Address-based Area Sampling: An Efficient Hybrid between Address-based Sampling and Area Sampling

A.C. Singh and Peter K. Kwok
NORC at the University Of Chicago, Chicago, IL 60603
singh-avi@norc.org, kwok-peter@norc.org

Abstract

Cost savings in area sampling (AS) due to use of address-based sampling (ABS) frame for listing addresses without making field visits are appealing but may lead to coverage bias due to problems in implementing it because some addresses, such as P.O. boxes and rural routes, cannot be linked to housing units (HU). In an analogous manner, cost savings in ABS due to telephone interviewing instead of field interviewing in AS are appealing but may lead to coverage bias due to problems in linking telephone numbers to all selected HUs. We propose an alternative design termed address-based area sampling (ABAS) which encompasses best of both AS and ABS. Instead of preparing a complete cluster or segment list by field staff, an initial segment list of only selected addresses from ABS is first prepared at the central office, and then a field staff or prompter is dispatched to verify validity of selected addresses, substitute new ones for invalid HUs, update addresses of selected list, and finally drop off short questionnaires to set up a telephone interview by the call center for administering the main or long questionnaire in the second phase. Substitution of invalid addresses is based on the methodology of rejection sampling recently developed by Singh and Wolter (2010) in the context of coverage of missing HUs under AS. It is observed from general practical considerations that the proposed ABAS design may provide an efficient compromise between a relatively inexpensive ABS design and expensive AS design while overcoming several limitations of both.

Key Words: Address-based Area Sampling; Field Interviewer; Field Prompter; Telephone Interviewer; Zones for One-Unit Rejection Sampling

Introduction

The main objective in the design of household surveys is to control cost from listing of housing units (HUs) and collecting information from HUs while maintaining estimation efficiency (with respect to bias and variance reduction). More specifically, estimation efficiency is concerned mainly with two types of bias and variance reduction issues each. Under bias reduction, first we have coverage bias which encompasses frame imperfections due to invalid or new HUs, under/over-coverage of certain subpopulations, and advance field listing of all HUs in a segment without incurring a serious undercoverage. Second, nonresponse bias which involves considerations of reducing high nonresponse by improved communication skills and in-person interactions; good auxiliary variables for effective model-based adjustments for nonresponse, having knowledge of the physical location of address of responding HUs needed for calibration adjustment for nonresponse using auxiliary totals from census about geo-demographic and socio-economic variables, as well as for in-person follow-up for obtaining nonrespondent characteristics. Under variance reduction, first we have local area estimator variance which entails considerations of stratification by local areas (*e.g.*, MSAs or other substate geographical regions) to control for adequate sample size and hence precision, and over/under sampling in local areas. Second, domain estimator variance (known to be difficult to deal with due to lack of control on domain sample sizes since they are not strata; *e.g.*, for an elderly subpopulation with special needs), which leads to two-phase designs with the screener or short questionnaire (SQ) for a large first phase sample to be used for providing some control on domain sample sizes for the main survey with the long questionnaire (LQ) in the second phase.

The issues listed above are not new and can be handled in principle for area sampling (AS) designs using field interviewers (FI) for in-person interviews. However, cost can be prohibitive. As an alternative, it would be desirable to use address-based sampling (ABS) with telephone interviews (telephone numbers for HUs are obtained by matching their addresses with available lists from marketing vendors) where the most recent US delivery sequence file is used to construct the sampling frame of HUs. In theory, such an approach is highly appealing as the listing cost of HUs becomes essentially negligible, and telephone interviews are much cheaper than in-person interviews. However, there are serious concerns in assigning telephone numbers to HUs by matching addresses from vendor's list with addresses in the ABS frame due to non-city style addresses such as P.O. Boxes, drop points for multi-unit dwellings, and rural routes. In addition, there are problems due to incompleteness of the ABS frame, lack of physical address of a significant portion of addresses for in-person nonresponse follow-up, and low response rate for the option of mail-in of SQ to obtain contact information for HUs having incorrect or unavailable telephone match.

Even if the problem of assigning telephone (landline or cell phone) to HUs could be overcome (while ignoring the problem of nontelephone HUs), the response rate to telephone surveys is known to be low and is only getting worse due to increase in public awareness about privacy concerns and use of technological developments for call screening or answering machines; see, *e.g.*, Wolter *et al.* (2009). On the other hand, response rates in traditional AS with in-person interviews have managed to stay at reasonably high levels. What is needed, perhaps, is a hybrid design that takes advantage of high response rate via in-person contact as in AS but for only SQ, and administers LQ by telephone as in ABS. The main purpose of this paper is to propose such a hybrid design termed address-based area sampling (ABAS). A motivation for the proposed design is presented in Section 2 by invoking analogy between the problem of missed HUs in AS and telephone unmatched HUs in ABS. A detailed stepwise description of the proposed design is given in Section 3. A comparison of ABAS with alternate designs of ABS and AS is discussed in Section 4 followed by summary and concluding remarks in Section 5.

1. Motivation for the Proposed Design

To motivate the proposed design, we first observe that the problem of addresses unmatched to telephone numbers in ABS is analogous to the problem of missed HUs in AS arising from outdated segment lists as both problems lead to coverage bias. To overcome the problem of missed HUs in AS, the method of half-open interval is generally used although it is known that it is rarely followed properly in the field because FI training is probably more focused on conducting interviews than checking listing errors. An alternative method termed zones for one-unit rejection sampling (ZOURS) was recently proposed by Singh and Wolter (2010) as an improved alternative to half-open interval. The proposed ABAS design is based on the ZOURS method. A summary of which is given below.

In ZOURS, the field interviewer (FI) in area sampling is provided with zone maps for each selected segment. Zones partition the segment such that they consist of contiguous land areas by grouping adjacent census blocks. The number of zones approximates the sample size of HUs allocated to the segment. One HU is selected per zone, but the total number of HUs per zone need not be equal. Using geographical information system (GIS), a map is created for each zone in the selected segment incorporating information about streets and other features for defining the walk or driving sequence for FI. Here the U.S. delivery sequence file can be used to glean appropriate information needed for zone mapping although actual listing of HUs along the carrier route is not needed for ZOURS.

With ZOURS, there is no need of segment listing. But FI selects one HU in each zone for conducting interviews from a list of several alternate random numbers in a prescribed order; the random numbers serve as indices for selecting one HU per zone. FI picks the first number that corresponds to a valid HU, and then records the address of the selected HU needed for possible follow-up as well as for quality control. FI is also required to count the total number of HUs (valid or invalid at the time of screener survey—invalid signifies business, vacant or inhabitable HU) in each zone. For this purpose, FI is provided with a clear rule to start counting from a well defined starting point such that all HUs can be covered in an unambiguous manner..

Under ZOURS the problem of missed HUs arising in AS is dealt with by using the method of rejection sampling. An upper bound on the number of HUs for each zone is stipulated (information from the delivery sequence file or Claritas data can be used here). Then alternate random numbers or indices are drawn at the central office from the conceptual list of numbers from 1 to the upper bound. It is possible that a randomly selected number may correspond to an invalid HU or a ghost HU. In that case, it is rejected; and the next number in the prescribed ordered list of random numbers is taken. It can be shown that ZOURS provides equal chance of selection for all valid HUs in the zone. If the upper bound is not very sharp, it may lead to more rejections. Average number of rejections is given by the ratio of upper bound to the actual number of valid HUs. In general, a total of five random selections containing four replacements are expected to be more than adequate.

In ZOURS, a count of the number of HUs (covering both valid and invalid HUs) for each zone is needed for weight calculation. Any new HUs are accounted for in this count as well as in the process of selecting HUs. FI can be asked to make a quick count by driving through the zone. Although adequate for calculating the basic weight, the count of total number of HUs in each zone may be subject to error. To help reduce this error, it is advised to impose certain structure for the counting process. In particular, we can ask FI to write down the address of the first HU at the starting point, followed by addresses of all the five random selections although some of them may be nonexistent due to ghost HUs, and end with the address of the last HU in the zone. This record would also be useful for quality control purposes. Incidentally, in cases when the total count of HUs is known *a priori*, there would still be the need of rejection sampling in order to avoid invalid HUs, where the number of HUs now serves as an upper bound.

The ZOURS method can also be used to provide a simple method of random substitution for nonresponding HUs. Analogous to the unknown number of valid HUs in each zone, the number of responding HUs is also unknown. In practice one could use a working definition of a nonresponding HU as one who does not respond even after two follow-ups, for example. The count of total number of HUs in each zone also serves as an upper bound on the number of responding HUs. Thus, if the goal is to select valid and responding HUs, then the FI can go back to the pre-selected random number list to replace a nonresponding HU after two follow-ups by a valid HU with the hope that new randomly substituted HU would respond.

In the next section, we show how ZOURS can be modified to suit telephone interviewing for the main survey under ABAS.

2. ABAS: The Proposed Design

The ZOURS method gives rise in a natural way to the proposed design which starts with segments as in AS but behaves like ABS for main interview via telephone. First for cost efficiency, FI is replaced by a filed prompter (FP) since no in-person interviews are conducted under ABAS. The role of FP can be defined as follows. With the help of zone maps, FP is required to count HUs in each zone as well as to select the first number corresponding to a valid HU in the prescribed list of random numbers using ZOURS. In addition, FP attempts to make an in-person contact with the selected HU resident and explains the purpose of survey, hands out a self-administered SQ (which typically would require 2 to 3 minutes to fill out), and urges for its completion during her/his presence. The completed questionnaire is placed in a sealed envelope to protect privacy for mail-in to the central office. The respondent can also send the response by mail in the pre-stamped envelope provided in the package. If there is no contact, FP hangs the material on the door with a card ‘Sorry, I missed you’ along with name and phone number. SQ asks for contact information for telephone interview for LQ if the HU gets selected for the main survey.

Thus, the problem of selected addresses unmatched to telephone numbers in ABS as well as undercoverage of the ABS frame can be addressed using ZOURS for the proposed

ABAS design. We can also perform random substitution of nonresponding HUs using ZOURS as mentioned in Section 2. Specifically, for HUs that didn't respond until the time for second follow-up, for example, the FP, in addition to making an in-person reminder for filling out SQ, can also use alternate random selections in the segment already provided as random substitutes for these HUs effectively treating them as nonrespondents. If some of them do respond in the time allocated to substitutes, then the SQ from the substitute can be discarded. Thus, under ABAS the realized sample size of SQ completes can be made very close to the target sample size.

We now provide a stepwise definition of ABAS in terms of seven modules or steps. It is assume that the design is a cluster design with segments of HUs at the final stage of clustering.

M1 (Zone Map with Anchors Using the ABS Frame): FP is provided with the GIS-based zone maps with input of latitude and longitude of a few anchors such as the first and last HU as per the ABS frame.

M2 (**HU Selection by ZOURS)**: FP validates the first selected HU from the list of prescribed random number for each zone. If not, then replaces it with the next random selection.

M3 (In-person Contact for Self-administered SQ): While performing module M2, in-person introduction and collection of SQ in a sealed envelope is conducted by FP; in case of no contact, FP leaves behind SQ for mail back or toll free number for callback.

M4 (SQ Prompting by Mail/Telephone): For SQ nonrespondents, follow-up reminders by mail or telephone if matched telephone available.

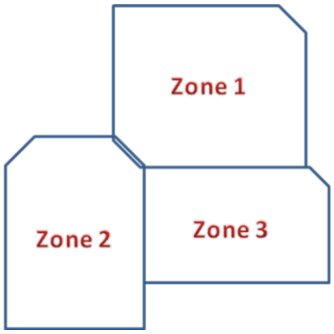
M5 (In-person SQ Prompting and HU Substitution): For the remaining SQ nonrespondents after module M4, FP makes in-person prompting as well as contacts new HUs as random substitutes.

M6 (Main Interview by Telephone Center): If a responding HU is eligible based on SQ and selected for the main survey, LQ is administered by the telephone call center either using the contact number provided by the SQ respondent or during toll free callback by the SQ respondent.

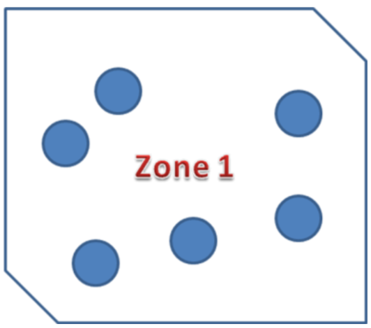
M7 (Mail Reminder for Main Interview): For LQ nonrespondents, mail reminders are sent for toll free callback.

We provide below a simple graphical illustration on how steps M1 and M2 are implemented in practice.

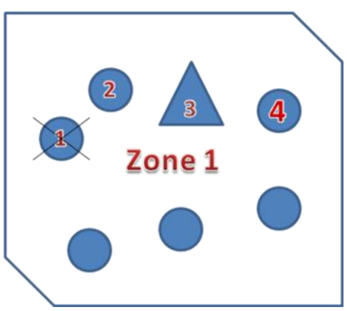
1. Suppose a segment has a quota of 3 sampling units. Partition it into 3 zones.



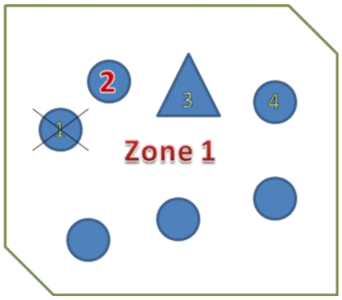
2. Further suppose Zone 1 has 6 units (blue circles) on the ABS frame. Central office prepares random indices between 1 and, say, 6 × 1.2 = 7.2. The upper bound 1.2 is chosen to be as close to 1 as possible, but should be realistic enough to capture any and all HUs missing from the frame. Suppose the selected random numbers in order are 4, 2, and 7.



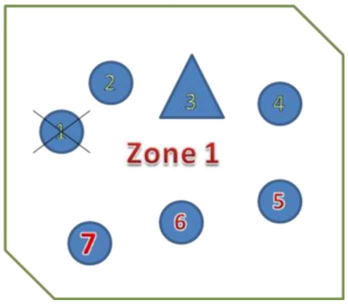
3. The ZOURS method allows for a conceptual enhancement of the initial ABS list as FP starts counting HUs in the zone by making any necessary additions or updates. In trying to find unit number 4 in zone 1, FP may find out that Unit 1 is invalid (denoted by cross), Unit 3 is a new addition (denoted by triangle), and the first candidate unit for selection corresponds to the fourth unit in the updated list of seven units. If Unit 4 is valid, it is selected by FP. Note that the actual knowledge of Unit 1 being invalid or Unit 3 being a new addition does not impact the process of counting under ZOURS because there is no actual updating of HU list needed for ZOURS.



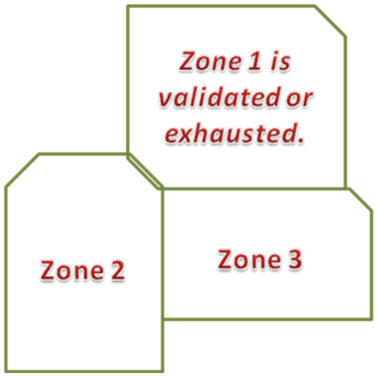
4. If Unit 4 is found to be invalid, FP proceeds to the next random number, which is 2 and was already counted by FP, but is now validated. If it is valid, FP attempts to contact the HU resident and proceeds to step M3.



5. Suppose, Unit 2 doesn't respond to SQ and needs to be substituted by another HU. Then Zone 1 is revisited, and FP proceeds to the next random number, which is 7. FP validates Unit 7. If Unit 7 is also invalid, then FP contacts central office for additional random numbers.



6. Repeat the same process in other zones.



3. Comparison with ABS and AS Designs

The proposed ABAS design combines the best features of ABS and AS to obtain an efficient hybrid design. We now consider how ABS and AS differ from ABAS in terms of the seven modules described in the previous section. Corresponding to M1 of ABAS, a segment list of selected HUs is prepared for ABS using the US delivery sequence file although it is known to be imperfect. In the case of AS, enhanced segment listing of all valid HUs is completed by field staff by updating the initial list of all HUs obtained from the US delivery sequence file. For M2, in the case of ABS, invalidity of a selected HU (found during telephone interviewing) basically reduces the allocated sample size. This problem is not likely to arise for AS because only valid HUs in each selected segment are listed. For missing HUs in AS, the method of half open interval or ZOURS can be used. There is no corresponding option for ABS. For module M3, under AS in-person interviews are performed for SQ. while under ABS, SQ is administered by telephone if a matching telephone can be obtained; else SQ is mailed to the address obtained from the ABS frame. Corresponding to M4, mail or telephone follow-up is conducted for ABS while for AS, in-person follow-up of SQ nonrespondents is conducted. For the remaining SQ nonrespondents, as in M5, random substitution can be made for both ABS and AS using the idea of rejection sampling as part of ZOURS. For administering LQ in M6, as in ABAS, telephone or toll free call back is used for ABS; note that if SQ for ABS is administered by telephone, then LQ could also be administered at the same time if the HU was found to be eligible and cooperative. However, for AS, this module is not required as both SQ and LQ are typically administered back to back by FI if HU is SQ respondent, eligible and cooperative. LQ nonresponse follow-up is conducted in-person for AS but for ABS, it is carried out by mail or telephone as in ABAS under M7.

It follows that in view of the serious problem of unmatched telephone HUs in ABS, it is only AS for which ABAS offers a serious alternative. In terms of cost, main differences between AS and ABAS are respectively due to listing of all HUs *vs.* counting all HUs but prompting of some HUs under field preparations, and in-person interview (generally CAPI) *vs.* telephone interview (typically CATI) under the main interview mode. Therefore, ABAS is expected to be considerably cheaper than AS although the prompting aspect of ABAS would be slightly more expensive than the listing aspect of AS.

4. Summary and Remarks

ABAS was proposed as a hybrid between ABS and AS. It is based on two key ideas. First, some sort of in-person contact is necessary to gain respondent cooperation for survey participation and thus increasing response rate. However, the traditional field interviewer (FI) approach may be cost prohibitive. Instead, in ABAS the idea of field prompter (FP) is introduced. With FP, cost is reduced because FPs are only required to introduce the survey to the respondent and the importance of their participation whenever someone in the selected HU answers the door. Also FPs handout SQs to selected HUs to collect contact information so that main interview is conducted by the call center, thus reducing the cost considerably. Use of SQ and LQ render ABAS as a two phase design for which standard single phase variance estimation methods could be used to obtain simplified variance estimates by using a slightly modified two phase design as suggested in Singh (2008).

The second key idea used in ABAS is that of rejection sampling (Singh and Wolter, 2010). A fairly simple version of rejection sampling (termed ZOURS) is used in ABAS, which is somewhat similar to the common practice of drawing a random sample from a list and rejecting a random selection whenever the associated unit doesn't belong to the target population. ZOURS provides a simpler and more efficient alternative to the method of half open interval for coverage of missed HUs, and is used in ABAS to address the problem of missed or unmatched telephone numbers for HUs with non-city-style addresses.

An additional advantage of using ZOURS for ABAS is that it provides a simple method for random substitution of SQ-nonresponding HUs, making the realized sample size of SQ completes under ABAS very close to the target sample size. Finally, we note that, to incentivize FP for taking due diligence in making in-person contacts and follow-up prompting, a reverse type of incentive can be introduced in which the FP responsible for a given segment gets a small bonus for each HU responding to LQ after being respondent to SQ and selected for the second phase. This keeps incentive cost under control as it is not tied to the large first phase sample. FPs would be discouraged from falsifying SQ response because the telephone center would have a chance to verify SQ response. The reverse incentive option may appeal to respondents as it has a community service aspect and demands only a few minutes of their time in return to qualify a local person for bonus to supplement their modest salaries. It is remarked that planning of a field experiment is underway to test potential benefits of the proposed ABAS design.

Acknowledgments

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