An Examination of Coverage Issues Associated with the U.S. Census Bureau's National Address List

Nancy R. Johnson & Kathleen Kephart
U.S. Census Bureau
4600 Silver Hill Road, Washington, DC 20323

Abstract

The U.S. Census Bureau's Master Address File (MAF) is a national address list that is used for numerous surveys, as well as the decennial census. In order to create an address frame for sampling, or an address list for the decennial census, an extract of the MAF is generated using criteria to determine address validity.

One year before the 2010 Census, the U.S. Census Bureau conducted one of the largest dependent address listing operations in the world, utilizing an extract of the MAF. As the first major field operation of the 2010 Census, it was important to provide an accurate address inventory for the census enumeration operations. An accurate inventory reduces census costs and lessens the risk of either census omissions or over-count. We will present added-in-error and deleted-in-error rates for later census operations, as well as the initial canvassing.

In addition to presenting the results of 2010 Census operations, we explore the characteristics and demographics of areas in the U.S. with poor address coverage. The majority of blocks in the U.S. only required validation (no actions) by Listers (Boies et al., 2012). Poor coverage is defined by areas that required a large number of addresses to be added to or deleted from the existing inventory.

Introduction

The U.S. Census Bureau's Master Address File (MAF) is a national address list used for the decennial census, as well as numerous surveys. To create an address frame either for the decennial census or for sampling, an extract of the MAF is generated using criteria or filters to determine address validity. For census enumeration operations, an accurate address frame reduces costs and lessens the risk of either census omissions or an over-count. Since the MAF is the address-based sampling frame for numerous federal surveys, its accuracy and coverage are critical for obtaining reliable information about the United States throughout the decade.

One of the evaluations in the 2010 Census Program for Evaluations and Experiments titled, "The 2010 Census Evaluation of Address Frame Accuracy and Quality" (Johnson and Kephart, 2013), examined the questions: How accurate was the address frame pre-Address Canvassing, post-Address Canvassing, and after final census operations? How can we improve address frame quality?

The purpose of this evaluation was to estimate the accuracy of the address frame after both the 2010 Census Address Canvassing operation and after completion of all 2010

Census operations. Using results from the 2010 Census Coverage Measurement (CCM) program and a special supplemental field operation, this evaluation analyzed housing units erroneously added and erroneously deleted by census operations. In addition, the authors examined the addresses coded as "missing" from the census by CCM to determine if the census included them as valid housing units, but incorrectly geocoded them to a collection block outside of the CCM geographic search area.

Since the accuracy and quality of the address frame is a broad topic that can include many components, this evaluation focused on changes and improvements to the census address inventory and narrowed the analysis to answer six operational study questions, as described in the following four paragraphs.

The address frame during the course of census operations is dynamic. The pre-Address Canvassing address inventory, serving as the basis for the 2010 Census, is called the MAF. Measuring the accuracy and quality of this address frame was outside the scope of this evaluation due to timing, resources, and limitations in the difficulty of evaluating this universe. Our analysis provides documentation of the changes that were made to the address frame in the course of conducting the 2010 Census, which cannot be interpreted as a direct measure of accuracy of the address frame, but can give an indication of what updates were required to get the address frame "ready" for the 2010 Census.

While some of the records on the MAF represent valid living quarters, other records represent duplicate units, nonresidential addresses, nonexistent units, uninhabitable units, or other types of invalid records. A subset of the MAF records that were the most likely to be potential valid living quarters went into the 2010 Census Address Canvassing operation for Listers to validate or correct. In addition, the Listers added addresses missing from this list. In the post-Address Canvassing list, this evaluation measured the accuracy of actions taken during Address Canvassing and, specifically, answered operational study questions one and two below.

After Address Canvassing, a Group Quarters Validation operation made further changes and enhancements to the census address inventory. This inventory then served as the basis for the Universe Control and Management (UCM) system. The UCM monitored the flow of data to and from the census enumeration operations. At the completion of all census operations, the final status of living quarters is reflected on the Census Unedited File (CUF). In the CUF, this evaluation measured the accuracy of housing units by answering the third through sixth operational study questions below.

The six operational study questions are:

1. By source/operation, what proportion of Address Canvassing "Adds" were correctly added and erroneously added, according to their Census Coverage Measurement status?
2. By source/operation, what proportion of Address Canvassing deleted/duplicated units were correctly deleted and erroneously deleted, according to their Census Coverage Measurement status?
3. By source/operation, what proportion of the post-Address Canvassing "Adds" were correctly added and erroneously added, according to their final Census Coverage Measurement status?

4. By source/operation, what proportion of the post-Address Canvassing deleted/duplicated units were correctly deleted and erroneously deleted, according to their final Census Coverage Measurement status?
5. What was the total estimated percentage of census addresses geocoded to the incorrect 2010 Census collection block?
6. Did the geocoding error estimate vary by type of enumeration area or by census region?

Background

Address Canvassing was the first major field operation of the 2010 Census. The Address Canvassing operation was a dependent listing with the purpose of a) updating the U.S. Census Bureau's address list (i.e., the MAF) to ensure an accurate frame for the enumeration of the population, and b) validating submissions from the Local Update of Census Addresses program and to allow the Census Bureau to provide feedback to the local governments participating in the program.

Overall, the Address Canvassing operation added 10,300,593 living quarters, excluding Puerto Rico. Of these added units, 6,149,446 were New Adds and 4,151,147 matched to an existing record on the MAF. A total of 15,529,724 records were deleted with an additional 3,968,495 units marked as duplicates (Address List Operations Implementation Team, 2011).

The **Census Coverage Measurement** program was a large, complex survey conducted independently of the census. The purpose of the 2010 CCM program was to evaluate coverage in the 2010 Census in order to aide in future censuses, meaning 2020 Census and beyond. The CCM program was designed to measure the coverage of housing units and persons, excluding Group Quarters (GQs) and persons residing in GQs. The CCM program provided estimates of net coverage (Olson and Viehdorfer, 2012), showing undercount and over count, and components of census coverage including omissions and erroneous inclusions (Keller and Fox 2012). Since the CCM was an independent evaluation, the results did not affect the 2010 Census.

The CCM program consisted of six sampling activities, five data collection activities, and three matching activities. An estimation operation followed these activities. The first data collection operation was an Independent Listing conducted separately from the 2010 Census in a sample of block clusters. During subsequent CCM operations the addresses collected were matched to census addresses. At the end of all operations, every address (both those in the census and those found by the CCM operations) had a match code that indicated both a final housing unit status (e.g., valid, nonexistent, under construction, duplicate, uninhabitable, etc.) and a final match status (e.g., CCM and census matched, found by CCM only, found by census only, or unresolved). The evaluation used these final status and match codes in the analysis.

Methods

The Evaluation of Address Frame Accuracy and Quality used results from the CCM as the "truth" measure for the added-in-error, deleted-in-error, and geocoding error estimates. However, the CCM program did not have information for addresses assigned a delete or duplicate status by Address Canvassing, so a small field operation was conducted to gather data on the status of the addresses. This field operation attempted to locate the delete or duplicate address to confirm whether it was nonexistent or a duplicate of another address; or if not, assign the correct status, such as valid living quarters, under construction, uninhabitable, etc.

To produce estimates of the geocoding error, the authors identified addresses that CCM indicated were missing-from-census. In the CCM operations, staff searched for census addresses within a sample block cluster plus one surrounding ring of census blocks. For the evaluation, clerical staff attempted to match the missing-from-census cases to addresses in an extended search area that included "buffer rings" of census blocks that traced around the shape of the block clusters. These buffer rings included distances of one kilometer, three kilometers and five kilometers beyond the edge of the sample block cluster. As a result, the authors were able to determine whether geocoding error occurred more frequently in blocks closest to the subject block (within one kilometer) or in blocks farther away from the subject block (three or five kilometers).

Limitations

The primary limitations of the results include the following:

- Remote Alaska and Puerto Rico were out-of-scope for the evaluation. Remote Alaska was not canvassed in the Address Canvassing operation and was also excluded from the CCM operations. Since the evaluation used data from CCM, the authors did not have information for this area. Puerto Rico was excluded due to the cost and logistics of conducting field operations in that area.
- The results from CCM used in this evaluation are based on a sample survey. Therefore, the estimates are subject to both sampling and nonsampling error.
- This evaluation repeats and expands on two Census 2000 evaluations. See Smith, et. al. (2003) and Ruhnke (2003). Where possible, the authors used the same methodology. However, differences in procedures exist between Census 2000 and the 2010 Census, and between the Census 2000 Accuracy and Coverage Evaluation and the 2010 Census CCM. As a result, estimates between the evaluations are similar but may not be directly comparable.

Results

This section provides the results for each of the study questions.

1. What proportion of Address Canvassing "Adds" were correctly added and erroneously added, according to their Census Coverage Measurement status?

Table 1 shows the 2010 Census Address Canvassing added-in-error rates. Out of approximately 10.6 million add actions, 1.7 million records, or 16.4 percent, did not represent actual valid housing units that existed in the CCM search area on Census Day (April 1). These 1.7 million added-in-error records represent only 1.2 percent of all records processed in Address Canvassing.

Table 1. 2010 CPEX* Address Frame Accuracy and Quality: Status of Address Canvassing Added Records

Add Status	Unweighted Count	Weighted Count	Weighted Percent (SE[1])
Total Adds……	**40,946**	**10,585,463**	**100.0**
Correctly Added……	34,532	8,853,529	83.6 (1.3)
Added-in-Error……...	6,414	1,731,934	16.4 (1.3)

Source: Address Canvassing Add Analysis File.
*Census Program for Evaluations and Experiments.
[1] Standard Error.

2. What proportion of Address Canvassing deleted/duplicated units were correctly deleted and erroneously deleted, according to their Census Coverage Measurement status?

Table 2 examines the Address Canvassing deleted-in-error rate. Address Canvassing correctly deleted most (95.7 percent) of the addresses having a delete or duplicate action and deleted-in-error 4.3 percent of the deleted/duplicated addresses. This represented a weighted count of 786,294 addresses deleted-in-error and about 0.5 percent of all records processed in the Address Canvassing operation.

Table 2. 2010 CPEX* Address Frame Accuracy and Quality: Status of Address Canvassing Deleted/Duplicated Records

Delete/Duplicate Status	Unweighted Count	Weighted Count	Weighted Percent (SE[1])
Total Deletes/Duplicates……	**30,476**	**18,445,131**	**100.0**
Correctly Deleted……	29,171	17,658,837	95.7 (0.6)
Deleted-in-Error……...	1,305	786,294	4.3 (0.6)

Source: Address Canvassing Delete/Duplicate Analysis File.
*Census Program for Evaluations and Experiments.
[1] Standard Error.

3. What proportion of the post-Address Canvassing "Adds" were correctly added and erroneously added, according to their final Census Coverage Measurement status?

Table 3 shows the distribution of the CUF Adds according to the Final Housing Unit (FHU) matching results and compares the 2010 Census to results from the Census 2000 evaluation. The 2010 CCM results confirm that the census operations correctly added 79.6 percent of the CUF Adds. This means census operations added-in-error 20.4 percent of the Adds. Although the rate of address records added-in-error was higher than the rate (16.1 percent) found in Smith, et al. (2003), the authors could not determine whether this difference was statistically significant because standard errors were not available from the Census 2000 evaluation. However, the ratio of total added addresses in the 2010 Census to valid housing units of 2.5 percent (3,338,775/131,704,730) was lower than the Census 2000 ratio of 3.3 percent (3,857,381/115,904,641).

Table 3. 2010 CPEX* Address Frame Accuracy and Quality: Status of Census Unedited File Adds

CUF Add Status	Census 2000		2010 Census		
	Weighted Total (Percent)	Weighted Percent (SE[1])	Unweighted CUF Adds	Weighted Total CUF Adds	Weighted Percent (SE[1])
Total CUF Adds ……	**3,857,381**	**100.0 (n/a)**	**4,769**	**3,601,110**	**100.0**
Correctly Added ……	3,235,099	83.9 (n/a)	3,449	2,867,070	79.6 (2.5)
Added-in-Error ……..	622,282	16.1 (n/a)	1,320	734,040	20.4 (2.5)

n/a is not available.
[1] Standard Error.
*Census Program for Evaluations and Experiments.
Source: Smith et al, 2003 and CUF Adds Analysis Files.

4. What proportion of the post-Address Canvassing deleted/duplicated units were correctly deleted and erroneously deleted, according to their final Census Coverage Measurement status?

Table 4 shows the deleted-in-error rate for the post-Address Canvassing addresses (i.e., records from the census enumeration operations). The census operations correctly deleted most (74.2 percent) of the CUF Deletes/Duplicates and deleted-in-error 25.8 percent of the deleted/duplicated records. The records deleted-in-error represented a weighted count of 1,251,366 addresses that may have been omitted by the census. This estimate was nearly identical to the weighted estimate of 1.2 million housing units found by Smith, et al. (2003) to be deleted-in-error in Census 2000.

Table 4. 2010 CPEX* Address Frame Accuracy and Quality: Status of Census Unedited File Deletes/Duplicates

CUF Delete/Duplicate Status	Census 2000		2010 Census		
	Weighted Count	Weighted Percent (SE[1])	Unweighted Count	Weighted Count	Weighted Percent (SE[1])
Total CUF Deletes/Duplicates	**8,536,752**	**100.0**	**8,013**	**4,850,528**	**100.0**
Correctly Deleted…….	7,309,409	85.6 (n/a)	5,854	3,599,162	74.2 (1.8)
Deleted-in-Error……	1,227,343	14.4 (n/a)	2,159	1,251,366	25.8 (1.8)

n/a is not available.
[1] Standard Error.
*Census Program for Evaluations and Experiments.
Source: Smith, et. al, 2003 and CUF Delete/Duplicate Analysis File.

5. What was the total estimated percentage of census addresses geocoded to the incorrect 2010 Census collection block?

As Table 5 shows, the geocoding error rate has decreased from 4.8 percent in Census 2000 as found by Ruhnke (2003) to 1.5 percent in the 2010 Census.

Table 5. 2010 CPEX* Address Frame Accuracy and Quality: Status of Geocoding in Census 2000 and the 2010 Census

Geocoding Error Rates	Weighted Percent	95 Percent Confidence Interval Lower	95 Percent Confidence Interval Upper	SE[1]
2000 Geocoded in Error Rate…….	4.8	4.2	5.4	0.3
2010 AFAQ Geocoded in Error Rate*(Errors of exclusion)*……..……..	1.5	1.3	1.7	0.1

n/a is not available.
[1] Standard Error.
*Census Program for Evaluations and Experiments.
Source: Ruhnke 2003 and Geocoding Analysis File.

As Table 6 indicates, this evaluation found a geocoding error rate of about 1.4 percent within the cluster and one surrounding ring of blocks. An additional 0.1 percent of units were found misgeocoded within the one kilometer buffer of the block cluster. Beyond one kilometer, not enough cases were found to produce a statistically valid estimate, with only 28 unweighted cases.

Table 6. 2010 CPEX* Address Frame Accuracy and Quality: Search Area Location for Geocoding Error

Block Location Relative to CCM Cluster	Unweighted Count	Weighted Count	Weighted Percent (SE[1])
Total Misgeocoded Records……	**6,714**	**1,992,600**	**100.0**
Within Cluster & ring of surrounding blocks	5,731	1,828,533	1.38 (0.1)
Between ring of surrounding blocks & 1 KM	955	156,322	0.12 (0.03)
Between 1 KM & 5 KM……...	28	**	**

[1] Standard Error.
*Census Program for Evaluations and Experiments.
Source: Geocoding Analysis File.
**There was not a sufficient quantity of cases to produce a reliable weighted estimate.

6. Did the geocoding error estimate vary by type of enumeration area or by census region?

Table 7 shows that the geocoding error rate is the same as the national average for the Mailout/Mailback enumeration areas (1.5 percent) and higher for Update/Leave areas at 1.9 percent.

Table 7. 2010 CPEX* Address Frame Accuracy and Quality: Geocoding Error Rate by Type of Enumeration Area

Status of Geocoding by TEA	Weighted Correctly Geocoded Count	Weighted Erroneously Geocoded Count	Weighted Percent Within TEA (SE[1])
Total Records……	**130,543,009[2]**	**1,992,600**	**1.5 (0.1)**
Mailout/ Mailback……..	118,383,050	1,752,323	1.5 (0.1)
Update/Leave……	10,780,391	209,750	1.9 (0.4)
Update/Enumerate……	1,274,600	**	**
Unknown TEA…….	105,985	**	**

[1] Standard Error.
[2] Subtotals may not sum due to rounding error.
*Census Program for Evaluations and Experiments.
Source: Geocoding Analysis File.
**There was not a sufficient quantity of cases to produce a reliable weighted estimate.

Table 8 shows the geocoding error rate for each census region. The geocoding error is highest in the South at 2.3 percent, while the Midwest has the lowest rate at 0.7 percent. The Northeast and the West had similar error rates at 1.2 percent and 1.1 percent, respectively.

Table 8. 2010 CPEX* Address Frame Accuracy and Quality: Geocoding Error Rate within Census Region

Status of Geocoding by Region	Weighted Erroneously Geocoded Count	Weighted Correctly Geocoded Count	Weighted Percent Within Region (SE[1])
Total Records……	**1,992,600[2]**	**130,543,009**	**1.5 (0.1)**
Midwest……..	206,175	28,743,504	0.7 (0.2)
Northeast……..…..	301,871	23,957,852	1.2 (0.2)
South…….…….	1,191,849	50,447,692	2.3 (0.3)
West…….……..	292,706	27,393,961	1.1 (0.2)

*Census Program for Evaluations and Experiments.
[1] Standard Error.
[2] Subtotals may not sum due to rounding error.
Source: Geocoding Analysis File.

Conclusions

As the first major field operation of the census, it was important for Address Canvassing to provide an accurate address inventory for the census enumeration operations. The results of this evaluation indicate that the Address Canvassing operation was highly successful in accurately deleting addresses considered either 'not a living quarters' or a duplicate record, with the percentage of deleted-in-error addresses at 4.3 percent.

Although the Address Canvassing added records had a higher error rate (16.4 percent), this was understandable, since the Address Canvassing procedures encouraged Listers to add addresses when in doubt about their status or potential future status. In addition, one of the objectives of Address Canvassing was to add any potential Other Living Quarters for the GQV operation to classify and process.

Both Address Canvassing and the GQV operations were successful in providing a "cleaner" address inventory for the census enumeration operations. Compared to Census 2000, the CUF for the 2010 Census had fewer added addresses and delete/duplicate records. As a ratio of added addresses to valid housing units, the 2010 Census ratio of 2.5 percent (3,338,775/131,704,730) was lower than the 3.3 percent (3,857,381/115,904,641) from Census 2000. The difference in delete/duplicate records was even greater. The 2010 Census ratio of delete/duplicate records to valid housing units was about 3.7 percent (4,877,483/131,704,730) , while the Census 2000 ratio was about 7.4 percent (8,536,752/115,904,641) . Despite the difference in total CUF added addresses and CUF deleted/duplicated records, the percentage of addresses added-in-error appeared to be roughly similar between the 2010 Census and Census 2000 while the percentage of addresses deleted-in-error appeared to be higher in the 2010 Census, however, the total number of deletes and duplicates was about the same.

The geocoding error rate improved between Census 2000 and the 2010 Census. In Census 2000, the geocoding error rate was 4.8 percent, while the error rate for the 2010 Census was 1.5 percent. A low geocoding error rate is important for accurately enumerating people in the correct location. It also allows surveys and future census operations to reduce costs in attempting to locate addresses. The lower geocoding error implies that the collection of GPS coordinates in Address Canvassing and other geocoding activities conducted by the Census Bureau throughout the decade have been successful.

Future Research

Understanding the characteristics and predictors of change to the census address inventory is an important step in maintaining an accurate and high quality address frame for surveys and future censuses. As the Census Bureau moves toward the 2020 Census, the planning, research, and testing efforts include a component that is investigating the characteristics and predictors of added and deleted addresses using simulations and modeling. This research will include information from additional data sources that may include the Census Planning Database, Administrative Records, the Partnership Program, and 2020 Census field tests. Results from the simulations and modeling could provide information on specific addresses or blocks that need targeted training, procedures, or updating.

Even though geocoding error has decreased, the Census Bureau continues to assess programs and initiatives that will keep this error at a low level. For example, partnership programs with local governments that collect Geographic Information Systems geocodes are a source of data that can maintain the accuracy of geocodes. Maintaining a low geocoding error is an important factor in locating and recording addresses in their correct locations and in limiting coverage error.

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