Predicting when to Adopt Given Frame Construction Methods: Modeling Coverage and Cost Benefits

Ned English[1], Colm O'Muircheartaigh[2], Katie Dekker[1], Ipek Bilgen[1], Lee Fiorio[1], Mark Clausen[1], and Tamara Brooks[1]

[1]NORC at the University of Chicago, 55 E. Monroe Street, Chicago, IL 60603
[2]Harris School of Public Policy Studies at the University of Chicago, 1155 E. 60th Street, Chicago, IL 60637

Abstract
At the present day there are multiple ways to construct sampling frames for address-based studies in any mode. Depending on the environment and available technology, one could implement traditional listing, enhanced (or "dependent") listing, or use an extract of the USPS delivery sequence file ("DSF" or "CDSF") alone. Each method has advantages in terms of coverage properties and cost which vary due to urbanicity, the availability of lists, and other factors. At question is how do the coverage and cost properties relate across frame construction methods and environments. We use data from an experiment embedded in the National Children's Study where selected segments were listed by each method and blindly verified in-person for coverage. This experiment was implemented in rural, suburban, and urban areas of varying housing age and socioeconomic environment. The results of our modeling show which frame construction methods carry the greatest coverage advantages in what situation, and the cost-benefit implied by each. Our paper contributes to the literature of predicting when it is most appropriate to adopt certain frame construction methods, as predicted through a priori information.

Key Words: Address-based samples, area probability, National Children's Study, listing, frame construction, modeling coverage

1. Introduction

The National Children's Study (NCS) is an innovative panel survey with the goal of understanding environmental, socioeconomic, and cultural impacts on child development (Montaquila et al. 2009, Montaquila et al. 2010a, Downs et al. 2010). As originally designed, the NCS intends to enroll a nationally-representative panel of 100,000 children to be monitored for health and environmental testing from pre-conception through age 21. The NCS thus represents a study of almost unprecedented scale and scope (Michael and O'Muircheartaigh 2008). In addition, the breadth of the NCS will magnify the short and long-term impact of decisions related to frame construction and sample design, as panel members are maintained for a considerable length of time (National Research Council 2008, Montaquila et al. 2010). In so doing the NCS could provide insight into key themes that underlie area-probability surveys, including sampling frame construction and its interrelated effects on household coverage and operational efficiency.

In recent years survey researchers have been investigating using the USPS delivery sequence file (DSF or CDSF) instead of listing in areas where appropriate

(O'Muircheartaigh, Eckman, and Weiss 2003, Kennel and Li 2009, Amaya et al. Forthcoming). The DSF is a list of all housing units in the United States that receive mail, and has been an avenue of considerable recent research in the survey world due to the potential for cost savings. It is clear that the DSF does not have perfect coverage everywhere, however, as households that receive mail via non city-style delivery (PO and RR BOX) cannot be directly linked to a dwelling unit. Listing would still be necessary in such areas, leading to the decision of what type of listing is best. Sampling frames had been constructed using "traditional" listing until recently, a method where field staff systematically record all addresses in an area. It is also possible to implement "enhanced" or "dependent" listing where an existing list of addresses is augmented and edited; enhanced listing is theoretically more efficient than traditional but may introduce confirmation bias where listers "believe" the list they have been given is accurate and potentially under-edit it (Eckman and Kreuter 2011).

The goal of this research was to further understand the impact of sampling frame construction on survey operations and results, using a formative research project based in two National Children's Study counties. In so doing we explore situations where the three major frame construction approaches outlined in the literature may be most applicable: traditional listing, enhanced listing, and sole usage of the US Postal Service Delivery Sequence File or "DSF"[1]. We listed a combination of segments with similar properties, using either traditional or enhanced methods, which were subsequently "field checked". After that, we investigated the profiles and type of areas in which the DSF provides sufficient coverage or is related to under-coverage. Subsequently, we compared traditional and enhanced methods to examine which types of areas are covered better and more efficiently by which method. Our research described herein compliments a recent field evaluation in one suburban NCS county showing that addresses not present on the DSF tended to be different from those found on the DSF (English et al. 2009, English et al. 2010).

2. Literature Review and Background

2.1 Sampling Frame Construction

We can define coverage as the number of housing units listed on a frame divided by the number that should have been listed (Eckman 2010). It is important to understand coverage as surveys are exposed to an increased risk of bias if particular kinds of housing units and the households that reside within them do not have a chance of selection. Multi-unit buildings, renter-occupied units, vacant units, low-income areas, rural areas, oddly shaped segments, and trailers are challenging for listing and, therefore, are at risk to be excluded during the listing process (Eckman and Kreuter, 2011, O'Muircheartaigh et al., 2006, 2007).

The NCS sample design was constructed around a housing unit frame generated by traditional listing in selected area-probability segments (Michael and O'Muircheartaigh 2008). Traditional listing is a method of address frame generation created by field staff who systematically record all residential addresses in defined geographies, regardless of occupancy status (Kish 1965, Eckman 2010). Until recently, this method of frame

[1] As described in subsequent sections, "traditional listing" involves the manual recording of addresses in a selected area, "Enhanced listing" is the editing of a pre-existing list, and "sole usage of the DSF" refers to employing the USPS delivery sequence file (DSF) as an address frame alone.

creation was considered the "gold standard" in the survey research industry but is also regarded as costly (O'Muircheartaigh et al, 2003, O'Muircheartaigh et al. 2006, O'Muircheartaigh et al. 2007). Estimates of net coverage in traditional listing range from 80% to more than 99%, depending on the environment (Eckman 2010, O'Muircheartaigh et al., 2006, 2007).

In the past decade, survey research and government organizations have been researching the use of the USPS DSF as a replacement for traditional listing due to the implications for cost savings (O'Muircheartaigh et al, 2003, Iannacchione et al. 2003, O'Muircheartaigh et al. 2007, Battaglia et al. 2008, Link et al. 2008, Montaquila et al. 2009). Various studies suggest that the DSF is often adequate itself in urban areas, but may not be so in rural areas with non-city style postal delivery (Staab and Iannacchione, 2003, Link et al. 2008, O'Muircheartaigh et al. 2009, Montaquila et al. 2010b, Shook-Sa 2010). One would, therefore, need to traditionally list or implement a different approach in such areas to avoid risk for undercoverage (Iannacchione et al. 2007, Montaquila et al 2010, Eckman 2010).

One hybrid approach is enhanced (or dependent) listing, where listers begin with the universe of DSF addresses believed to be in an area, and then edit and augment the list where necessary (Eckman and Kreuter 2011). Examples of the use of enhanced listing include the U.S. Census Bureau update of the Master Address File (MAF), The National Survey of Family Growth at the University of Michigan, and various NORC studies. Enhanced listing is often considered to be more efficient than traditional listing, due to the presence of a starting list, and carries coverage advantages of the DSF in urban areas related to multi-unit or hard-to-find buildings (Eckman 2010). At question is when it would be best to enhance the DSF, use the DSF without edits or augmentation, or to list traditionally.

We know that the DSF performs comparably to traditional listings in urban and suburban areas, especially those areas with regular block-patterns and relative housing stability. Using the DSF alone would be ideal if we could know a priori that coverage would be sufficient for a given study. A primary indicator of urbanicity, and thus DSF coverage, is the Census TEA code. TEA, or Type of Enumeration Area, indicates how the Census bureau enumerated a block. Blocks with TEA code equal to "1" were deemed urban enough for a "mail-out/mail-back" approach for the decennial Census. We would expect segments where all or nearly all of the blocks were TEA code equal to "1" to carry high coverage on the DSF, as most households would have geocodable city-style addresses. Rural areas, however, are known to contain a larger share of non-geocodable addresses, including PO and rural route box addresses. Because survey research organizations are generally interested in targeting small areas, non-geocodable addresses are prone to undercoverage for in-person studies where the DSF is used alone. Consequently, the coverage of the DSF in rural areas is not yet adequate for in-person surveys as these surveys require a housing unit address for sampling purposes (Eckman et al. 2010).

Ultimately, what is important in terms of survey quality is not the relative coverage rates of each method, but a better understanding of "who" is missing from either list. Specifically, we would like to know if households at risk of undercoverage via one method or another are eligible for the NCS. If so, it would also be important to understand if including them in the survey alter critical estimates. The literature does indicate that different kinds of households tend to be included by alternative listing approaches (English et al. 2009, Shore et al. 2010). Because the NCS has attempted in-

person interviews with all households in the frame, the study theoretically presents an opportunity, through direct evaluation, to compare the properties of those that tend to be captured by traditional listing with those obtained by the DSF.

3. Methods

.

3.1 Traditional and Enhanced Listing Process

The purpose of our research was to compare the properties of enhanced listing, traditional listing, and using the DSF alone. We designed our experiment around paired segments in similar geographies, where one segment would be traditionally listed and the other enhanced listed. Pairs were designed in consultation with local experts to associate segments with similar attributes, especially related to urbanicity and overall environment. We did so in order to control for factors that impact quality when comparing methods. Both segments in a pair could then be compared to the DSF alone, as the enhanced listed segment is a direct extract of the DSF and the traditionally listed segment may be matched.

Materials given to the listers differed depending on listing method. On traditional listing sheets, all listing lines are blank, except for summary information. For enhanced listing, listing sheets were preprinted with addresses expected to be in each block, derived from the geocoded DSF. In either case, listers proceeded through selected blocks systematically, editing the DSF in the case of enhanced listing and recording all found addresses for traditional listing.

We can consider the results of our original listing as traditional (T) list or enhanced (E) list in a given segment. Following the initial listing, an independent "frame-checker" verified the original lister's work. Field checking consisted of validating the addresses from the initial listing, as well as adding any that may have been missed. The frame-checking step theoretically corrects for errors and undercoverage; we call this frame-checked list the best or (B) frame. Following listing and frame-checking, we can determine how well the traditional and enhanced listing approaches compare to the B frame in different environments as our measure of coverage.

3.2 Predictive Modeling

Our primary motivation in this research was to examine the association between the coverage for different listing methods and segment profiles along key variables. In so doing we investigated two primary research questions: what kinds of geographic locations are best suited to the DSF; where is enhanced listing more effective than traditional listing overall when the DSF is not appropriate. Our two research questions were examined using two different logistic regression models in which the dependent variables varied depending on the research questions. The dependent variable for the first research question was identified as the percentage of the DSF frame (U) that matched the best frame (B). For the second research question, we investigated the percentage of E in B and T in B as the dependent variables.

Both models included the following independent variables at the block and segment level: urbanicity (urban housing unit percentage); housing unit density; county (Marion versus Worcester); segment type (urban-suburban versus rural); the ratio of geocoded

DSF addresses compared to the number of housing units in Census 2010; median household income; housing unit count change since 2000; percent population White non-Latino. For the purposes of interpretation, all of the continuous independent variables were grand-mean centered with the exception of the segment type.

4. Results and Discussion

4.1 Listing

Tables 4.1 and 4.2 show key intersection rates for Marion, WV and Worcester, MA by segment pair. We use intersections, that is, the percentage of one frame that overlaps with another, as the main indicator of similarity. In these tables, the "B" frame refers to our version of "reality". "T" represents the traditional listings, "E" the enhanced listings, and "U" the unenhanced listings or raw USPS list. Therefore, higher percentages imply greater coverage.

Of primary interest is how well the T and E frames performed in comparison with the reality captured by the B frame. The intersection of T or E as a percentage of B is listed as intersection 1 in all tables. In each situation, we observe that in Marion County nearly all of reality (i.e., the B frame) was captured by the T or E frames respectively. Note that a given segment was either T or E listed, and so we make the comparison between the two within a pair. Upon first examination neither T nor E appears to be superior in Marion County as each represented a very high share of B. We can see, however, in the subset table 4.1a below, that the E frames did perform better than the T frame by two percentage points or more in pairs C and F. Overall, either approach would be suitable for a study requiring at least 95% coverage in Marion County in the examined segments. Worcester County (subset table 4.2a below) shows a similar pattern, but with instances where T had somewhat better coverage than the E., as in pairs 2 and 8. It is important to keep in mind that the pairs are not perfectly comparable due to the original segment design (e.g., the segments were designed to be as homogenous as possible and thus shouldn't be entirely comparable). Therefore, cost would likely be a driver of the decision of where to E or T list, all else being equal.

It is of key interest to know how well the USPS list (U) would have performed alone had we not enhanced it, as shown by the percentage of the U frame that intersects with reality (B) indicated as *intersection 2*. Using the USPS DSF without enhancement represents the least costly approach to frame construction, and has been shown to be equal or superior to the performance of traditional listings in urban and suburban areas in terms of coverage (O'Muircheartaigh et al. 2007). It is important to emphasize that the intersection of B and U in traditionally listed segments is less reliable than in enhanced listed segments, due to the required *post-hoc* matching process[2], while enhanced segments have already been matched. As expected, the U frame performed poorly in rural areas with limited DSF coverage. U performs poorly in rural areas for two reasons: households often do not have city style mail delivery as well as less-developed geocoding databases[3] (Eckman and

[2] Many traditionally-listed addresses cannot be reliably matched to a DSF address due to the absence of visible address information

[3] Segments 3 and 24 in Marion County are two examples of where less developed geocoding databases in rural areas reduce the effectiveness of the DSF, even in areas with city-style addresses

English 2012). Some segments that otherwise would be expected to have high U coverage appear to be limited due to new construction not on the DSF (i.e., pair 5 in Worcester) and/or geocoding error. As expected, we can see that the U frame performed best in urban areas, especially in Worcester County. The majority of Worcester County, in fact, would have been suitable for using the DSF alone, as enhancement did not contribute a substantial number of housing units. Marion County, WV is considerably less urban, and, therefore, saw less success with the DSF alone.

Because we know some listing will be required for national surveys, it is of interest to know how much better the T or E listing would perform in contrast with the U list alone. We can make such a determination by comparing the percentage of B not in T or E (*intersection 3*) to the percentage of B not in U (*intersection 4*); these intersections can be considered our primary measure of undercoverage as they indicate what is absent from reality. In Marion County, some kind of field-based listing would be required for sufficient coverage in most segments due to the overall rurality. The T list is not necessarily better than the E list, however, as shown by pairs in which the T list was missing a greater share of B than did E (pairs A, B, E). In Worcester County, the differences between methods were smaller, except in the most rural parts of the county. Still, we see that either T or E listing would bring coverage to very high levels in most instances. The question again becomes how cost effective E listing may be in comparison with T listing.

"Overcoverage" can be defined as the percentage of addresses that are on a frame (U, E, or T) but not present in reality (B). While such addresses do not necessarily influence survey data, since they are not in a selected segment and thus would not always be interviewed[4], they do affect survey operations due to the implied expended effort. We show overcoverage on U in *intersection 5* (the percentage of U not in B) and on T or E in *intersection 6*. It is important to again emphasize that the intersection of U and T is imperfect as it was the product of matching between the two disparate lists. As such, the rates are pessimistic and likely underreport the true relationship between T and U due to "unmatchable" addresses.

As shown in tables 4.1 and 4.2, U tended to exhibit more general overcoverage. B and T, however, did contain addresses that were not present during frame checking. We see both rural and urban segments with overcoverage on our lists, perhaps indicating that it is a more haphazard or unpredictable phenomenon than undercoverage. Most overcoverage likely stems from geocoding error, and does not appear to have a geographic pattern.

Cost is always of primary importance in areas that require listing; we can describe cost as the amount of labor required to list a housing unit in a given area, or the minutes-per housing unit. Distilling cost to time required rather than actual dollars removes pay rates and other expenses that may vary between markets. This difference was exacerbated in the rural sections of the county and outskirts of towns, with particular segments standing out. In the urban parts of Marion County enhanced and traditional were more similar in effort required per housing unit, with the exception of one inner-city area where traditional listing was more efficient.

[4] It would be up to an individual study to have interviewing staff check that selected addresses are within segment boundaries; if a study did not check, than it would be possible that survey data could be affected if geographically ineligible units were included and differed substantially from those eligible

Table 4.1 Key Intersections in Marion County, WV

#	Pairing	*A*		*B*		*C*		*D*		*E*		*F*	
	Pair Description	*Inner City*		*Outskirts*		*Outskirts/Rural*		*Outskirts*		*Inner City/Small Town*		*Urban/Outskirts*	
	Listing Type	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*
1	**(B ∩ TorE)/B**	99.3%	99.6%	98.9%	99.2%	100.0%	95.0%	99.4%	98.9%	98.7%	99.1%	99.2%	96.7%
2	**(B ∩ U)/B**	83.4%	78.3%	1.8%	89.2%	84.6%	43.7%	49.1%	5.6%	87.8%	10.5%	91.3%	82.6%
3	**(B not TorE)/B**	0.7%	0.4%	1.1%	0.8%	0.0%	5.0%	0.6%	1.1%	1.3%	0.9%	0.8%	3.3%
4	**(B not U)/B**	16.6%	21.7%	98.2%	10.8%	15.4%	56.3%	50.9%	94.4%	12.2%	89.5%	8.7%	17.4%
5	**(U not B)/U**	35.7%	53.6%	88.4%	51.7%	37.2%	48.8%	41.2%	30.0%	50.7%	60.2%	49.2%	67.5%
6	**(TorE not B)/TorE**	0.7%	0.2%	0.5%	0.4%	0.4%	5.6%	0.4%	0.3%	1.8%	0.9%	2.4%	1.4%
7	**%(Not Checked)**	0.5%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%

Table 4.2 Key Intersections in Worcester County, MA

#	Pairing	**2**		**3**		**4**		**5**		**7**		**8**		**9**	
	Pair Description	Rural		Urban		Dense Suburban		Rural/Suburban		Rural/Suburban		Suburban/Urban		Suburban/Urban	
	Listing Type	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*	*Enhanced*	*Trad.*
1	**(B ∩ TorE)/B**	92.7%	97.5%	100.0%	99.7%	99.7%	100.0%	99.8%	97.9%	99.2%	99.7%	89.6%	99.8%	100.0%	99.2%
2	**(B ∩ U)/B**	84.6%	59.1%	97.7%	96.9%	100.0%	97.7%	81.2%	86.3%	94.8%	95.5%	98.9%	97.9%	100.0%	95.7%
3	**(B not TorE)/B**	7.3%	2.5%	0.0%	0.3%	0.3%	0.0%	0.2%	2.1%	0.8%	0.3%	10.4%	0.2%	0.0%	0.8%
4	**(B not U)/B**	15.4%	40.9%	2.3%	3.1%	0.0%	2.3%	18.8%	13.7%	5.2%	4.5%	1.1%	2.1%	0.0%	4.3%
5	**(U not B)/U**	12.8%	21.3%	1.0%	2.6%	1.4%	4.7%	10.5%	6.2%	11.7%	1.8%	8.4%	5.1%	11.3%	23.7%
6	**(TorE not B)/TorE**	5.4%	3.8%	0.5%	0.0%	0.2%	0.0%	1.2%	0.0%	1.0%	0.0%	6.5%	1.0%	1.6%	0.0%
	%(Not Checked)	0.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.1a Highlighted Intersections in Marion County, WV

County		**Marion, WV**			
	Pairing	**C**	**C**	**F**	**F**
	Pair Description	Outskirts/Rural		Urban/Outskirts	
Intersection	**Listing Type**	Enhanced	Traditional	Enhanced	Traditional
1	**(B ∩ T or E)/B**	100.0%	95.0%	99.2%	96.7%

Table 4.2a Highlighted Intersections in Worcester County, WV

County		**Worcester, MA**			
	Pairing	**2**	**2**	**8**	**8**
	Pair Description	Rural		Suburban/Urban	
Intersection	**Listing Type**	Enhanced	Traditional	Enhanced	Traditional
1	**(B ∩ TorE)/B**	92.7%	97.5%	89.6%	99.8%

In assessing the time required for listing Worcester County, enhanced listing was slightly more efficient than traditional, with the mean enhanced segment requiring 2.9 minutes per housing unit and 3.1 for traditional. As in Marion County, the differences were exacerbated in rural segments, with urban and suburban segments essentially requiring the same effort. As Worcester County can be described as generally being a suburban/urban county, we do not see as much variation as in Marion County with the mean enhanced segment requiring 3.9 minutes per housing unit and 5.1 for traditional.

There are two important considerations that one should keep in mind when discussing cost. First, while the listers that were part of this research project were all trained and experienced, there is still variability in length of career. So, one could expect variability in listing time as influenced by listing experience in addition to familiarity with local areas in general, which were beyond the scope of the current analysis. Secondly, our research was conducted using paper and pencil technology for listing. NORC, however, has recently developed hand-held devices that integrate Global Positioning Systems (GPS). We would expect to see decreases in time required for both enhanced and traditional listing, based on anecdotal evidence thus far. It would be beneficial to examine the differences in effort required for enhanced and traditional listing using the new technology, as the patterns may deviate from paper and pencil.

4.2 Modeling Results

We used logistic modeling to pursue our two main research questions: what kinds of places are best suited for the DSF, and where would enhanced listing be more effective than traditional listing. The most basic question is what kinds of places are most appropriate to use the DSF. According to the literature, we would expect the DSF to do best in urban areas with stable development, as these are the areas where the USPS DSF list would be the most up-to-date and complete (O'Muircheartaigh et al. 2006). For the first research question, we examined the type of segments in which the percentage of DSF frame (U) was closest to the independently-checked best frame (B). We focus on block-level analyses, due to expected within-segment heterogeneity.

TABLE 4.3: Profiles of B in U/B (good and poor places for DSF)

Variable Description	Estimate	SE	P-value
Intercept	1.1429	0.0966	<.0001
Segment Type *(0-Urban/Suburban, 1- Rural)*	0.5800	0.1310	<.0001
Ratio of geo-coded DSF/Census 2010 Housing Unit Counts	0.3639	0.0404	<.0001
HU count change since 2000	0.1029	0.0470	0.0287
% HU urban (American Community Survey)	0.8219	0.1108	<.0001
% HU TEA 1 (Census 2010)	1.8361	0.0838	<.0001
Housing unit density (per square mile)	0.0002	0.0000	<.0001
% HU Occupied (Census 2010)	4.9668	0.3423	<.0001
Segment area (mi^2)	0.2676	0.0638	<.0001
Number of Census blocks in segment	-0.0074	0.0008	<.0001
Median household income (American Community Survey)	0.0776	0.0186	<.0001
% White non-Latino per block (Census 2010)	-1.4150	0.2616	<.0001
% addresses that are multi-unit	0.2990	0.1669	0.0733
Goodness of Fit Measures			
Log Likelihood	-1546.6620		
AIC	3123.3240		
BIC	3187.3888		
N (Sample Size)	529		

According to the findings in Table 4.3, it would generally be preferable to use the DSF rather than list in the following areas:

- The ratio of geocoded DSF/Census 2010 housing units is higher than average, indicative of DSF coverage

- There has been above-average growth in housing since 2000
- The percentage of housing units that are "urban" (according to Census 2010) is higher than average
- The percentage of housing units that are TEA 1 (according to Census 2010) is higher than average
- The housing unit density (per square mile) is higher than average
- The percentage of housing units that are occupied is higher than average
- The segment is larger in area than average
- Median household income is higher than average
- The percentage of population that is White non-Latino per block is lower than average
- The percentage of addresses that are in multi-unit buildings is higher than average.

TABLE 4.4: Profiles of where B in E/B is higher than B in T/B

Variable Description	Estimate	SE	P-value
Intercept	4.2482	0.2543	<.0001
County *(0-Marion; 1-Worcester)*	0.0779	0.3453	0.8216
Segment Type *(0-Urban/Suburban, 1- Rural)*	0.2190	0.2717	0.4201
Listing Method *(0-Traditional, 1- Enhanced)*	1.2167	0.3523	0.0006
Ratio of geo-coded DSF/Census	-0.0361	0.1120	0.7472
HU count change since 2000	0.2041	0.1060	0.0541
Housing unit density (per square mile)	-0.0001	0.0000	0.0021
% HU Occupied	2.0718	0.8396	0.0136
Segment area	0.6029	0.2528	0.0171
Number of Census blocks in segment	-0.0056	0.0020	0.0065
Median household income (per 10,000)	-0.0556	0.0492	0.2584
% White non-Latino per block	-4.8219	0.8851	<.0001
% addresses that are multi-unit	2.5142	0.4903	<.0001
Listing Method*County	-2.8114	0.4685	<.0001
Listing Method* Ratio of geo-coded DSF/Census	0.6243	0.2383	0.0088
Listing Method* Segment area	1.8101	0.6671	0.0067
Listing Method* Median household income	0.1657	0.0676	0.0143
Goodness of Fit Measures			
Log Likelihood	-943.8029		
AIC	1073.7198		
BIC	1146.3266		
N (Sample Size)	529		

Our second research question relates to which types of areas enhanced listing would be expected to outperform traditional listing or vice versa. According to the literature, we would expect enhanced listing to equal or exceed the efficiency of traditional listing in most instances (Eckman and Kreuter 2011). In our models, we examined the interaction between the key block characteristics and the listing method to compare the performance of the listing methods. According to the findings in Table 4.4, it would be preferable to use enhanced listing instead of traditional listing in blocks where:

- The ratio of geocoded DSF/Census is higher than average, implying urbanicity
- Segment areas are larger than average
- Median household incomes are higher than average

So, segments that have some DSF lines would more appropriate for enhanced listing than very rural segments with none. Consistent to the analyses above, block-level characteristics play a prominent role when determining which listing method is most appropriate. Overall, however, enhanced listing provided higher coverage rates than traditional in our analyses.

5. Conclusions and Recommendations

While our analysis has only considered two counties that are not necessarily representative of the entire USA, they do carry national implications as they embody rural, suburban, and urban environments. First, we recommend using the USPS DSF as the primary source of address sample for most sites. We suggest first comparing the ratio of DSF addresses that geocode in a segment to controls from Census 2010. If the ratio were below a suitable threshold, we recommend augmenting the DSF through enhanced listing. We argue for enhanced listing due to the high quality and overall lower cost than traditional listing in most situations. Our results show that enhanced listing improves coverage sufficiently in all environments.

Our modeling did demonstrate within-segment heterogeneity, and so we recommend adopting a tailored approach to sampling frame construction. So, blocks that contained a threshold amount of DSF addresses could use the DSF alone. Other blocks that did not contain suitable DSF addresses could be listed, allowing for minimal listing effort while maintaining coverage. For those segments needing listing, one should consider taking the enhanced listing approach for blocks that have some DSF lines to start; small segments with zero DSF lines may be better serviced with traditional listing.

6. References

Amaya, Ashley, Felicia Leclere, Lee Fiorio, and Ned English. Forthcoming. Improving the Utility of the DSF Address-Based Frame through Ancillary Information. *Field Methods.*

Battaglia, M. P., M. W. Link, M. R. Frankel, L. Osborn, and A. H. Mokdad. 2008. An Evaluation of Respondent Selection Methods for Household Mail Surveys. *Public Opinion Quarterly*, 72(3), 459-469.

Downs TJ, Ogneva-Himmelberger Y, Aupont O, Wang Y, Raj A, et al. 2010 Vulnerability-Based Spatial Sampling Stratification for the National Children's Study, Worcester County, Massachusetts: Capturing Health-Relevant Environmental and Sociodemographic Variability. Environ Health Perspect 118(9): doi:10.1289/ehp.0901315

Eckman, S. 2010. Errors in Housing Unit Listing and Their Effects of Survey Estimates. Ph.D. Thesis, University of Maryland. *Proceedings of the Survey Research Methods Section, American Statistical Association.*

Eckman, S and English, N. (2012) *Creating Housing Unit Frames from Address Databases: Geocoding Precision and Net Coverage Rates* Field Methods. http://fmx.sagepub.com/content/early/2012/07/02/1525822X12445141.abstract?papetoc

Eckman, S. and F. Kreuter. 2011. Confirmation Bias in Housing Unit Listing. *Public Opinion Quarterly* 75 (1): 139-150

English, N., C. O'Muircheartaigh, K. Dekker, M. Latterner, and S. Eckman. 2009. Coverage Rates and Coverage Bias in Housing Unit Frames. *Proceedings of the Survey Research Methods Section, American Statistical Association.*

English, Ned, Colm O'Muircheartaigh, Katie Dekker, and Lee Fiorio. Qualities of Coverage: Who is Included or Excluded by Definitions of Frame Composition. 2010. *Proceedings of the American Statistical Association, Survey Research Methods Section, American Statistical Association.*

Iannacchione, V. G., J. M. Staab, and D. T. Redden. 2003. Evaluating the Use of Residential Mailing Addresses in a Metropolitan Household Survey. *Public Opinion Quarterly*, 67(2), 202-210.

Iannacchione, V., Morton, K., McMichael, J., Cunningham, D., Cajka, J. and Chromy, J. 2007. Comparing the Coverage of a Household Sampling Frame Based on Mailing Addresses to a Frame Based on Field Enumeration. *Proceedings of the Survey Research Methods Section, American Statistical Association.*

Kennel, T. L. and M. Li. 2009. Content and Coverage Quality of a Commercial Address List as a National Sampling Frame for Household Surveys. *Proceedings of the Survey Research Methods Section, American Statistical Association.*

Kish, Leslie. 1965. *Survey Sampling*. New York: John Wiley and Sons, Inc.

Michael, R.T. and O'Muircheartaigh, C. 2008. Design Priorities and Disciplinary Perspectives: The Case of the U.S. National Children's Study. *Journal of the Royal Statistical Society: Series A*, 171, Part 2, 465-480.

Montaquila, J. M., J. M. Brick, and L. R. Curtin. 2010a. Statistical and Practical Issues in the Design of a National Probability Sample of Births for the Vanguard Study of the National Children's Study. *Stat Med*, 29(13), 1399-90.

Montaquila, J. M., V. Hsu, and J. M. Brick. 2010b. Using a Match Rate Model to Predict Areas Where USPS-Based Address Lists May Be Used in Place of Traditional Listing. *Public Opinion Quarterly* 75 (2): 317-335.

Montaquila, J., V. Hsu, J. Michael Brick, N. English, and C. O'Muircheartaigh. 2009. A Comparative Evaluation of Traditional Listing vs. Address-Based Sampling Frames: Matching with Field Investigation of Discrepancies. *Proceedings of the Survey Research Methods Section, American Statistical Association*.

National Research Council (US) and Institute of Medicine (US) Panel to Review the National Children's Study Research Plan. 2008 Washington (DC): National Academies Press (US).

O'Muircheartaigh, C. A., S. A. Eckman, and C. Weiss. 2003. Traditional and Enhanced Field Listing for Probability Sampling. *Proceedings of the Survey Research Methods Section, American Statistical Association*.

O'Muircheartaigh, C., English, N., Eckman, S., Upchurch, H., Garcia, E., and Lepkowski, J. 2006. Validating a Sampling Revolution: Benchmarking Address Lists against Traditional Listing. *Proceedings of the Survey Research Methods Section, American Statistical Association*.

O'Muircheartaigh, C., English, N., Eckman, S. 2007. Predicting the Relative Quality of Alternative Sampling Frames. *Proceedings of the Survey Research Methods Section, American Statistical Association*.

Shook-Sa, B.E., McMichael, J.P., Ridenhour, J.L., Iannacchione, V.G. 2010 The Implications of Geocoding Error on Address-Based Sampling. *Proceedings of the Survey Research Methods Section, American Statistical Association*. 3303-3312.

Shore, S.P., Montaquila, J.M., and Hsu, V. 2010. The presence and characteristics of households at addresses obtained by traditional field listing and from USPS-based lists. *Proceedings of the Survey Research Methods Section, American Statistical Association*.

Staab, J. M. and V. G. Iannacchione. 2003. Evaluating the Use of Residential Mailing Addresses in a National Household Survey. *Proceedings of the Survey Research Methods Section, American Statistical Association*.