Benefit-Cost Analysis Sustainment and Enhancements

Distributional Weights Methodology Report

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1. Introduction

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. To account for diminishing marginal utility using distributional weights, a multiplier is applied 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. 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 Hazard Mitigation Assistance (HMA) program access by incorporating distributional weights into its benefit-cost analysis (BCA) procedures and Toolkit.

In December 2022, the Working Group recommended applying distributional weights to the Building Replacement Value (BRV) for select modules of FEMA's BCA Tool. 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. FEMA is publishing this report to describe the Working Group's recommended methodology and to explain how it has been implemented. FEMA will continue to assess whether additional enhancements should be made to this methodology in the future.

2. Methodology for Calculating the BRV DWM

The Working Group recommended using an approach for developing distributional weights that corresponds with guidelines described in Circular A-94 (OMB, 2023b). The approach described by the Working Group uses an isoelastic utility function with elasticity estimates that equivalize 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 and to use data available from the U.S. Census Bureau, the Working Group recommended calculating a BRV DWM using the National MHI and the MHI for the census tract in which a hazard mitigation project is located. The methodology was refined to use MHI data at the census block group level instead of at the census tract level to improve the geographic resolution and the accuracy of the BRV DWM calculation. The BRV is a standard economic value in FEMA's BCA Toolkit for which it is possible to apply distributional weights.[1] The BRV is used for analyzing hazard

[1] The BRV is the cost per square foot to repair a building with functionally equivalent construction after it is (hypothetically) damaged by a hazard event. The BRV represents a cost that would be avoided by hazard mitigation, and thus factors into

mitigation projects in the Riverine, Coastal A, Coastal V, Coastal Unknown, Landslide, Hurricane Wind, Seismic Structural, and Wildfire modules of the BCA Toolkit.

As indicated in Equation 1, the BRV DWM is calculated using the MHI of the census block group in which a proposed hazard mitigation project is located relative to the national MHI.[2]

$$\text{BRV DWM} = \left(\frac{\text{MHI}_{\text{National}}}{\text{MHI}_{\text{CensusBlockGroupi}}}\right)^{1.4} \qquad (1)$$

Where:

$\text{MHI}_{\text{National}}$	= The national MHI (Census Bureau, 2022b)[3]
Census Block Group i	= The census block group in which a proposed hazard mitigation project is located
$\text{MHI}_{\text{CensusBlockGroupi}}$	= The MHI of Census Block Group *i* (Census Bureau, 2022b)

The exponent (1.4) in Equation 1 is a parameter representing the elasticity of marginal utility of income, which can be interpreted as a measure of societal aversion to income inequality.[4] If the National MHI remains the same, Equation 1 shows that a decrease in the MHI of Census Block Group *i* will result in an increase in the BRV DWM.

3. Procedure for Implementing the BRV DWM in the BCA Toolkit

To implement distributional weights in the BCA Toolkit, a BRV DWM is pre-calculated for each census block group, and those values are stored as lookup data. Using the location of each project structure, the BCA Toolkit identifies the census block group in which the hazard mitigation project is

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the calculation of the benefits of the hazard mitigation project. The default value of the BRV in the BCA Toolkit is $100 per square foot, although users can supply a different value.

[2] The BRV DMW for a given census block group is relatively stable from year to year if income growth is relatively uniform across census block groups. When income growth is not uniform across census block groups, the BRV DWM can change as a census block group's income changes relative to the national U.S. value.

[3] The U.S. Census Bureau releases data for their 5-year American Community Survey (ACS) Median Household Income in December of the following year.

[4] For guidance, see OMB Circular A-94, and for an overview of the guidance, see Adler (2016), p. 266. For a recent analysis of empirical estimates of the elasticity of marginal utility of income, see Acland and Greenberg (2023).

located and then retrieves the associated BRV DWM. The BCA Toolkit then calculates the Total Building Replacement Value.

The following steps are used for calculating the BRV DWM and the Total BRV:

1. **Identify the Project Location.**
   The BCA Toolkit uses the location information supplied by the user to identify the census block group in which each structure associated with a hazard mitigation project is located. A single mitigation project may include multiple buildings/structures, which may be located in more than one census block group. The BCA Toolkit calculates a BRV DWM for each structure in a hazard mitigation project.

   To complete a BCA for a hazard mitigation project located on tribal lands, the BCA Toolkit prompts the user to indicate whether the structure being analyzed is included in a tribal project. If the user confirms the project will be located on tribal lands, the BCA Toolkit will then use the BRV DWM for the MHI from the relevant tribal block group.

2. **Retrieve Median Household Income Data for Census Block Groups, Census Tracts, Counties, and States.**

   For the United States and Puerto Rico, the data processing script retrieves, for a given year, the 5-year American Community Survey (ACS) national median household income for the United States and the 5-year ACS median household incomes with its corresponding margin of error for all census block groups, census tracts, counties, and states in the United States from the U.S. Census Bureau to use in Equation 1 (Census Bureau, 2022b).

   For the territories of American Samoa, Commonwealth of Northern Mariana Islands, U.S. Virgin Islands, and Guam, the data processing script uses the most recent Decennial Census MHI data by census block group and the national MHI for the same year (Census Bureau, 2020a, 2020b, 2020c, and 2020d) in Equation 1. Census data for the four territories does not include margin of error values, so the MHI estimates are used without a replacement for imprecise values.

3. **Calculate the MHI Percent Margin of Error.**

   The data processing script then calculates the ratio of the MHI MOE to the MHI Estimate, which is a measure of the precision (confidence) of the estimate, for each census block group, census tract, and county, and then converts it to a percentage as shown in Equation 2.

$$\text{MHI Percent Margin of Error} = \left(\frac{\text{MHI}_{\text{MOE}}}{\text{MHI}_{\text{Estimate}}}\right) \times 100 \tag{2}$$

4. **Replace High Margin of Error and Missing Median Household Income Values.**

   The data processing script then hierarchically replaces missing MHI estimates and MHI estimates that have an MHI MOE that is more than 50 percent of the MHI estimate, beginning with the census block group, and proceeding hierarchically in the nested geographic structure to the census tract and then to the county.[5] As noted previously, hierarchical replacement occurs for U.S. territories only when MHI estimates are missing since MOE values are not included in the ACS MHI data. Appendix A explains the technical basis for this replacement threshold.

   In tribal areas, hierarchical replacement occurs using the hierarchical sequence of tribal block groups, tribal census tracts, and U.S. County. When tribal block groups are replaced with county data AND overlap multiple counties, the address of the hazard mitigation project is used to determine which county's BRV DWM to use.

5. **Calculate the BRV DWM and Apply Minimum and Maximum BRV DWM values.**

   The data processing script inserts the two replaced MHI values into Equation 1 and calculates the BRV DWM. The BRV DWM values are then rounded to the tenths place.

   The benefit-cost ratio (BCR) of a hazard mitigation project is calculated as the project benefits divided by the project costs. To avoid decreasing a project's BCR due to the use of a BRV DWM, FEMA is setting the minimum BRV DWM value equal to 1.0. This means that projects in census block groups where an MHI of Census Block Group *i* is greater than the National MHI are not penalized by the use of Equation 1 to calculate the BRV DWM. If FEMA allowed a BRV DWM below 1.0, then projects in census block groups with a MHI of Census Block Group *i* above the National MHI would result in decreasing the BRV DWMs and the BCRs. Because the BCR is used to determine *eligibility* for funding consideration, not *prioritization* among the pool of eligible hazard mitigation projects, establishing a minimum BRV DWM value at 1.0 is expected to increase the number of eligible projects without penalizing any projects in the evaluation and prioritization process.[6]

   To mitigate the effect of extreme BRV DWM values and to establish a conservative baseline for implementing a BRV DWM methodology, FEMA is setting a maximum BRV DWM at 3.7. This means all census block groups that would otherwise have a BRV DWM value greater than 3.7 are replaced with a DWM value equal to 3.7. The positional percentile is used to determine the number of affected census block groups. The value of 3.7 corresponds to the 96th percentile of the distribution of BRV DWM values (measured from the bottom of the distribution and rounded to the tenths place). The BRV DWM and MHI are inversely related (see Equation 1), and their two

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[5] When replacement occurs using the geographic hierarchy, a tradeoff between accuracy and precision may arise in which the precision of a higher level in the hierarchy (i.e., census tracts) is accepted at the expense of accuracy at the lower level in the hierarchy (i.e., census block groups). Tradeoffs between accuracy and precision are commonplace in statistical analysis of survey data.

[6] Academic research on distributional weighting widely assumes the use of a benefit-cost ratio as a prioritization metric, not as an eligibility screen. For example, see Adler (2016) and Brent (2024).

distributions are also inversely related. The x^{th} percentile of one distribution corresponds to the $(1-x)^{th}$ percentile of the other distribution. For example, the maximum DWM value of 3.7 corresponds with the 4^{th} percentile of the MHI distribution (i.e., only 4 percent of households have a lower income) and corresponds with the 96^{th} percentile of the BRV DWM distribution (i.e., only 4 percent of census block groups have a higher DWM value). A DWM of 3.7 in the current methodology equates to 4% of the census block groups which contains 3% of the total population.

6. **Calculate the Total Building Replacement Value.**
The BCA Toolkit then calculates the Total Building Replacement Value by multiplying the BRV by the BRV DWM as shown in Equation 3.

$$\text{Total Building Replacement Value} = \text{Building Size} \times \text{BRV} \times \text{BRV DWM} \tag{3}$$

Where:

$\text{Total Building Replacement Value}$ = The total cost to replace the building(s) with a functionally equivalent building

Building Size = The total square footage the building protected by the project

BRV = The cost per square foot to replace the building with a functionally equivalent building, based on the current cost of labor and materials

BRV DWM = The calculated distributional weight multiplier

4. Examples of Implementing the BRV DWM in the BCA Toolkit

The following example illustrates the calculation of a BRV DWM for a building located in a lower income census block group (i.e., a census block group with an MHI below the National MHI). For this census block group *i*, the 2022 MHI was $53,611 while the 2022 National MHI was $75,149.[7] These values are used in Equation 1 to calculate the BRV DWM for that census block group as shown in Equation 4:

$$\text{BRV DWM} = \left(\frac{\$75{,}149}{\$53{,}611}\right)^{1.4} = 1.6 \tag{4}$$

As shown in the BCA Toolkit screenshot in Figure 1, the Total Building Replacement Value is calculated using Equation 3 as the Building Size (2000 square feet) x BRV ($100 per square foot) x BRV DMW (1.6) = $320,000.

[7] This example is based on Census Block Group 261635721002 located in Dearborn Heights, MI.

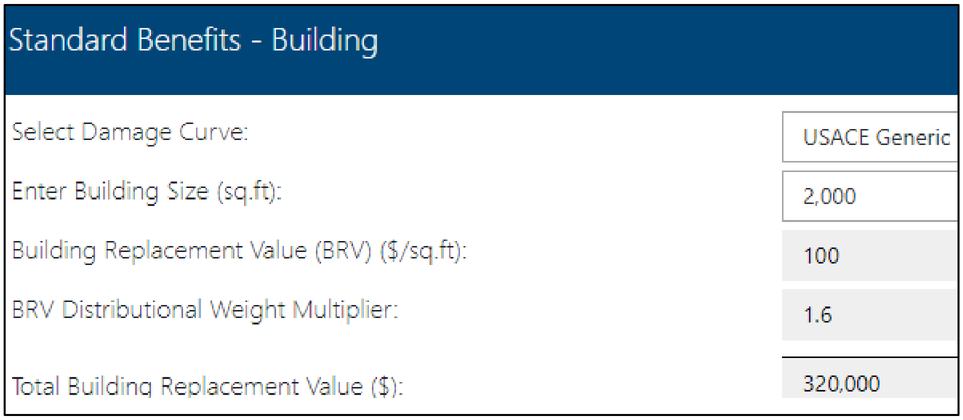

Figure 1. Example of Implementing a BRV DWM for a Lower Income Census Block Group

Another example can be used to show the calculation of the Total Building Replacement Value if this same building is located in a higher income census block group, i.e., a census block group that has an MHI equal to or greater than the National MHI. As explained in Step 5 of Section 3, because FEMA has set the minimum BRV DWM value to 1.0 to ensure census block groups with higher-than-average median household incomes are not penalized by use of the DWM methodology, the BCA Toolkit sets the BRV DWM equal to 1.0 in this example. As shown in Figure 2, the Total Building Replacement Value for this example is calculated using Equation 3 as Building Size (2,000 square feet) x BRV ($100 per square foot) x replaced BRV DWM (1.0) = $200,000. Comparing the Total Building Replacement Value in Figures 1 and 2 shows that the BRV DWM increases the Total Building Replacement Value in the lower income census block group (Figure 1) but does not change the Total Building Replacement Value in the higher income census block group (Figure 2).

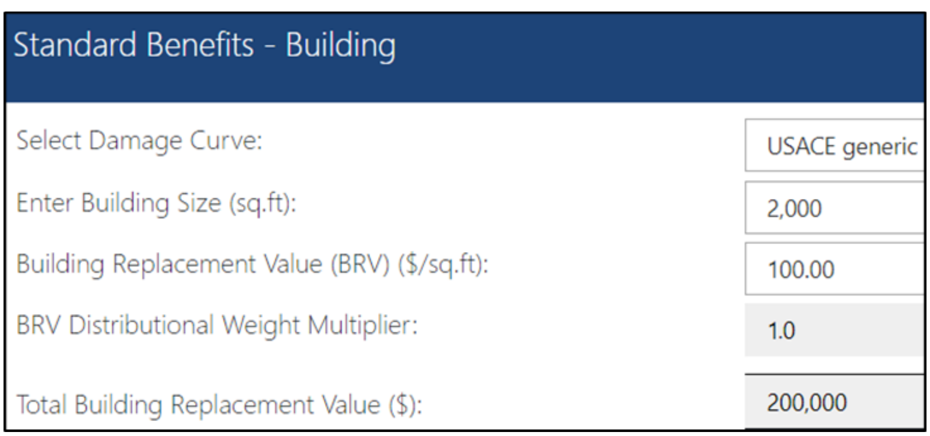

Figure 2. Example of Implementing a BRV DWM for a Higher Income Census Block Group

Table 1 shows how the BRV DWM in lower income census block groups changes based on differences in the MHI in each of these census block groups. As in the two previous examples, the building size is assumed to be 2,000 square feet and the BRV is $100 per square foot. As the MHI of a census block group decreases (column 1), both the BRV DWM (column 2) and the Total Building Replacement Value (column 3) increase. To illustrate the effect of the BRV DWM on the benefit-cost ratio (column 4), the Total Building Replacement Value (column 3) was divided by a total project cost of $775,411, which is FEMA's threshold for applying the pre-calculated benefits value for acquisition projects (FEMA, 2024). To simplify this illustration, the values in Table 1 assume the project only produces one type of benefit: avoiding the loss (cost) of replacing the building.[8]

Table 1. Results of Implementing the BRV Distributional Weight Multiplier in the BCA Toolkit for a Range of Median Household Incomes

Median Household Income of Census Block Group i	*BRV DWM*[a]	*Total Building Replacement Value*[b]	*Benefit-Cost Ratio using the Distributional Weight Multiplier*[c]
Equal to or greater than the national median household income of the United States[d]	1.0	$200,000[e]	0.26
$60,000	1.4	$280,000	0.36
$50,000	1.8	$360,000	0.46
$40,000	2.4	$480,000	0.62
$30,000	3.6	$720,000	0.93
$2,579[f]	3.7	$740,000	0.95

[a] The BRV DWM is calculated using Equation 1.
[b] The Total Building Replacement Value is calculated using Equation 3 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 in column 2.
[c] Calculated by dividing the project benefit of the Total Building Replacement Value (in column 3) by an assumed project cost of $775,411.
[d] The 2022 National MHI for the United States was $75,149 (Census Bureau, 2022b).
[e] For census block groups with MHIs above the National MHI, there is no impact on the Total Building Replacement Value.
[f] This was the lowest MHI for a census block group in 2022 (Census Bureau, 2022b). If there was no maximum set for the BRV DWM as explained in Step 5 of Section 3, the BRV DWM would be 112.3, the Total Replacement Value of Building would be $22,453,839, and the resulting Benefit-Cost Ratio would be 62.4.

As the project benefit based on the Total Building Replacement Value increases for a given project cost, the corresponding benefit-cost ratio (BCR) (column 4) increases. The distributional weight multiplier provides a boost to calculated benefits in lower income census block groups, which increases the BCRs, which makes it easier for project subapplications in these areas to be cost-effective, which is one of FEMA's minimum eligibility criteria.[9] FEMA will continue to review the

[8] Most mitigation projects result in additional avoided losses to building contents damage, displacement costs, and others benefit categories.

[9] Cost-effectiveness is 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). FEMA does not prioritize subapplications for funding based on the order of the highest BCR. For all of FEMA's hazard mitigation programs, each applicant (e.g., State, Territory, or Tribe)

results of implementing this methodology to adjust the BCR and may update the methodology in the future.

determines their own subapplication prioritization, and FEMA attempts to follow that prioritization when making selections and funding decisions.

5. References

Acland, D., and Greenberg, D.H. 2023. The Elasticity of Marginal Utility of Income for Distributional Weighting and Social Discounting: A Meta-Analysis. *Journal of Benefit-Cost Analysis*, 14(*2*): 386-405 (June 18). https://ssrn.com/abstract=4483436

Adler, M.D. 2016. Benefit–Cost Analysis and Distributional Weights: An Overview. *Review of Environmental Economics and Policy*, 10(22): 264–285. https://doi.org/10.1093/reep/rew005

Brent, R.J. 2024. Use of Distributional Weights in Cost-Benefit Analysis Revisited. *Applied Economics*, 56(*29*): 3485-3498.

Census Bureau. 2019. Instructions for Applying Statistical Testing to American Community Survey Data. https://www2.census.gov/programs-surveys/acs/tech_docs/statistical_testing/2019_Instructions_for_Stat_Testing_ACS.pdf

Census Bureau. 2020a. Median Household Income in 2019 (Dollars), Decennial Census of Island Areas, DECIA American Samoa Demographic and Housing Characteristics, Table PBG43. https://data.census.gov/table/DECENNIALDHCAS2020.PBG43?q=income&g=040XX00US60$1500000

Census Bureau. 2020b. Median Household Income in 2019 (Dollars), Decennial Census of Island Areas, DECIA Commonwealth of the Northern Mariana Islands Demographic and Housing Characteristics, Table PBG43. https://data.census.gov/table/DECENNIALDHCMP2020.PBG43?q=income&g=040XX00US69$1500000

Census Bureau. 2020c. Median Household Income in 2019 (Dollars), Decennial Census of Island Areas, DECIA U.S. Virgin Islands Demographic and Housing Characteristics, Table PBG43. https://data.census.gov/table/DECENNIALDHCVI2020.PBG43?q=income&g=040XX00US78$1500000

Census Bureau. 2020d. Median Household Income in 2019 (Dollars) (Excluding People in Military Housing Units), Decennial Census of Island Areas, DECIA Guam Demographic and Housing Characteristics, Table PBG43. https://data.census.gov/table/DECENNIALDHCGU2020.PBG43?q=income&g=040XX00US66$1500000

Census Bureau. 2022a. Increased Margins of Error in the 5-Year Estimates Containing Data Collected in 2020. https://www.census.gov/programs-surveys/acs/technical-documentation/user-notes/2022-04.html

Census Bureau. 2022b. Median Income in the Past 12 Months (In 2022 Inflation-Adjusted Dollars). American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B19013. https://data.census.gov/table/ACSDT5Y2022.B19013?q=b19013&g=010XX00US$1500000

Federal Emergency Management Agency (FEMA). 2024. *How to Complete a Streamlined BCA.* https://www.fema.gov/grants/guidance-tools/benefit-cost-analysis/streamlined-bca

His Majesty's Treasury (HM Treasury). (2022). *The Green Book*. Updated November 18. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020

Office of Management and Budget (OMB). (2023a). *Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.* https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-94.pdf

Office of Management and Budget (OMB). (2023b). *Circular A-4: Regulatory Analysis*. https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf

Appendix A: Technical Basis for Replacement Threshold

This appendix describes FEMA's approach for replacing median household income (MHI) data that are missing at the census block group level or replacing MHI data that are available but are estimated with a large margin of error (MOE).

Distributional weights are calculated using MHI estimates produced by the Census Bureau, based on sampling data collected through its American Community Survey (ACS) (Census Bureau, 2022b). In addition to the estimated MHI, the Census Bureau also provides an MOE value corresponding to the 90 percent confidence interval.

FEMA has concluded that excessively uncertain MHI estimates at the census block group level should be replaced with MHI estimates at the census tract level, since the larger sample sizes at the census tract level typically result in smaller MOEs relative to MHI estimates. In these instances, FEMA's method for replacement represents a statistical choice to improve precision, which is represented by the ratio of the MHI MOE to the MHI estimate, shown in Equation 2, at the expense of accuracy, which is represented by the geographic scope of the area being represented by the MHI estimate. All else being equal, the accuracy of an MHI estimate should increase when the geographic area gets smaller and thus "closer" to the location of the hazard mitigation project. The trade-off between precision and accuracy does not occur when FEMA uses its replacement approach to substitute for missing data, since in these instances, replacement improves the accuracy of the estimate compared to having no estimate at all.

FEMA has determined to replace census block group MHI estimates in which the MHI MOE is 50 percent or more of the census block group MHI estimate with the census tract MHI estimate. If the census tract MHI MOE is at least 50 percent of the census block group MHI estimate, then it is replaced with the county-level MHI estimate. In the one instance in which the county-level MHI MOE is at least 50 percent of its MHI estimate, the census block group MHI estimate is replaced with the state-level MHI estimate. (The one instance is for census block group 483019501001, located in Loving County, Texas, which has the same geographic boundary as the census block group, census tract, and county levels. Loving County has a total population of 96 people.)

A similar geographic hierarchy is used for tribes, but the hierarchy is ordered as tribal block group, tribal census tract, census tract, counties, state. This hierarchy of tribal data is geographically nested only at the tribal block group and tribal census tract level, and not at the more aggregated county and state levels. To operationalize this process, the BCA Toolkit uses the address of the tribal hazard mitigation project to identify the census tract that then serves as a geographic proxy when tribal block group and tribal census tract data are missing or are imprecise (i.e., when MHI MOE/MHI Estimate ≥ 0.50).

The decision by FEMA to set the replacement threshold at 50 percent is informed by the Census Bureau's methodology for evaluating the quality of its data. Specifically, the Census Bureau's Statistical Quality Standard F1: Releasing Information Products, stipulates that data are of adequate quality if the "coefficient of variation, defined as the standard error divided by the estimate, for a majority of the key estimates is less than 0.30" (Census Bureau, 2022a). FEMA uses this quality standard as the basis for its replacement protocol for imprecise MHI estimates. Mathematically, this is shown in Equation 5 as:

$$\mathrm{CV} = \frac{\mathrm{SE}}{\mathrm{MHI\ Estimate}} = 0.30 \tag{5}$$

Where:

CV	= the coefficient of variation
SE	= the standard error
$\mathrm{MHI\ Estimate}$	= the MHI estimate
0.30	= the benchmark value for *CV*

This equation, with the benchmark value, is then algebraically solved for SE as shown in Equation 6.

$$\mathrm{SE} = 0.30 \times \mathrm{MHI\ Estimate} \tag{6}$$

In a separate methodology document (Census Bureau, 2019), the Census Bureau converts the ACS MOE to standard errors using Equation 7.

$$\mathrm{SE} = \frac{\mathrm{MHI\ MOE}}{1.645} \tag{7}$$

Where:

$\mathrm{MHI\ MOE}$	= Margin of Error
1.645	= the z-score corresponding to the 90% confidence interval in a standard normal distribution

Setting Equations 6 and 7 for SE to be equal produces Equation 8:

$$0.30 \times \mathrm{MHI\ Estimate} = \frac{\mathrm{MHI\ MOE}}{1.645} \tag{8}$$

Equation 8 can then be solved for the ratio of MHI MOE to the MHI Estimate, which serves as the replacement threshold shown in Equation 9. The ratio results in a value of 0.50 when rounded to the hundredths place.

$$\frac{\mathrm{MHI\ MOE}}{\mathrm{MHI\ Estimate}} = 0.30 \times 1.645 = 0.4935 = 0.50 \tag{9}$$

Therefore, the Census Bureau's quality standard of 0.30 for CV provides an empirical basis for FEMA's use of an MHI MOE/MHI Estimate ratio of 0.50 as the empirical threshold for replacing more accurate but less precise MHI estimates at the census block group level with less accurate but more precise MHI estimates at the census tract level.