Economics of Equity in Infrastructure Investments

Application to Broadband Expansion and Digital Equity Planning

Digital Inclusion Research Forum, Oct. 13, 2023
Federal Reserve Bank, Dallas

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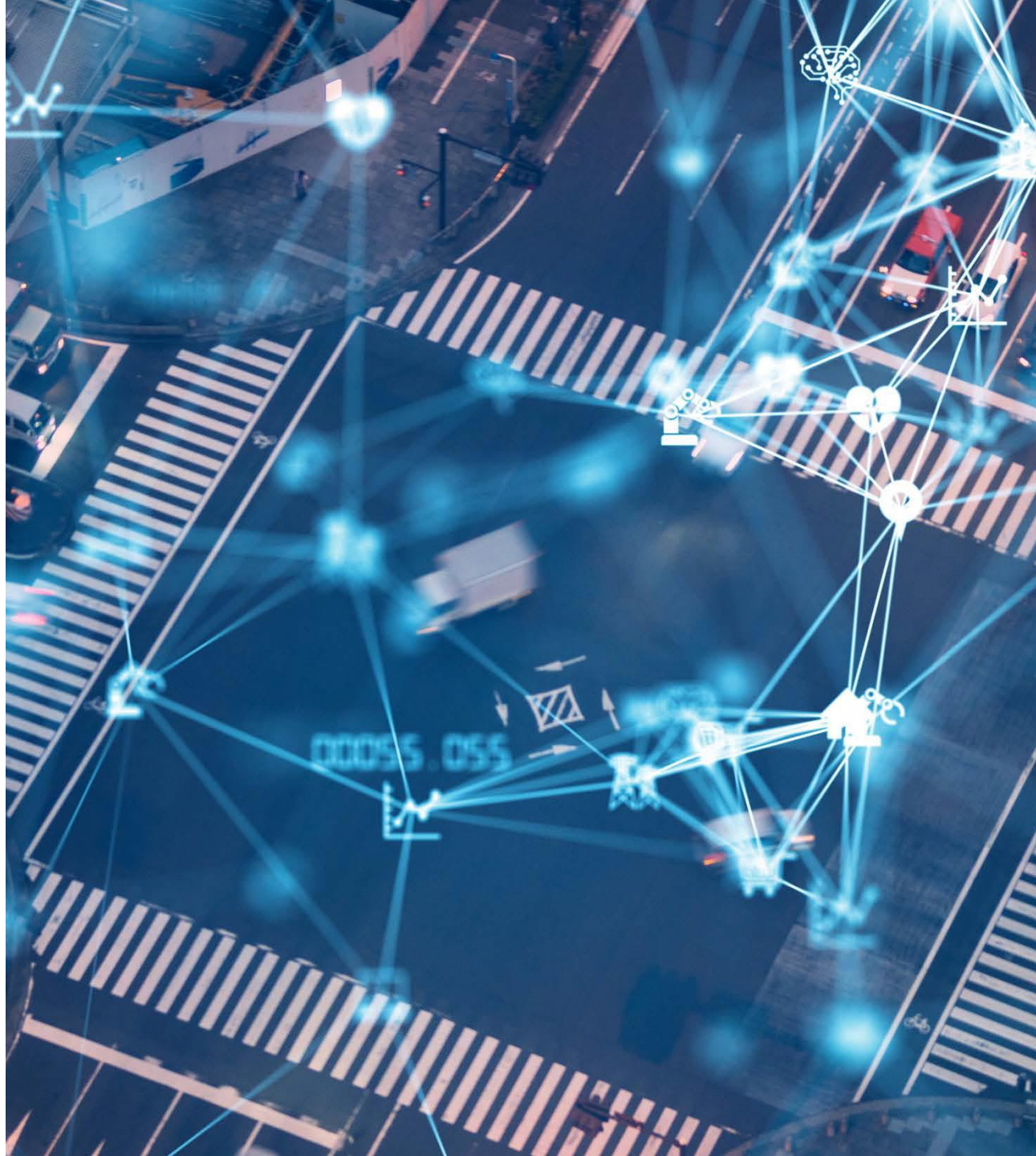
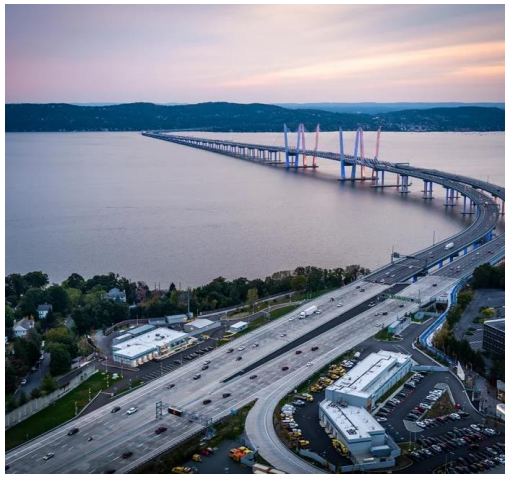


Introduction to HDR

- HDR Overview
  - Top global engineering and architecture firm
  - Plans, designs, builds essential infrastructure (transportation, water, energy, waste, etc.)
  - Multidisciplinary broadband services
  - *HDR Fellowship (supported this research)*
- HDR Economics and Finance Group
  - 40+ economists in the U.S. and Canada
  - Conducted hundreds of BCAs and related analyses, using best available information and methods
  - Established *Sustainable Value Analysis* approach



Agenda

1. Background and Overview of BCA
2. Introduction to ***Weighted*** BCA
3. Completed Project Examples
4. Conceptual Application to Broadband
5. Discussion

Infrastructure, Distributional Effects, and Equity

- Dramatic rise in income inequality since 1980s
- Infrastructure has inherent distributional effects
  - **Access:** Infrastructure serves individuals who have access to it
  - **Service quality:** Safe and reliable service can vary area
  - **Targeted improvements:** Some improvements for target groups
  - **Barriers:** Differences arise among individuals' abilities to pay
  - **Externalities of use:** Infrastructure can impact non-users
  - **Project scale:** Large projects are infrequently implemented
  - **Budget constraints:** Financial constraints limit implementation
  - **Cost burden:** More people contribute to costs than benefit
- Agencies seek sound, defensible methods to assess equity and distributional impacts

- Key Question: What role can economics play?

Standard BCA Methods

- **Standard Approach**
  - Follows **federal BCA guidelines**
  - Analytical focus: **"market" value** of improvements
  - **Applied on major projects** for decades
    - Build vs. Base Case
    - Benefits and costs over planning horizon
    - Measurable, monetizable
    - Multiple benefit categories
  - **Standardized methods** for different infrastructure
- **BCA results and contribution to decisions**
  - Increasingly **required in Federal grants**
  - **Ignores differences** in people, such as income
  - *BCA provides **no input** on equity evaluation*
  - *Distributional analyses **=> alongside BCA***

Elements of Benefit Calculations:

	Scale Factors	Impact Factors	Valuation
Transit (travel time benefits)	# of users	Travel / wait time savings	Value of time per trip
Flood Risk (residences)	# of properties	Depth of damage	Property value
Energy conversion	# of kWh of production	Pollutant emissions per kWh	Value per ton of pollutant
Broadband (labor market)	# of employable pop (over 16)	% increase in job placement	Value of jobs (wages)

Alternative Approach: Weighted BCA

- Theoretically sound framework, similar to BCA
- WBCA incorporates information on the value of projects to people relative to incomes
- *Weights are computed based on value of $ to a person, according to that person's income*
- Weights multiply with estimated benefits B_{ij} and costs C_{ik} to determine weighted net present value (wNPV)

$$wNPV = \sum_{i}^{I}\left[\sum_{j}^{J} w_i^{\alpha} \cdot B_{ij} - \sum_{k}^{K} w_i^{\alpha} \cdot C_{ik}\right]$$

$$w_i^{\alpha} = \left(\frac{y_{\alpha}}{y_i}\right)^{\varepsilon}$$

ε = *elasticity of marginal utility of income*

y_{α} = *benchmark income of region*

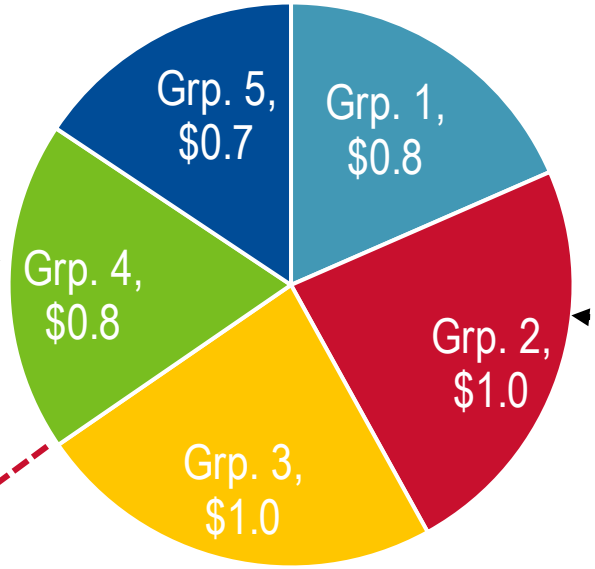
y_i = *income group i in region*

Analytical Summary

Standard BCA

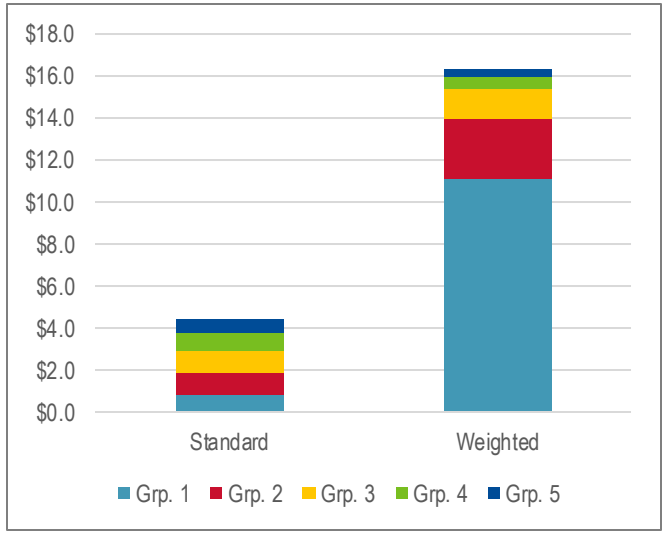
Category	Present Value
Time Savings	$6.5
Cost Savings	$4.46
Safety	$1.80
Emissions	$0.80

Distributed Benefits

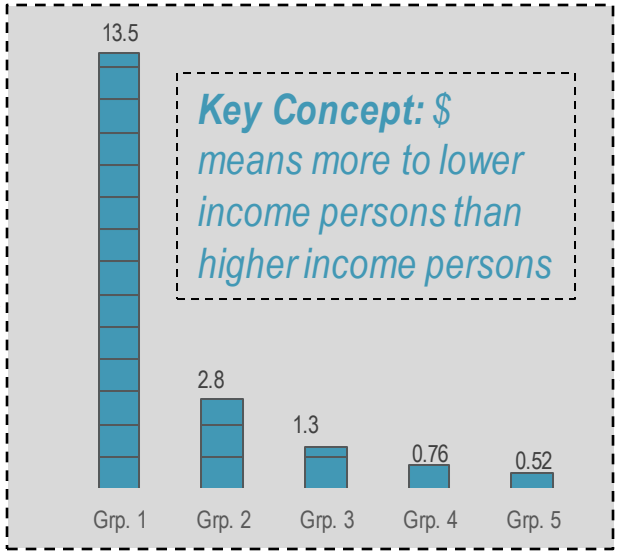


Income distribution of beneficiaries

Weighted BCA



Income-based Weights



Income distribution of region

Project Example – Transit Improvement, Lynn, MA

- Location: Lynn, MA, a northern, suburb of Boston
- Multi-modal improvements
- Local area is low-income
- Regional median inc.= $94k
- Benefits differ by mode and affected population
- Source of costs are state and federal grant funding
- Benefit categories: time savings, cost savings, safety, amenities, emissions, O&M

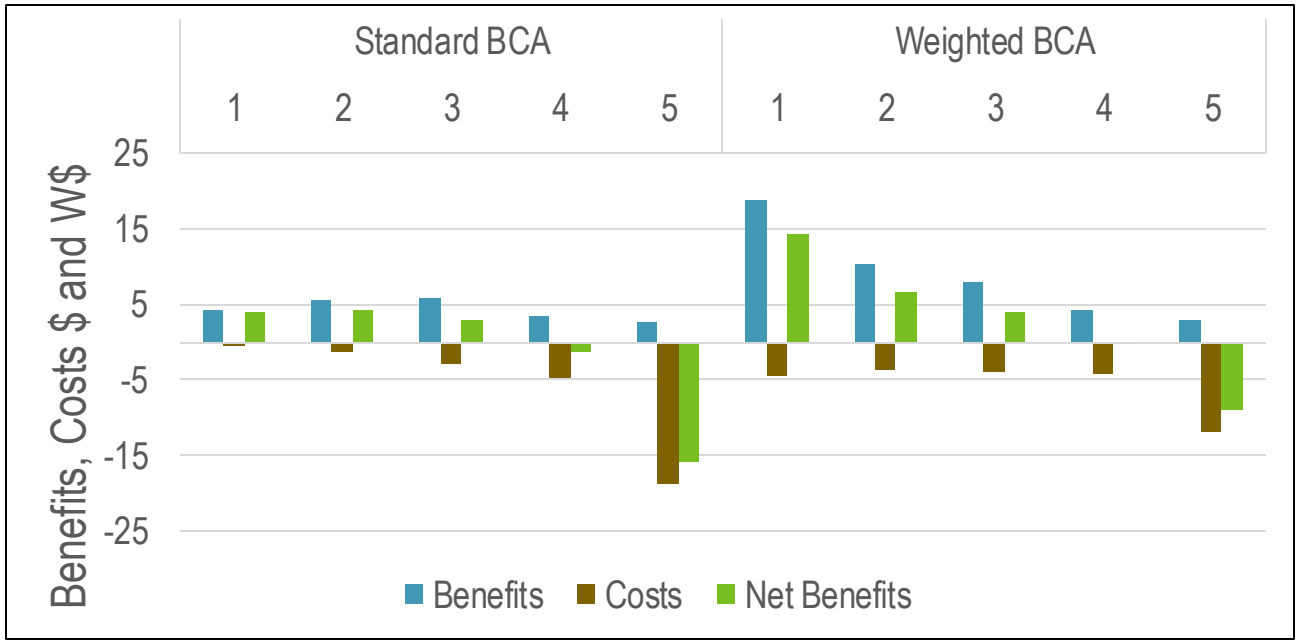
Category	BCA Totals
Travel Time Savings	$6.52
Vehicle Op. Cost Savings	$4.46
Safety Benefits	$1.30
Emissions	$1.12
Amenity Benefits	$8.88
O&M Costs	-$3.47
Total Benefits	**$18.8**
Cost	$24.83
BC Ratio	0.76
NPV	-$6.0

Note: Net present values, at 7% discount rate

Evaluation of Example Results

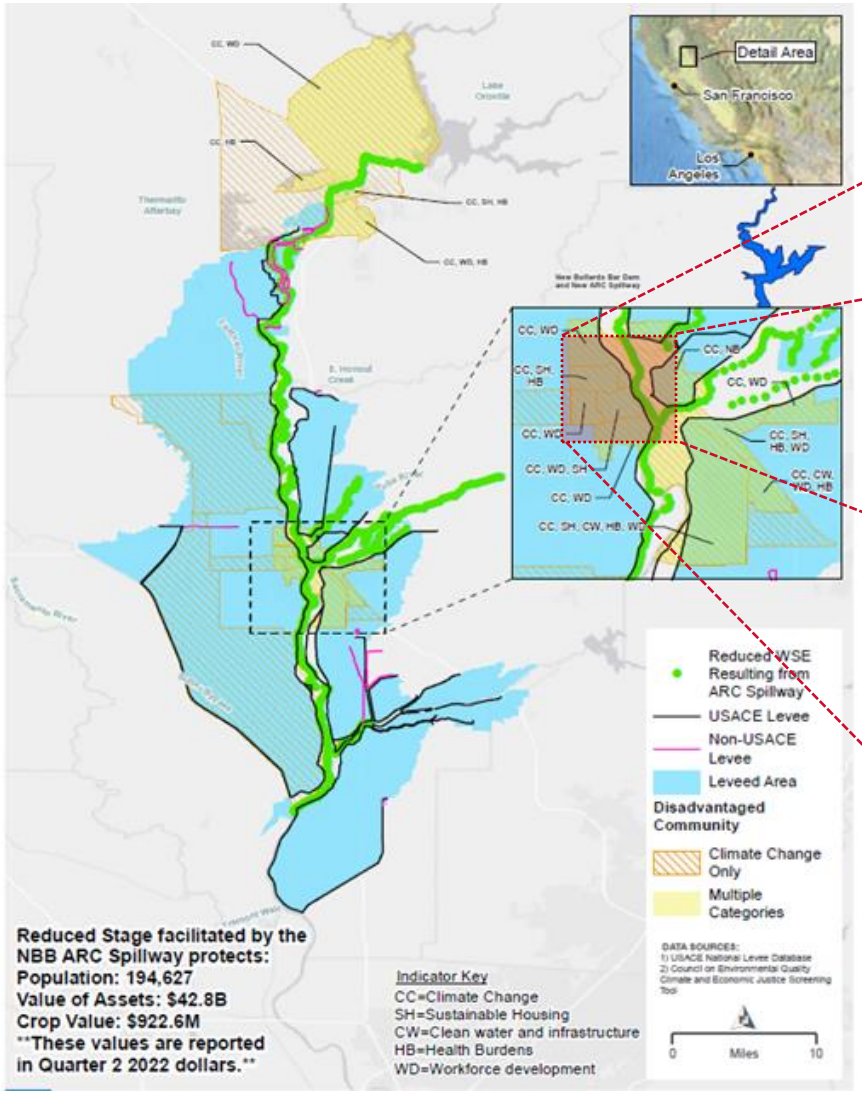
- BCA:
  - Negative NPV: it is not a project that people would be willing to pay for
- Weighted BCA:
  - Positive W-NPV: ***value of benefits to users*** exceeds ***value of money raised from taxpayers (and fee payers)***
  - Weighted BC ratio > 1 provides compelling case of a positive ***societal value-for-money***
  - ***Magnitude of differences*** of weighted benefits versus benefits differs by income
  - Low threshold elasticity (compared to baseline value of 1.2) indicates that these ***results are robust***

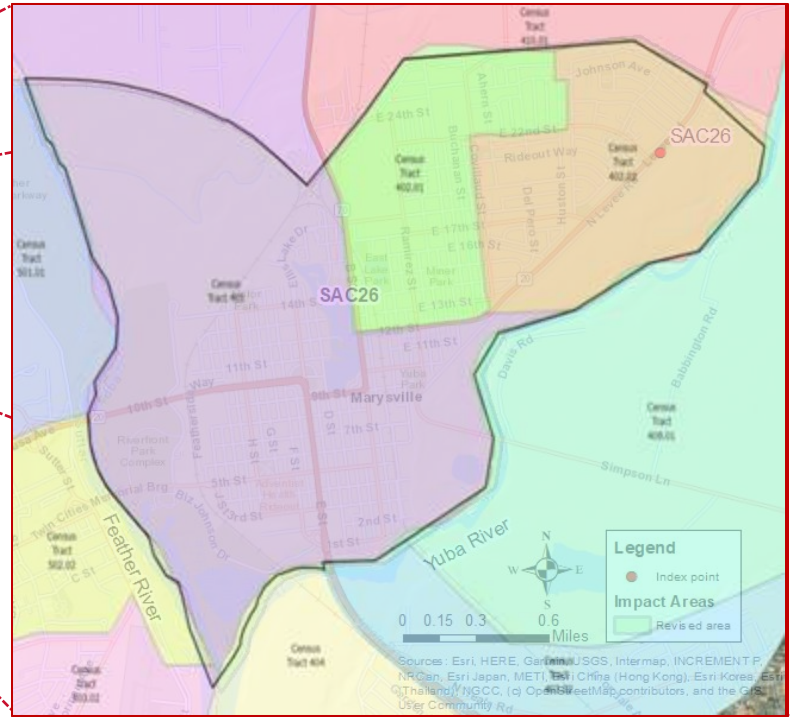
BCA Metric	BCA (PV 7% $M)	Weighted BCA (PV 7% W$M)
Benefits	$22.3	W$54.9
Costs	$28.3	W$28.3
NPV	-$6.0	W$26.6
BC Ratio	0.8	1.9
Threshold Elasticity		0.15



Project Example – Flood Risk Reduction, Marysville, CA

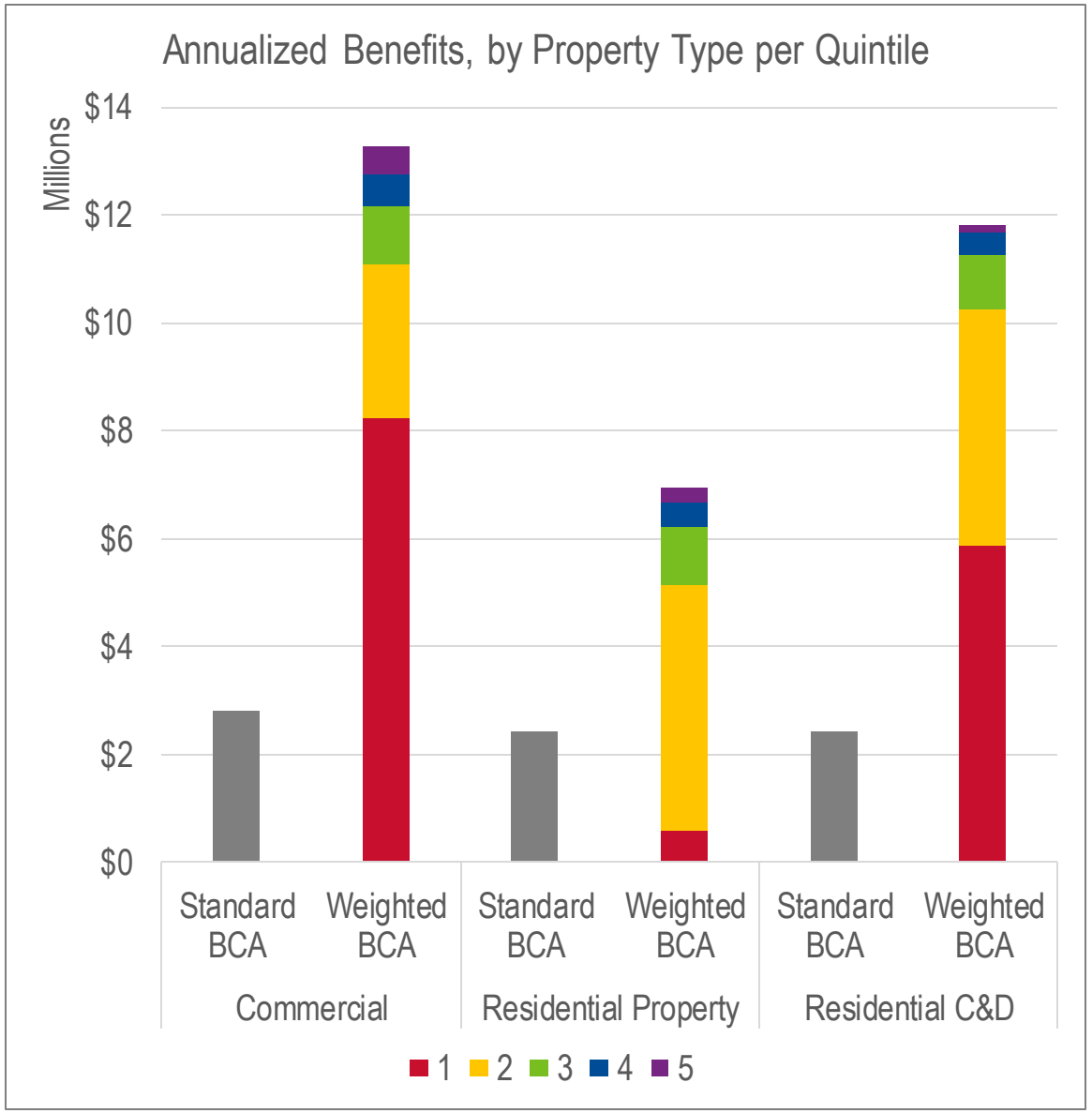
- Potential flood risk to properties (green shaded zone)
- Residential and commercial properties at risk
- Flood damages have been evaluated for several return periods
- Analysis supported a FEMA grant application
- Multiple census tracts affected
- Benefit categories: structures, agricultural crops, life loss, O&M response





Benefits Comparison

Recurrence Interval (varies in Pre- and Post-)	Total Damages - BCA		Total Damages - WBCA	
	Pre-Mitigation Damages	Post-Mitigation Damages	Pre-Mitigation Damages	Post-Mitigation Damages
	Annual ($M)	Annual ($M)	Annual ($M)	Annual ($M)
1	$5.24	$3.36	$21.87	$14.04
2	$5.27	$0.18	$22.01	$0.74
3	$5.61	$4.87	$23.42	$20.33
Total Annualized	**$16.11**	**$8.41**	**$67.30**	**$35.11**
Ann. Net Benefits	**$7.7**		**$32.2**	
PV Benefits	**$106.0**		**$444.0**	
PV Costs	**$236.6**		**$236.6**	
BCR	**0.45**		**1.88**	
NPV	**-$130.6**		**$207.4**	



Summary of Research

- Relevant form of distributional analysis (differences: across geographical areas, and targeted to income groups)
- Weights are **evidenced based**, but some details need to be developed
- Weights can be **integrated with results** from standard methods
- Weighted benefits for low-income users are **substantially higher than standard**
- Results can **influence the investment location and type** (e.g. level of protection)
- Research areas: better understand **nuances in approach** and **local agency perspectives**

Potential Use Cases:

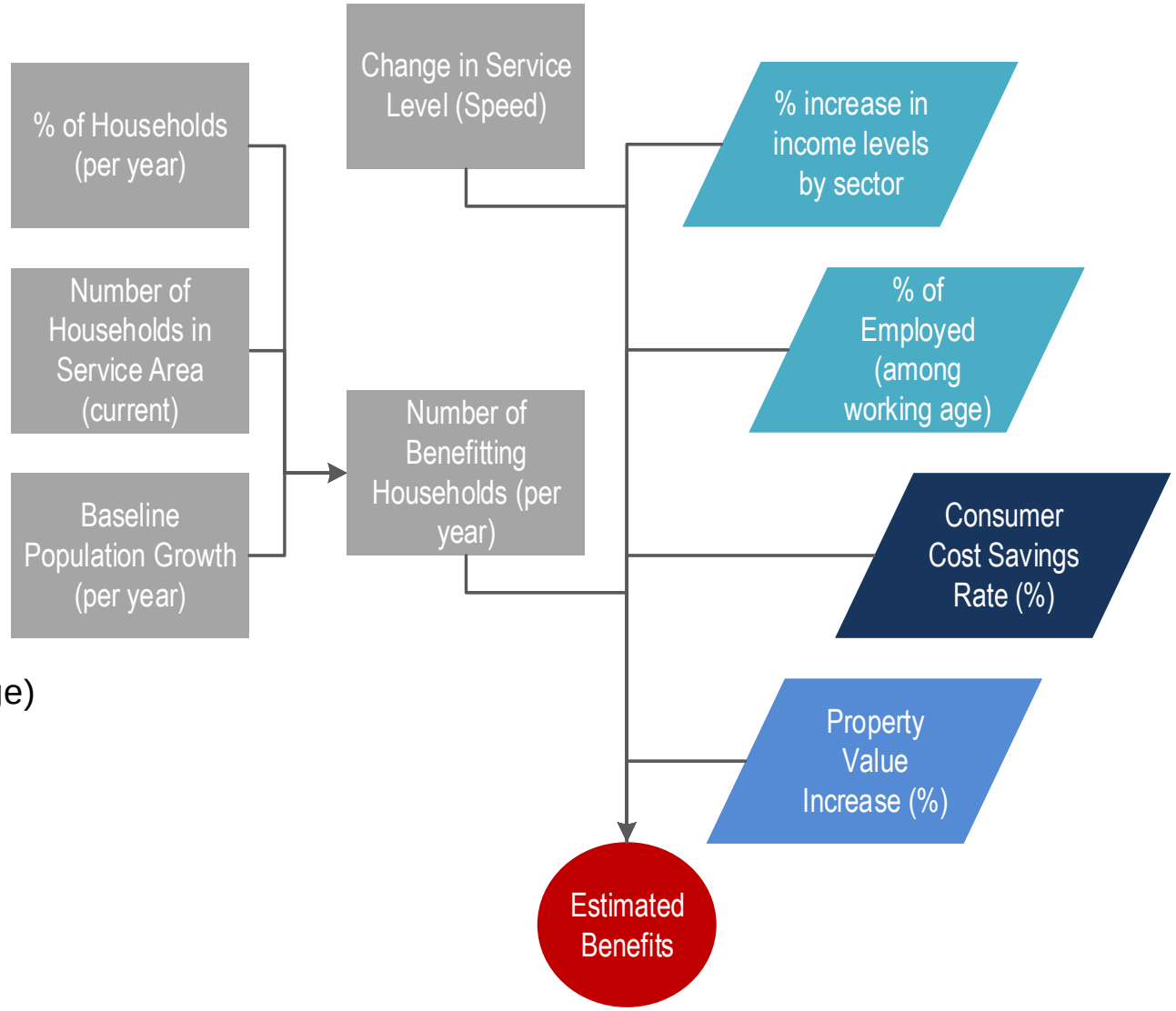
- Transit: service routes; mode choice
- Roadways: facility expansion, toll road access
- Flood mitigation: neighborhood protection
- ***Digital Inclusion: benefits of access***
- Water: affordability analyses; siting
- Waste management: service provision
- Energy: residential energy efficiency or solar
- Public health facilities: access to services

Data Needs

- Facility / service location & description
- Distribution of incomes / wealth of beneficiaries
- Project (notional) scope and benefits

Exploration – BCA of Broadband Expansion

- Characteristics of program
  - Location characteristics
  - Baseline level of broadband access (speed)
  - Change in level of broadband access
- Scale of impact
  - Determine numbers of persons affected
    - Existing number of users
    - % annual growth in users
  - Characteristics of households
    - Household size
    - Demographics (e.g. % working age, % school age)
    - Current income distribution
- Value of impact
  - Adapt results of economic research
  - Standardize economic valuation parameters



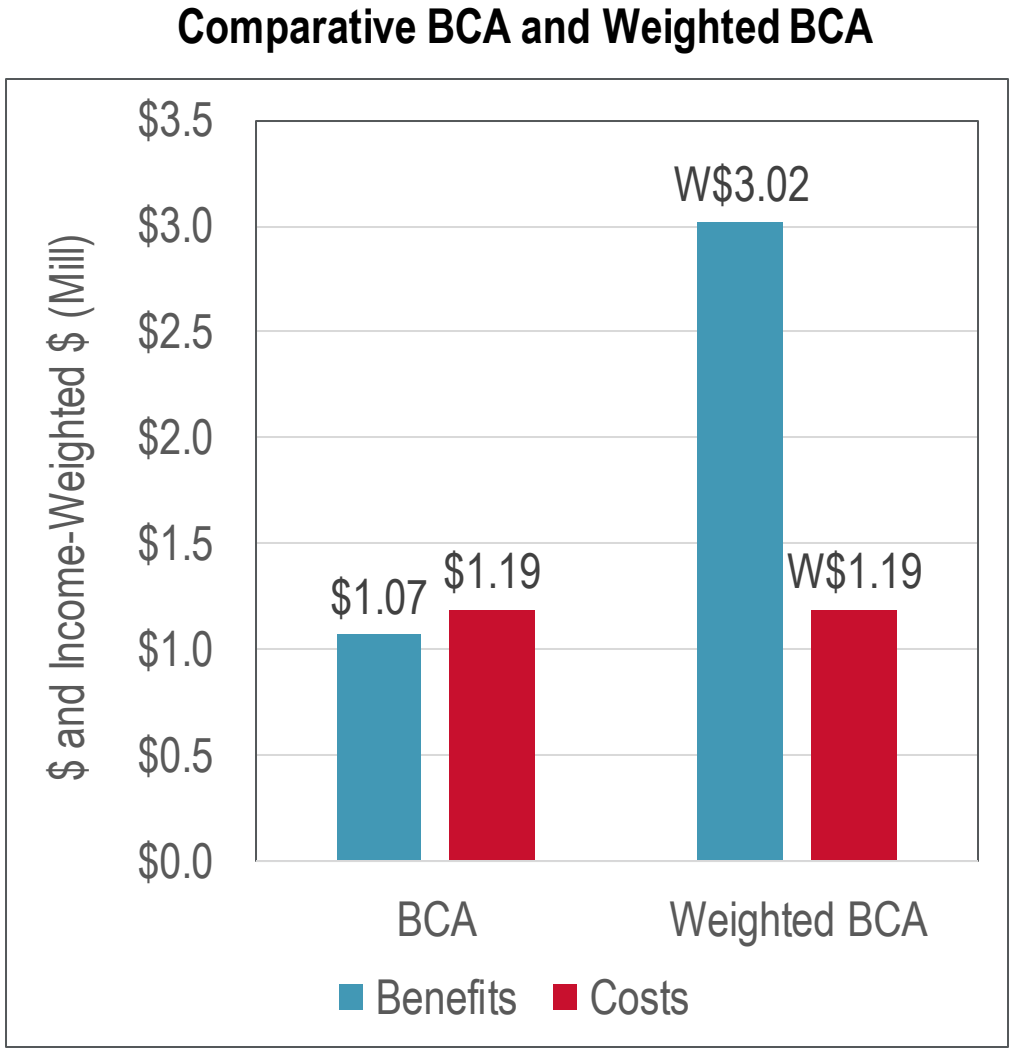
Benefits and Valuation Sources

- BCA models:
  - Census data on beneficiaries
  - Initial valuation parameters
  - Long run trend assumptions
- Distributional analyses:
  - Identify income distributions of affected population
  - Estimate and apply weights
- Sensitivity analyses:
  - Identify key parameters
  - Model uncertainty
  - Assess robustness of results

Benefit Category	Impact	Affected Persons	Sources
Willingness To Pay	"Catch all" measure of value that accounts for improvements in speed, reliability, etc.	Households	Rabbani, Bogulski, Eswaran, Hayes, 2023
Economic development	Increases in higher median household income	Employees (over 16)	*Gallardo, and Strover, 2014*
Farm profits	Increase in sales, expenditures, and profits	Farmer Households	*Kandilov, Kandilov, Liu, Renkow, 2017*
Education and Income	Long-range wage growth of access at primary & secondary levels	School children (under 18)	*Chen, Mittal, and Sridhar, 2020*
Consumer pricing	Annual consumer savings: from $500 - $1500 / year per HH	Households	*Greenstein and McDevitt, 2012*
Property Values	Rural single-family homes sell for 2.5% higher price	Homeowners	*Molnar, Savage, & Sicker, 2019; Deller, Whitacre, 2019*

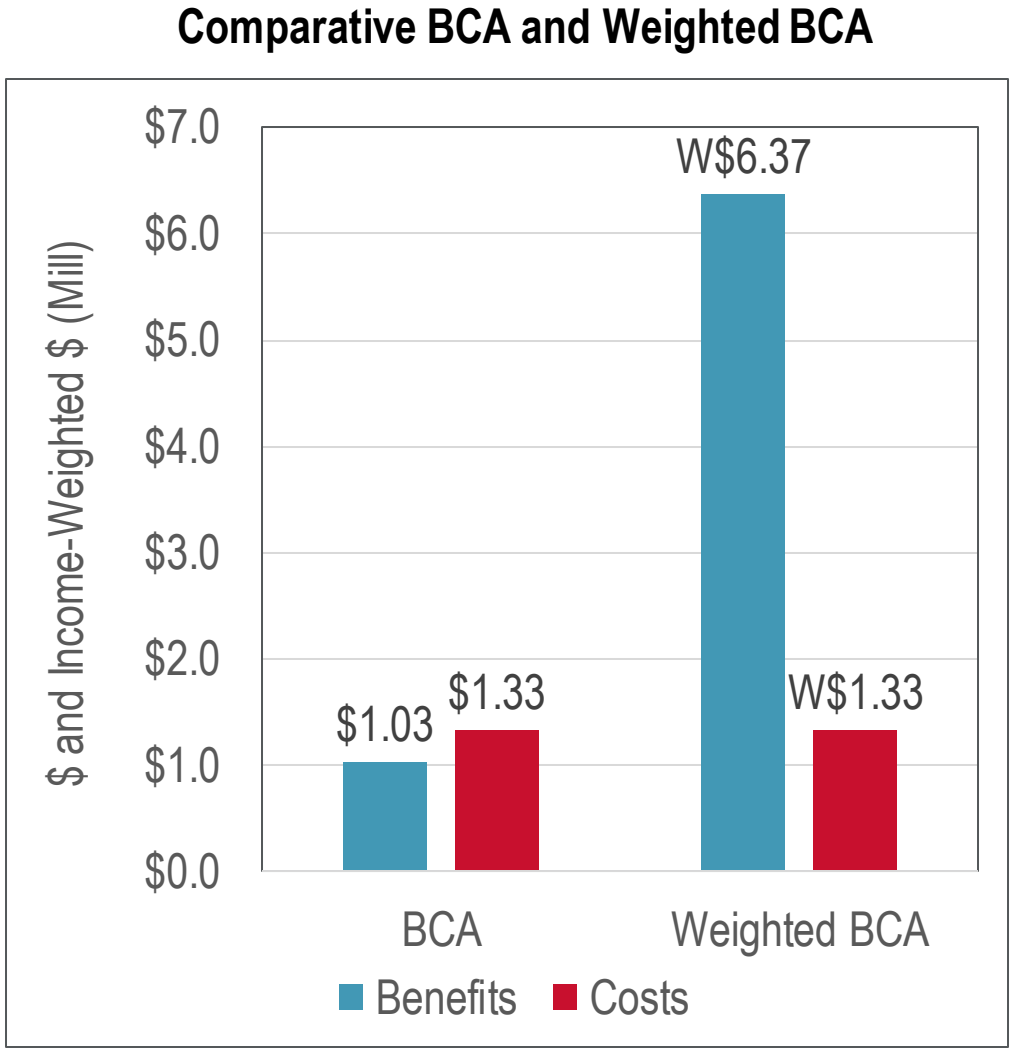
Illustrative Results – KS Broadband Acceleration Grants

- Location: Seward County, KS
- Number of households: 250
- Income eligibility (up to ~$54k)
- Impact: Increase from average 10 to 25 MBps
- WTP - higher speed: ~$31.44 (Rabbani, et al, 2023)
- Capital cost only (state): $1.19 M
- Weighting parameters factors: $w_i^{\alpha} = \left(\frac{y_{\alpha}}{y_i}\right)^{\varepsilon}$
  - Elasticity 1.2
  - Benchmark income: $108k
  - Avg beneficiary incomes: 2nd quintile (average $46k)
  - Weight = 2.82



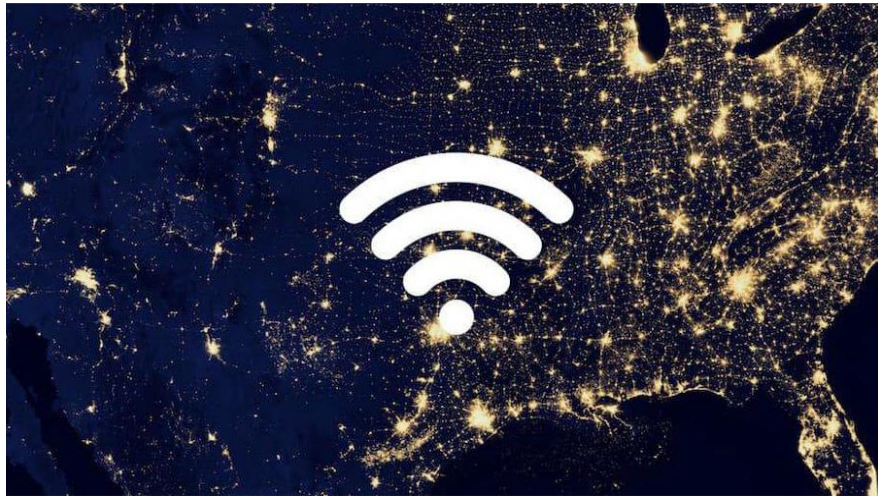
Illustrative Results – ACP Subsidy

- Location: Seward County, KS
- Income eligibility (up to ~$30k)
- Baseline number of households: 250
- Growth in number of users: 75
  - Baseline cost: $50 average
  - Program impact: lower cost by $30/month
  - Valuation: elasticity of demand: -0.5% (Ford, 2021)
- Annual program cost impact (federal): $0.12 M
- Weighting parameters factors: $w_i^{\alpha} = \left(\frac{y_{\alpha}}{y_i}\right)^{\varepsilon}$
  - Elasticity 1.2
  - Benchmark income: $145k
  - Avg beneficiary incomes: 1st quintile (average $30k)
  - Weight = 6.1



Discussion on Application for Broadband

- Would this form of distributional analysis support decisions?
  - If so, where and when, relative to digital equity plans and goals?
  - Is this approach more relevant at federal or state levels?
- What are potential (or perceived) limitations in applications?
  - Data availability?
  - Assumptions in valuation?
  - Viability of alternative – based on weights of quantitative impacts (e.g. # of students)?
- Can we identify case studies for an actual demonstration?
  - Which agencies have interests in results and access to data?
  - Are there potential funding sources / contracting options?



Thank you

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