Benefit-Cost Analysis Sustainment and Enhancements

Interim Distributional Weights Methodology Report

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FEMA

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1. Introduction

The Federal Emergency Management Agency (FEMA) and the Office of Management and Budget (OMB) established the Distributional Weights Working Group in February 2022 (referred to hereafter as "Working Group"). The Working Group's purpose was to discuss how FEMA might improve program access by incorporating distributional weights into its benefit-cost analysis (BCA) procedures and Toolkit. The standard practice for conducting a BCA has been to assume that everyone—regardless of income—values a marginal dollar of costs and benefits equally. Accounting for diminishing marginal utility using distributional weighting means applying a multiplier when a program or project can affect different groups differently, depending on how the relevant groups of people value the welfare gains or losses from policy decisions (OMB, 2023b). When a program or project is expected to have differential effects on subgroups of the population, an agency may choose to use these distributional weights in a BCA.

In December 2022, the Working Group recommended applying distributional weights to the Building Replacement Value for select BCA modules. As explained in Circular A-94 (OMB, 2023a) and Circular A-4 (OMB, 2023b), performing distributional analysis or applying distributional weights may not be feasible or appropriate in all contexts. FEMA has determined that it is both feasible and appropriate to apply distributional weights in certain contexts and is publishing this interim report to describe the Working Group's recommended methodology and explain how it is being initially implemented. FEMA will review the implementation of this change routinely and may update the methodology in the future.

2. Methodology for Applying Distributional Weights for Building Replacement Value

The Working Group found that many of the standard economic values used in FEMA's BCA Toolkit were already implicitly weighted because they were developed using averages. For other standard economic values, it would be too complex to deconstruct the methodologies for developing them to try to reweight the values. However, the Building Replacement Value (BRV) is a standard economic value for which it is possible to apply distributional weights. The BRV is predominantly used for residential flood mitigation projects, i.e., in the Riverine, Coastal A, Coastal V, and Coastal Unknown BCA modules, but the BRV is also a user-provided input in the Landslide, Hurricane Wind, Seismic Structural, and Wildfire BCA modules. The methodology for applying distributional weights described in this report is being implemented for all these BCA modules.

The Working Group recommended using an approach for developing distributional weights that matches Circular A-94 (OMB, 2023b), and is similar to the approach described in the United Kingdom's *The Green Book* (HM Treasury, 2022). This approach uses an isoelastic utility function with elasticity estimates that equivalizes income based on happiness surveys, risk aversion (insurance), and time preferences. The formula uses the median equivalized income of average taxpayers and the median equivalized income of program participants.

To apply the formula to the United States and to take advantage of the data available from the U.S. Census Bureau, the Working Group recommended calculating a BRV Distributional Weight Multiplier (DWM) using the median household income of the United States and the median household income for the census tract in which a mitigation project is located.

The formula proposed by the Working Group is:

$$\text{BRV DWM} = \left(\frac{\text{median household income of U.S.}}{\text{median household income of Census Tract } i}\right)^{1.4} \quad (1)$$

Where:

The median household income of the United States is available from the most recent Census Bureau's American Community Survey (ACS) 5-year estimates.

Census Tract *i* is the census tract in which a proposed mitigation project is to be located.

The median household income of Census Tract *i* is also available from the Census Bureau's American Community Survey (ACS) 5-year estimates.

The exponent 1.4 is the value for the elasticity of marginal utility of income recommended by the Working Group.

3. Methodology for Implementing the Building Replacement Value Distributional Weight Multiplier in the BCA Toolkit

To implement distributional weights in the BCA Toolkit, a BRV Distributional Weight Multiplier (DWM) is pre-calculated for each census tract and stored as lookup data. Using each project structure's location, the BCA Toolkit identifies the census tract in which the project is located and retrieves the associated BRV DWM. The BCA Toolkit then calculates the Total Building Replacement Value by multiplying the BRV by the DWM. The steps for calculating the DWM are described in more detail as follows:

1. Retrieve Median Household Income Data for Census Tracts.

   For the United States and Puerto Rico, the data processing script retrieves, for a given year, the 5-year ACS national median household income for the United States and the 5-year ACS median household incomes for all census tracts in the United States from the U.S. Census Bureau to use in Equation 1 (Census Bureau, 2023). For the four territories of American Samoa, Commonwealth of Northern Mariana Islands, Guam, and U.S. Virgin Islands, the data processing script uses the most recent Decennial Census median household income data by census tract and the same year United States national median household income (Census Bureau, 2020) in Equation 1.

2. **Calculate the Income Ratio.**

   The data processing script then calculates an Income Ratio, which is shown in Equation 2 and is defined as the ratio of the median household income in Census Tract *i* to the median household income of the U.S. overall.

$$Income\ Ratio = \frac{median\ household\ income\ of\ Census\ Tract\ i}{median\ household\ income\ of\ U.S.} \quad (2)$$

3. **Calculate the BRV Distributional Weights Multiplier (DWM).**

   The data processing script calculates the DWM by inserting the Income Ratio into Equation 1. However, due to the mathematical structure of Equation 1, the Income Ratio is inverted when calculating a DWM, implying an inverse relationship between the DWM in Census Tract *i* and its median household income (i.e., an increase in the median household income of Census Tract *i* will result in a decrease in its BRV DWM). BRV DWM values are then rounded to the tenths place.

4. **Apply Minimum and Maximum BRV DWM values.**

   To avoid decreasing a project's BCR due to the use of a BRV DWM, FEMA is setting the minimum DWM value at 1. This means that projects in census tracts with a median household income greater than the national value are not penalized by the use of the Income Ratio to calculate the DWM. Specifically, if FEMA allowed a DWM below 1, then projects in census tracts with a median household income *above* the national average would see their BRVs and BCRs *decrease*. Because the BCR is used to determine *eligibility* for funding consideration, not *prioritization* among the pool of eligible projects, establishing a minimum DWM value at 1 is expected to increase the number of eligible projects without penalizing any projects in the evaluation and prioritization process.

   To mitigate the effect of extreme values and to establish a conservative baseline for implementing a DWM methodology, FEMA is setting a maximum DWM at 3.7, which corresponds to the 95th percentile of the distribution of BRV DWM values (measured from the bottom and rounded to the tenths place).[1] The DWM values in census tracts that would otherwise have a DWM value greater than 3.7 are replaced with a DWM value equal to 3.7.

[1] FEMA considered different percentiles of the DWM distribution for selecting the maximum DWM value. The DWM values at different percentiles (e.g., 1st percentile, 2nd percentile, etc.) were estimated by applying a common statistical technique using the mean and standard deviation of the distribution of the DWM values across all census tracts. This approach requires assuming a normally distributed DWM distribution and identifying specific percentiles using z-scores (multiples of the standard deviation measured from the mean). Analysis of the DWM distribution indicated that it is approximately normally distributed, with a small leftward skew (mean<median) toward lower DWM values. Because the DWM and median household income are inversely related (see Equations 1 and 2), the two distributions are also inversely related. Thus, the x^{th} percentile on one distribution corresponds to the $(1\text{-}x)^{th}$ percentile on the other. For example, the maximum DWM value of 3.7 corresponds to the 5th percentile of the median household income distribution (only 5 percent of households have a lower income) and the 95th percentile of the DWM distribution (only 5 percent of census tracts have a higher DWM value).

The BCA Toolkit's Flood, Landslide, Hurricane Wind, Seismic Structural, and Wildfire BCA modules support implementing the distributional weights methodology as follows:

- The BCA Toolkit uses the location information supplied by the user to identify the census tract in which each structure associated with a hazard mitigation project is located.
    - A mitigation project may include buildings/structures located in more than one census tract. Because the BCA Toolkit analyzes each building/structure included in a project separately, it calculates a BRV DWM for each individual building/structure.
    - To complete a BCA for a project located on Tribal lands, the BCA Toolkit uses the BRV DWM for the median household income for the U.S. census tract in which the Tribal land is located.
- Based on the census tract in which a structure is located, the BCA Toolkit retrieves and applies the BRV DWM lookup value associated with that census tract. The BCA Toolkit then multiplies a structure's BRV by the associated DWM lookup value to calculate the weighted Total Building Replacement Value.

4. Example Results of Implementing Distributional Weights for Building Replacement Value in the BCA Toolkit

To illustrate the calculation of a DWM for a building located in a lower income census tract (i.e., a census tract with a median household income *below* the median income of the United States), consider the following example.[2] For this census tract, the 2021 median household income was $52,053, while the 2021 median household income for the United States was $69,021.[3] These values are used to calculate the Income Ratio (Equation 2), which is then inverted and plugged into Equation 1 to calculate the DWM for that census tract as follows:

$$\text{BRV DWM} = \left(\frac{\$69{,}021}{\$52{,}053}\right)^{1.4} = 1.5$$

FEMA may consider other statistical techniques for calculating percentiles and determining the maximum DWM values in the future.

[2] This example is based on Census Tract 26163572100 located in Dearborn Heights, MI.

[3] The BCA Toolkit is initially populated using 2021 Census data. FEMA anticipates updating the Census data periodically to ensure that changes in a census tract's median household income relative to the median household income of the U.S. are reflected in the BCA Toolkit.

As shown in the BCA Toolkit screenshot in Figure 1, the Total Value of Building is calculated as the Building Size (2000 square feet) x BRV ($100 per square foot) x BRV distributional weight multiplier (1.5) = $300,000.

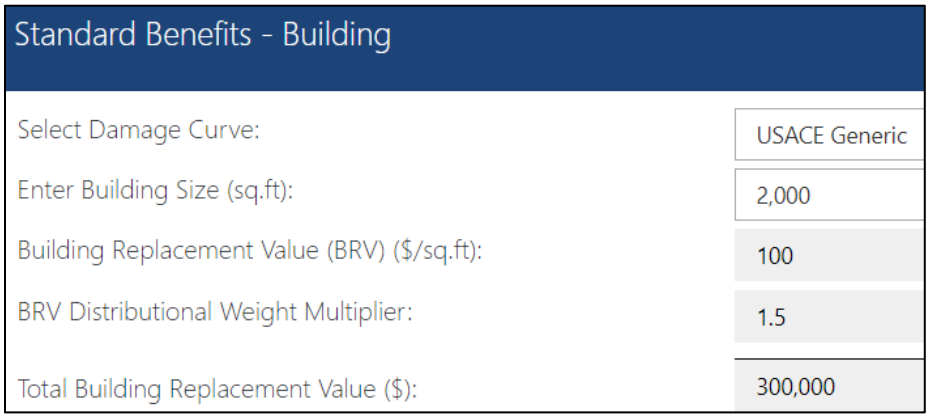

Figure 1. Example of Implementing a BRV Distributional Weight Multiplier for a Lower Income Census Tract

Now consider the calculation of the Total Building Replacement Value if this same building is in a census tract that has a median household income *equal to or greater than* the median household income of the United States (i.e., a census tract that is not lower income). Because FEMA has set the minimum DWM value to 1 to ensure census tracts with higher-than-average median household incomes are not penalized by the DWM methodology, the BCA Toolkit sets the BRV DWM equal to 1 in this example. As shown in Figure 2, the Total Value of Building is calculated as 2,000 square feet x $100 per square foot x 1.0 = $200,000. Comparing the Total Value of Building in Figures 1 and 2 shows that the BRV DWM increases the Total Value of Building in the lower income census tract but does not change the Total Value of Building in the higher income census tract.

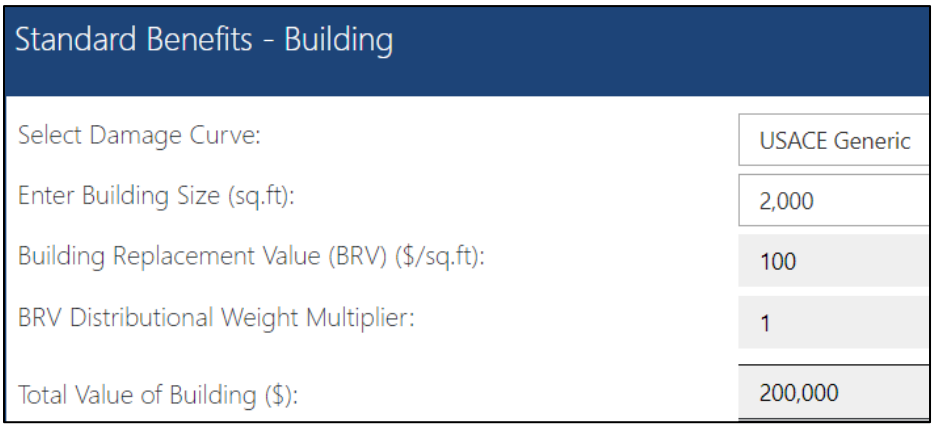

Figure 2. Example of Implementing a BRV Distributional Weight Multiplier for a Higher Income Census Tract

Next, consider how the DWM changes in lower income census tracts based on differences in the median household income in each of these tracts. As in the previous examples, assume the building

size is 2,000 square feet and the BRV is $100 per square foot. As the median household income decreases (moving down column 1), the BRV DWM (column 2) and Total Value of the Building (column 3) increase. To illustrate the effect of the DWM on the benefit-cost ratio (column 4), divide the Total Value of Building by a total project cost of $360,000, which is FEMA's threshold for applying the pre-calculated benefits value for acquisition projects (FEMA, 2023).[4]

Table 1. BRV Distributional Weight Multiplier, Total Value of Building, and Benefit-Cost Ratios for Range of Median Household Incomes

Median Household Income of Census Tract	*BRV DWM*[a]	*Total Value of Building*[b]	*Benefit-Cost Ratio using the Distributional Weight Multiplier*
Equal to or greater than the median household income of United States[c]	1.0	$200,000[d]	0.6
$60,000	1.2	$240,000	0.7
$50,000	1.6	$320,000	0.9
$40,000	2.2	$440,000	1.2
$30,000	3.2	$640,000	1.8
$2,514[e]	3.7	$740,000	2.1[f]

[a] The BRV DWM is calculated using Equation 1.
[b] The Total Value of Building is calculated by multiplying an assumed building size of 2,000 square foot by a BRV of $100 per square foot and then by the BRV DWM.
[c] The 2021 median household income for the United States was $69,021 (Census Bureau, 2023).
[d] For census tracts with household incomes above the national median household income, there is no impact on the Total Value of Building.
[e] This was the lowest median household income for a census tract in 2021 (Census Bureau, 2023).
[f] This BCR value is calculated using the maximum BRV DWM. If there was no maximum DWM, the BRV DWM would be 103.3, the Total Value of Building would be $20,658,194, and the Benefit-Cost Ratio would be 57.4.

The effect of the DWM on the benefit-cost ratio is observed by tracking the median household income (column 1) across to the benefit-cost ratio (column 4). As the median household income for a census tract decreases (column 1), the higher are the DWM (column 2) and the total value of a building (column 3) values, which for a given project cost, increases the project benefits and the corresponding benefit-cost ratio (BCR) (column 4). In turn, the higher benefit-cost ratio increases the likelihood that the project is determined to be cost-effective (i.e., where the BCR is greater than or equal to 1) and eligible for FEMA funding. Note that a determination that a project is cost-effective is

[4] To simplify this illustration, assume the project produces only one type of benefit – avoiding the loss (cost) of replacing the building. In this case, the Benefit-Cost Ratio (BCR) is calculated by dividing the Total Value of Building (column 3) by the total project cost, which is assumed to be $360,000 (FEMA, 2023). If the project results in other benefits, they would be added to the numerator in the benefit-cost ratio without applying a DWM to those benefits.

generally a condition of eligibility for award and is distinct from the criteria by which projects are selected for award (among the pool of eligible projects).

5. References

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