	$7.000M
25	Education K-12 and Beyond	$0.514M	$2.514M
18	Land Navigation and Safety	$0.316M	$7,125,000M[1]
27	Telecommunications	$0.185M	$1.850M
26	Recreation	$0.100M	$0.100M
23	Health and Human Services	$0.000M	$1.000M
19	Marine Navigation and Safety	$0.000M	$0.000M
24	Real Estate, Banking, Mortgage, Insurance	$0.000M	$0.000M
6	Rangeland Management	$0.000M	$0.000M
	Total Estimated Annual Dollar Benefits	**$1,393.793M**	**$13,313.164M**

[1] The major potential benefits for BU#18 would not be realized until car/truck/bus manufacturers start deploying vehicles that save fuel by automatically downshifting or upshifting, in advance of changing curves and grades ahead, based on LiDAR or other 3-D mapping technology that will provide the 3-D roadway geometry. Research programs and car manufacturers have estimated that road elevation/slope data, combined with transmission-control technology and in-vehicle location and navigation products, will enable fuel consumption to decrease by 4-12%, saving many billions of dollars annually for American drivers. State and county DOTs will also greatly benefit.

assumes 5 percent for USGS to manage the acquisition and processing of data. Column F includes the total cost per square mile used in the CBA. Dewberry provided cost estimates for QL5 IFSAR (Interferometric Synthetic Aperture Radar) in Alaska ($94.50/mi²) and reduced costs for QL5 IFSAR in the other 49 states ($80/mi²) where acquisition costs were estimated to be about 18 percent lower because of improved access to suitable airports and facilities. All costs assumed that the same Quality Level of elevation data is acquired in the most efficient manner for entire 1-degree cells (1° latitude by 1° longitude). As of 2017, LiDAR costs are much lower than estimated in 2011, so that the ROI today would be significantly higher than totaled in these tables.

Reduced Benefits Value Multipliers

Recognizing that benefits are degraded if users do not receive the Quality Level and update frequency required, Dewberry developed a procedure for degrading annual dollar benefits with reduced *value multipliers*. **Table 3** shows how the benefits *value multiplier* is decreased for a Functional Activity that has the most demanding requirement (QL1 LiDAR with annual updates) and

Table 2. Estimation of Costs per Square Mile for the Five Quality Levels

A	B	C	D	E	F
Quality Level	**$/mi²**	**QA/QC**	**Subtotal**	**USGS**	**Total $/mi²**
QL1 LiDAR (48 states)	$453.25	$67.99	$521.24	$26.06	$547.30
QL2 LiDAR (48 states)	$277.00	$41.55	$318.55	$15.93	$344.48
QL3 LiDAR (48 states)	$209.25	$31.39	$240.64	$12.03	$252.67
QL4 1-m Image DEM (48 states)	$134.00	$20.10	$154.10	$7.71	$161.81
QL5 IFSAR (Alaska)	$90.00	Included	$90.00	$4.50	$94.50
QL5 IFSAR (49 states)					$80.00

Table 3. Reduced Benefits Value Multipliers with Poorer Quality Level and Update Frequency

Update Frequency	QL1 LiDAR	QL2 LiDAR	QL3 LiDAR	QL4 DEM	QL5 IFSAR
Annually	1	1/2	1/4	1/8	1/16
2-3 years	1/2	1/4	1/8	1/16	1/32
4-5 years	1/4	1/8	1/16	1/32	1/64
6-10 years	1/8	1/16	1/32	1/64	1/128
>10 years	1/16	1/32	1/64	1/128	1/256

receives something less than that (shown in the other 24 alternatives). For other less-demanding requirements, the *value multiplier* is 1.0 (full benefit value) if the Quality Level and update frequency is equal to or better than required, but decreased by half for every column to the right for Quality Level and for every row beneath for update frequency. For example, if a FA required QL1 LiDAR updated every 4-5 years to achieve a $100,000 annual benefit, but received QL2 LiDAR updated every 6-10 years, the benefit would be reduced to a $25,000 annual benefit.

Two widely used methods for performing Benefit Cost Analyses are: (1) Net Benefits (NB) where costs are subtracted from the benefits (NB = benefits minus costs); and (2) Benefit/Cost Ratio (B/C Ratio) where the benefits are divided by the costs (B/C Ratio = benefits/costs). Dewberry used the master geodatabase to optimize Net Benefits, but also computed the B/C Ratio for multiple options.

Cost-Benefit Analyses

The CBA demonstrate the synergy achieved if sectors work together to meet their common needs. **Table 4** shows that if the federal government, state governments, and nongovernmental organizations work as independent groups, their subtotal aggregate annual costs would be higher ($289M), their aggregate benefits would be lower ($891M), and the annual net benefits ($602M) would be lower (yellow), than if the groups worked collaboratively to optimize the overall benefit-cost model (green). At this stage of the NEEA study, we were considering potentially different Quality Levels and update frequencies for each individual 1-degree cell in all 50 states and U.S. territories.

Dewberry used the power of the geodatabase to evaluate all 25 options (five update frequencies for each Quality Level) for collecting consistent elevation data (**Table 5**.) Each option would result in a uniform Quality Level and a uniform update frequency for the 48 conterminous states, excluding Alaska, Hawaii and U.S. territories where costs were uncertain. For each option, **Table 5** shows annual total data costs, annual total benefits, annual net benefits (negative net benefits for red numbers in parentheses) and B/C Ratios. The five colors in this table match those used in all maps in the NEEA report that show Quality Levels.

Although Option 3 (QL1 LiDAR, 4-5 year update frequency) has the highest Net Benefits, Option 9 (QL2 LiDAR, 6-10 year update frequency) provides the best B/C Ratio (5.356) with annual Net Benefits of $548M. Therefore Option 9 would provide the "biggest bang for the buck" if a uniform Quality Level and update frequency option is desired for the 48 conterminous states.

Table 5 does not imply that alternatives are limited to uniform data Quality Levels for the 48 conterminous states, and certainly not for all 50 states and U.S. territories. For example, Alaska has many requirements for LiDAR, but IFSAR provides a more-realistic

Table 4. The combined (synergistic) net benefits exceed the individual federal, state and nongovernmental benefits

User Group	Annual Costs	Annual Benefits	Annual Net Benefits	B/C Ratio
Federal highest net benefits	$124M/year	$252M/year	$128M/year	2.031
State highest net benefits	$105M/year	$506M/year	$401M/year	4.820
Nongovernmental highest net benefits	$60M/year	$133M/year	$73M/year	2.206
Subtotal highest net benefits	$289M/year	$891M/year	$602M/year	3.079
Combined highest net benefits	$213M/year	$1,008M/year	$795M/year	4.728

Table 5. Comparison of Benefit/Cost Ratios and Net Benefits for all 25 Quality Level and Update Frequency Options

Option #	Quality Level	Update Frequency	Annual Total Costs	Annual Total Benefits	Benefit/Cost Ratio	Net Benefits (Benefits - Costs)
1	1	Annual	$1,646M	$1,111M	0.674	**($536M)**
2	1	2-3 years	$659M	$1,110M	1.685	$451M
3	1	4-5 years	$366M	$1,066M	2.914	$700M
4	1	6-10 years	$206M	$800M	3.887	$594M
5	1	>10 years	$110M	$403M	3.671	$293M
6	2	Annual	$1,006M	$923M	0.917	**($84M)**
7	2	2-3 years	$402M	$922M	2.291	$520M
8	2	4-5 years	$224M	$888M	3.970	$664M
9	2	6-10 years	$126M	$674M	5.356	$548M
10	2	>10 years	$67M	$339M	5.049	$272M
11	3	Annual	$760M	$697M	0.917	**($63M)**
12	3	2-3 years	$304M	$696M	2.291	$392M
13	3	4-5 years	$169M	$673M	3.983	$504M
14	3	6-10 years	$95M	$501M	5.278	$406M
15	3	>10 years	$51M	$252M	4.970	$201M
16	4	Annual	$487M	$361M	0.741	**($126M)**
17	4	2-3 years	$195M	$360M	1.851	$166M
18	4	4-5 years	$108M	$346M	3.198	$238M
19	4	6-10 years	$61M	$256M	4.204	$195M
20	4	>10 years	$32M	$129M	3.962	$96M
21	5	Annual	$241M	$190M	0.788	**($51M)**
22	5	2-3 years	$96M	$190M	1.970	$93M
23	5	4-5 years	$53M	$180M	3.365	$126M
24	5	6-10 years	$30M	$131M	4.369	$101M
25	5	>10 years	$16M	$66M	4.118	$50M

and achievable statewide solution for Alaska because IFSAR maps through clouds and fog that would make LiDAR unachievable or unaffordable throughout much of that state.

3D Elevation Program (3DEP) and Future 3D Nation

After evaluating these options and multiple nationwide implementation scenarios prepared by Dewberry, USGS developed the 3DEP based on QL2 LiDAR nationwide, except for QL5 IfSAR in Alaska, with updates on an 8-year cycle if possible. USGS called the NEEA report "the most comprehensive benefit/cost analysis ever performed for any layer of The National Map," and similar cost-benefit analysis processes are planned for the ongoing NEEA Update and Coastal Nearshore/Offshore Bathymetry Requirements and Benefits Study now in progress, with a goal to obtain a seamless, consistent, high-accuracy, high-resolution 3D Nation, from the tops of the mountains to the depths of the sea, that is cost-effective and up-to-date. The NEEA was a vital part of this vision for the future.

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