Applying Geographic-Based Demographic Targeting in Household Travel Survey Sampling Plans: Case Study from the Phoenix, Arizona Region

Brent Selby
(Corresponding Author)
Cambridge Systematics Inc.,
E-mail: bselby@camsys.com

Anurag Komanduri
Cambridge Systematics Inc.,
E-mail: akomanduri@camsys.com

Ted Brown
Maricopa Association of Governments
E-mail: ebrown@azmag.gov

Vladimir Livshits
Maricopa Association of Governments
E-mail: vlivshits@azmag.gov

Submitted to the 96th Annual Meeting of Transportation Research Board, January 8 – 12, 2017

Word Count Abstract: 211
Word Count Manuscript: 4,126 + 5 Tables (1,250) + 2 Figures (500) = 5,876

Manuscript prepared on July 29, 2016
Manuscript revised on November 14, 2016

ABSTRACT

Response rates in household travel surveys are declining nationwide, yet data requirements to support model estimation continue to become more complex – especially in areas that are migrating to activity-based models (ABM). Segments with complex travel behaviors, such as transit users, large households, auto-deficient households, increasingly need to be oversampled to support ABM frameworks. In response, a slew of operational improvements have been considered, including higher incentives, use of new technology, relational databases that minimize respondent burden, and design of questionnaires that only focus on the most needed information.

However, there has been limited focus to-date in the US on the development of more fine-grained sampling plans, and on the ways to refine sample purchase that could help stratify the geographic area and identify the concentration of key markets of interest. The authors showcase a sampling plan that builds on the best practices of geography-based sampling and introduces two new concepts: the use of demographics/groups of interest and the use of non-contiguous boundaries to help enhance survey efforts. This method employs oversampling and block-group based monitoring integrated into the survey plan. The objective is efficiency in getting sufficient representation of hard-to-reach or low responding populations as well as supplying models with enough information on the choices of those with more complex behavioral patterns or choices.

keywords: household travel survey, sampling plan, household demographics, hard-to-reach populations, address-based sampling,

INTRODUCTION

The goal of any survey is to obtain a representative sample of a population. In household travel surveys, the travel behavior of individuals in all households in a region is measured. Demographics, location, economics, and transportation options heavily influence the choices people make. With this in mind, sampling plans are usually designed around proportionally measuring segments of a population that are divided by a selection of these characteristics. Traditionally, sampling plans have been developed at a regional level. However, more recent efforts have broken down the regional totals geographically to support targeted approaches that ensure representativeness across the region, either by establishing targets for counties (in the case of multi-county MPOs), or by breaking down the region into large contiguous superdistricts for sampling purposes.

For instance, a geographic random sampling plan may aim to get 10% of its responses from zero vehicle households in the central business district (CBD), because 1 in 10 households in the population are in this group. For this group in a survey targeting 1,000 responses, this goal could be met by randomly sampling until 100 are received from zero vehicle CBD households. Therefore, there is great value in replacing the random sample with a more efficient sampling method that is random, yet allows targeting geographies where households of desired characteristics may reside prior to sample purchase.

This process may still be limited as it is unknown which exact households do not have vehicles until they are contacted. Continuing with this example, if after 1,000 household responses are received, and it is observed that only 75 come from those CBD households with no auto ownership, surveyors will need to continue to collect more data, or employ survey expansion methods that account for this undersampling. Sometimes, the simple random probability-based method, which created this uneven result, can run out of the purchased sample and never meet survey targets. If there are households yet to be contacted, they may not be in the areas with higher numbers of the desired demographics.

There is thus a need for enhanced geography-based sampling that provides surveyors with detailed insights that influence sample purchase. In an era where survey response rates continue to drop due to general respondent fatigue, providing critical insights at the sampling stage could help determine the success of the sample. The method described in this paper applies this idea of extending a geographically-targeted oversampling process by anticipating the practical concerns of gathering responses from key market segments. Recognizing that certain households are likely to respond at a lower rate, small non-contiguous geographies in which they are more highly concentrated were identified. In addition to demographics targets, these special non-contiguous areas were given goals for a number of responses. The surveyor begins the mail outs with a strategy for finding those who are hard to reach and making adjustments as progress is made. In this way, the region can be randomly sampled, achieve a representative and proportional sample, and increase surveying efficiency. A case study from the Maricopa Association of Government's (MAG) MPO region, that includes the Phoenix Metropolitan Area in Arizona, is presented.

This paper starts with an overview of previous surveys in Phoenix. In the next section, the data used and the region of interest are described. This is followed by an explanation of the methodology put into practice. The results of the application are presented and illustrated with maps and tables. The conclusion discusses the advantages of this new approach as well as future considerations.

BACKGROUND AND MOTIVATION

Activity-based Modeling Needs

Activity-based microsimulation models (ABM) have truly arrived in the US. Currently, many of the largest metropolitan areas including New York, Houston, Denver, Minneapolis, Miami, Baltimore, Los Angeles, Chicago, San Francisco, Tampa, San Diego, Atlanta, Portland, and Seattle have either implemented or in the process of implementing an ABM for their region.

As ABMs become ubiquitous, the degree to which they depend on household travel and activity surveys is becoming increasingly apparent. They are and will continue to be the primary source for model estimation, and for the calibration of a majority of the individual models as well. Because the model frameworks that need to be estimated are complex, sufficiently large data samples are required to support model estimation. Robust samples are needed even for under-represented choices such as bike-ped or transit use (which previously relied on transit on-board surveys), joint travel, and travel choices made by young adults – who are tech savvy and rely on shared modes of transportation.

As a result, there is a great and pressing need to employ a procedure that targets such users within the household survey process. It is not merely enough to set targets for such groups; there must also be a multi-faceted plan in place to attract users of such groups to the survey process. Some of these efforts are driven through a smart implementation plan that utilizes technology, incentives, and outreach. However this targeting must also be driven by the use of a smart sampling plan.

Targeting Demographics

Based on reviews of other surveys, it is apparent that survey administrators and modelers identified their hard-to-reach populations. In Minneapolis-St. Paul, these were “single respondents without a car in suburban or rural locations”, “couples without a car available”, and larger households with one or no cars. Son, et al., identified Hispanics, younger people, and single person households as under-responding though improved by address-based sampling (which was used in this survey). Bradley, et al., also expected a lower rate from zero vehicle, lower income, and single-per/non-family households. In Bradley, et al., the authors used a similar method to that applied here of block group categorization that focused on the income in the Seattle metropolitan area. They developed their oversampling based on response rates in a previous survey in that region. A block group expected response rate was estimated using a regression based on local demographics.

In designing the 2011 Census for England and Wales, as described in Brown, et al., the usage of non-contiguous geographic sampling units was considered to reduce the grouping of heterogenous areas together, but not used in favor of a smaller basic geographic unit. A 3-tier rating system was created based on the expected difficulty of reaching the people in the area. Stewart and Moudon suggest analyzing built environment to target desired populations. In their example they compared an already completed survey to area classifications focusing on environmental variables associated with bike, walk, and transit. Mode choice

Previous Survey Efforts in Phoenix

The National Household Travel Survey (NHTS) 2008-2009 sample included 4707 households for the MAG region (consisting of samples from National Survey and Add-on Survey). The survey has data on households, persons, vehicles and trips by all modes of transportation. Most of the data for the MAG region was collected in the Fall of 2008. MAG conducted extensive analysis for the

purposes of analyzing data applicability for estimation of MAG activity-based model and trip based four step modeling procedures maintained by MAG. The identified deficiencies included insufficient representation of transit users and biases in the raw data sample in terms of special data distribution.

Overall, the performed analysis demonstrated general applicability of the survey data for analytical purposes as well as for the purposes of models estimation, calibration and validation. However, it was documented that any following survey efforts must address the issues of spatial distribution, as well as capturing under-represented users effectively.

DATA PREPARATION AND USE

Area of Interest

The population of the MAG MPO region is 4.3 million (July 1, 2015, estimate), which is 64% of the population of the state of Arizona. The MAG MPO area is 10,654 square miles and consists of 27 cities and towns, three Native American Indian Communities, all of Maricopa County, and portions of Pinal County. Phoenix, Mesa, and Chandler are the three largest population centers in the region. The current survey covers the entirety of Pinal and Maricopa Counties as well as small portions of Gila and Yavapai, as shown in ***Figure 1***.

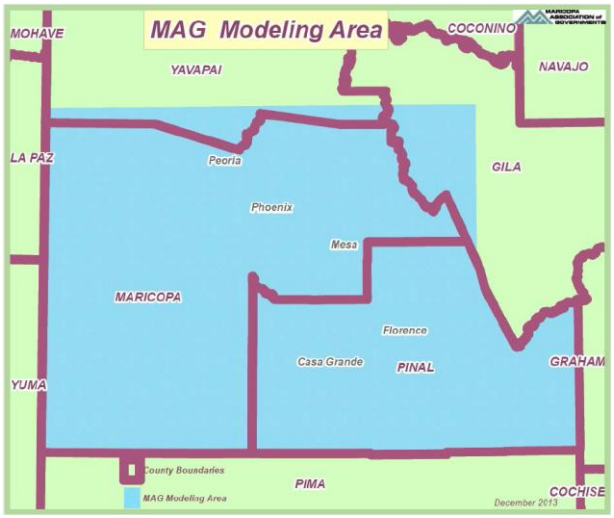

Figure 1: Modeling and survey target area

Maricopa County contains almost 90% of the population in the region. Since 1980, it has been among the fastest growing counties in the nation. Average annual growth had slowed during the recession, but has begun to pick up, increasing from 1.1% in 2012 to 1.7% growth in 2014. The county continues to show stronger annual growth than the state, which grew 1.4% from 2014 to 2015. In June 2015, total non-farm employment for the Phoenix MSA was estimated at 1.87 million, which is 73% of total non-farm employment in Arizona.

The Valley Metro Regional Public Transportation Authority (RPTA) operates bus and light rail service in Maricopa County. This includes 102 commuter and local bus routes with an annual ridership of over 56 million. The light rail service runs a single line from Mesa to the north side of Phoenix, through Tempe and downtown Phoenix, with an annual ridership of 14.3 million. Transit share in the region translates to about 0.2-0.3 percent of total travel. So, despite the fact that half of the county's population lives within a quarter mile of a bus stop, the number

of users is very small and special strategies are required to target these users within a household travel survey.

Segmentation Variables

There is a deep and exhausting body of research that identifies key determinants of travel. From this household size, number of workers, vehicle ownership, and household income were chosen as the backbone of the Phoenix sampling plan.

In addition to these traditional variables, the team determined that the distribution of transit users, auto "deficient" households (fewer vehicles than workers), and Hispanic individuals should be considered when developing the sampling plan. This was determined based on the NHTS survey in Phoenix, other survey efforts throughout the country, and a general understanding of the data required to updated the ABM in the MAG region.

Data Used

The majority of the data used in this and other HTS sampling plans comes from the US Census American Community Survey (ACS). For this effort, the 2009-2013 ACS data were used, to take advantage of the robust sample sizes of 5-year summaries. The ACS data provides summaries of a variety for different variables at either a single variable level or using crosstabs at the tract, block group, and block level.These geographic units average 4,300, 1,570, and 45 residents, respectively, in this region. **Table 1** shows the spatial level at which certain variables used in sampling are made available.

Table 1: Example of ACS data of interest by geography type

Description	Geographic Unit
Workers by Vehicles	Tract
Workers by Household Size	Tract
Population Hispanic/Latino	Block Group
Number of Household Vehicles	Block Group
Workers by location of work	Block Group
Income	Block Group
Household Size	Block
Age and Sex	Block

The block group is used as the primary unit of geography because it is small enough to capture a good deal of neighborhood effects while still having segmented characteristics for key variables. Where necessary, block groups were assumed to have similar shares of segments for variables as the tract in which they reside. This is the case with vehicle deficiency which is only available at a tract level. The survey area includes 2,715 block groups. A summary of their demographics can be found in **Table 2**.

Table 2: ACS block group data summed by county (ACS 5-year summary 2009-2013)

	Households	People			Block Groups
	Total	Total	Hispanic	Workers	
Maricopa	1,411,727	3,889,161	1,155,592	1,705,638	2,505
Pinal	123,733	379,128	109,232	130,542	199
Gila	2,374	5,020	579	1,589	6

Yavapai	4,067	8,675	652	2,429	5
Total	1,541,901	4,281,984	1,266,055	1,840,198	2,715

*Includes only the portion of Gila and Yavapai in the study area.

To aid in locating transit users, bus and train stop data were acquired from the MPO and the transit agency. Initially, bus stops were mapped to the block groups, and the number of stops was considered as the indicator of transit usage in the region. Later, stops were replaced by boardings activity from the regional model to better reflect transit activity. While increased bus usage in a block group suggests more transit users living there, this is only part of the story. Local residency information was compared to better understand zones where they live versus attractions where they are going.

METHODOLOGY

The first step for any sampling plan is to establish the area of interest and obtain data for its population. The geographic boundaries may be customized, but having them match to aggregate Census borders – county or tract – makes planning easier. The household and person totals are then summarized by any variables of interest for fairly small selected geography. For this case, block groups were used, due to their size and availability in Census data. Geographic analysis as well as tabulations were developed to help understand the demographic and geographic makeup of the area's population.

In addition to segmentation variables, groups of interest must be identified. These groups can be hard-to-reach populations, a small niche market, or people with a more complex set of choices or behaviors. For this study, after a preliminary investigation, three groups of interest were chosen to target – transit users, vehicle deficient households, and Hispanic households. As discussed previously, even though transit users and vehicle deficient households constitute a minority of the population, activity-based modeling requires a large enough sample in order to analyze their decisions and use them for model estimation. Hispanic households are often hard to reach, as per Son et al., and can have unique travel patterns as described in FHWA NHTS brief "Hispanics and Transportation".

Large households and low income households were also considered. Large households make up one quarter of the population and can respond at lower rates due to the difficulty in recording every member's trip. They are targeted in segmentation and sampled at the average rate, but excluded in favor of the aforementioned groups of interest. Low income households can also be less likely to complete travel surveys, however they correlate highly with the other groups already identified (in the case of Phoenix).

Block groups were analyzed for concentration of transit stops and usage, zero and low vehicle ownership, and Hispanic household (all are groups of interest). They were then rated by the percentiles of those concentrations. A single block group (BG) type was then assigned by this rubric:

- If a block group is above a threshold of transit intensity and usage, its BG type is 1 – i.e. Block Groups belonging to this classification scheme have a much higher share of transit demand and supply than do other TAZs in the region;
- Else if it is above the 75th percentile for a share of vehicle deficient households, its BG type is 2;
- Else if it is above the 50th percentile for percentage Hispanic, its BG type is 3;
- Else it is 4.

This resulted in a non-contiguous geographic distribution of distinct BG Types. Following this, segmentation variables were chosen to reflect the characteristics which most influence travel behavior. The households are divided by size, number of workers, Hispanic/non-Hispanic, and number of vehicles. The population totals of these variables are used to set the targets for completed surveys. Small segments were combined with others or their targets were artificially inflated to meet a minimum representation or due to special interest in the behavior of a group. The segmentation does not necessarily have to represent all of the hard-to-reach groups, and vice versa.

A target of 7,000 responses was determined by MAG for the survey effort. BG type 1 was assigned the highest sampling rate to ensure enough information about choices involving transit. Vehicle deficient areas were also oversampled, but at a rate much closer to the overall rate. Note that the Hispanic households group was not oversampled. While it is important to ensure a proportional response from these locations, it was not deemed necessary to get more than that.

Table 3: Sampling rates of BG types (Proxy for High Incidence of Groups of Interest)

	Population	Rate	Totals
BG Type 1	108,551	1.10%	1,194
BG Type 2	501,211	0.55%	2,757
BG Type 3	435,192	0.33%	1,424
BG Type 4	496,947	0.33%	1,626
Total	1,541,901	0.45%	7,000

Tables were set up which summarized totals by segmentation variables as well as the aforementioned BG type. These show the number of households by BG type and apply the sampling rates to produce a schedule of expected surveys. The shares of households in each BG type are summed by segment to show the resulting segment totals. This also reveals correlation between the types and segments.

The result is a roadmap of what to target and how to do it. It is important to note that the summaries of BG and of segments have different purposes. The segment sums give the number of households in each type which are needed, like a standard sampling plan. The BG type totals direct the surveyor in purchasing data from the sampling frame to efficiently meet survey responses needed.

RESULTS

Household Travel Survey Sampling Plan

This method produces a geographical distribution of households in non-contiguous block groups, as well as totals by segment. Unlike some sampling plans, this does not have a county or city component (though the geographic distribution of recruitment is monitored). Figure 2 shows expected clustering for some BG Types, as well as some, mixing of the groups. Rather than a map of political boundaries, this is a map of transportation behavior and expected survey responsiveness.

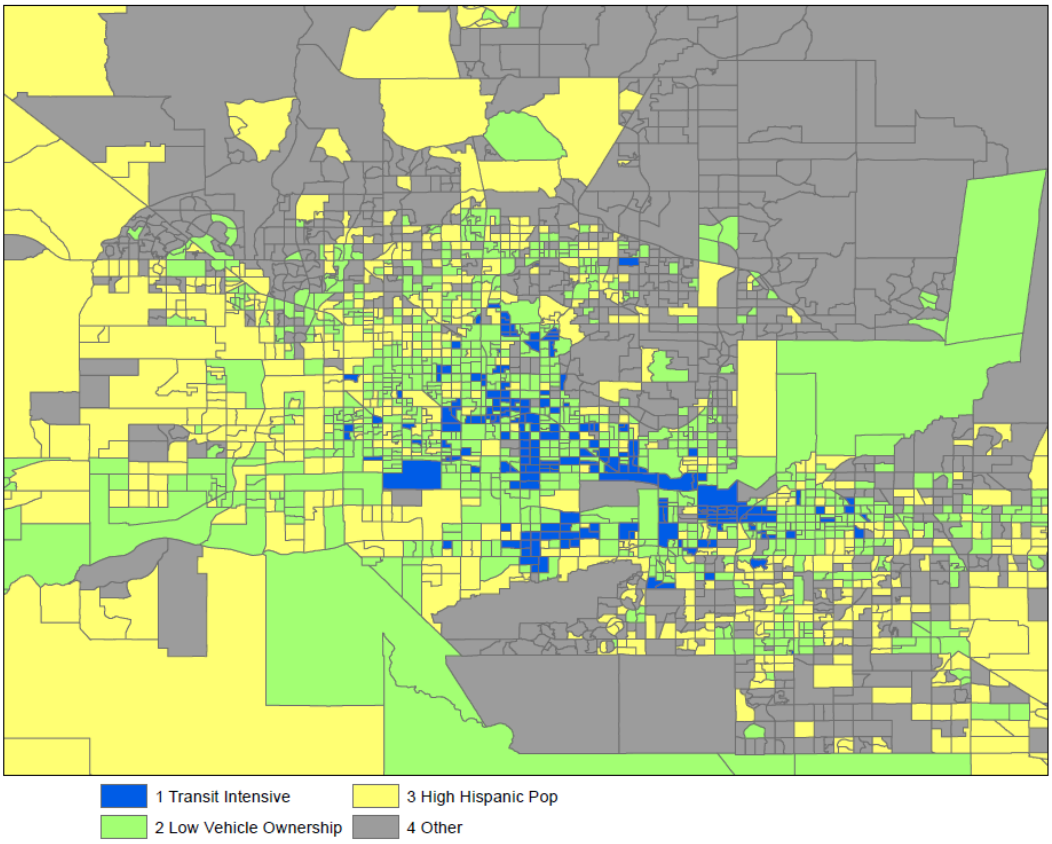

Figure 2: Map of central Maricopa County BG types

The highest transit activity occurs in the central part of Phoenix with a trail of zones following the light rail line to Tempe and Mesa. Oversampling here ensures that choices regarding light rail will be well represented. This is of particular interest to MAG as they are considering extensions and new lines. Residents in these areas have lower car ownership as do residents in BG type 2, which is spread around the region. Areas west of the city, in Glendale and Peoria, are home to many of the Hispanic households. The last type is scattered throughout, and dominant in Sun City West, Scottsdale, the northeast part of Phoenix, and the northern outskirts.

Table 4 shows crosstabs of the BG types with the household size, household workers, people identifying as Hispanic, income, and vehicles. The totals on the bottom of each table show the number of households of the given characteristic – i.e. 102,479 with zero vehicles. In the right side of the tables, in green, are the sampling plan targets, and in the left, in purple, are the population totals on which they are based.

Table 4: Population and targets in BG types by auto ownership, household workers, and Hispanic people

	Population					Targets			
Area/Auto Ownership	**0-Auto**	**Deficient**	**Surplus**	**Total**	**Rate**	**0-Auto**	**Deficient**	**Surplus**	**Total**
BG Type 1	19,253	7,792	81,506	108,551	1.10%	212	86	897	1,194
BG Type 2	66,585	34,483	400,143	501,211	0.55%	366	190	2,201	2,757
BG Type 3	7,297	18,729	409,166	435,192	0.33%	24	61	1,338	1,424
BG Type 4	9,344	13,377	474,226	496,947	0.33%	31	44	1,551	1,626
Total	102,479	74,381	1,365,041	1,541,901	0.45%	632	380	5,987	7,000
	7%	5%	89%	100%		0.62%	0.51%	0.44%	0.45%
Area/HH Workers	**0 Worker**	**1 Worker**	**2+ Worker**	**Total**	**Rate**	**0 Worker**	**1 Worker**	**2+ Worker**	**Total**

BG Type 1	28,661	50,716	29,174	108,551	1.10%	315	558	321	1,194
BG Type 2	136,431	216,686	148,094	501,211	0.55%	750	1,192	815	2,757
BG Type 3	89,049	180,864	165,279	435,192	0.33%	291	592	541	1,424
BG Type 4	157,005	181,617	158,325	496,947	0.33%	514	594	518	1,626
Total	411,146	629,884	500,872	1,541,901	0.45%	1,871	2,935	2,194	7,000
	27%	41%	32%	100%		0.45%	0.47%	0.44%	0.45%

Area/People*	**Hispanic**	**Non-Hispanic**	**Total**	**Rate**	**Hispanic**	**Non-Hispanic**
BG Type 1	144,621	152,595	297,216	1.10%	1,591	1,679
BG Type 2	583,266	802,515	1,385,781	0.55%	3,208	4,414
BG Type 3	454,962	905,233	1,360,195	0.33%	1,488	2,961
BG Type 4	83,206	1,155,586	1,238,792	0.33%	272	3,780
Total	1,266,055	3,015,929	4,281,984	0.45%	6,559	12,834
* People, not households	30%	70%	100%		0.52%	0.43%

The transit intense area type comprise less than a tenth of the population, but due to the increased sampling rate, were expected to complete more than 15% of the surveys from that area. In addition to having the highest share of transit-user households, these block groups also have the highest share of low income (see Table 5) and single worker households. The second type, vehicle deficient block groups, has similar shares in household size, income, and number of workers, although skews slightly higher in income.

Table 5: Population and targets in BG types by household size and income

	Population				**Target**			
Area/HH Size	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**
BG Type 1	37,892	30,756	15,017	24,886	417	338	165	274
BG Type 2	160,310	147,647	70,773	122,481	882	812	389	674
BG Type 3	87,685	137,480	74,102	135,925	287	450	242	445
BG Type 4	122,020	215,368	64,419	95,140	399	705	211	311
Total	407,907	531,251	224,311	378,432	1,985	2,305	1,008	1,703
	26%	34%	15%	25%	0.49%	0.43%	0.45%	0.45%

Area/HH Income	**$0-25k**	**$25-50k**	**$50-100k**	**> $100k**	**$0-25k**	**$25-50k**	**$50-100k**	**> $100k**
BG Type 1	42,905	32,286	24,300	9,060	472	355	267	100
BG Type 2	157,671	148,012	136,066	59,462	867	814	748	327
BG Type 3	66,551	110,972	161,482	96,187	218	363	528	315
BG Type 4	66,607	100,012	159,490	170,838	218	327	522	559
Total	333,734	391,282	481,338	335,547	1,775	1,859	2,066	1,300
	22%	25%	31%	22%	0.53%	0.48%	0.43%	0.39%

The surveyors aimed to collect 2,757 surveys from area type 2 (as per the rightmost column), but most of these will not be vehicle deficient households. 80% of households there have as many vehicles as workers. However, they are much more likely to be deficient in BG Type 2 than in BG Type 3 and BG Type 4, where they only make up 5% of total households. Therefore, surveys received from there are counted towards the type 2 goal, 2,757, and towards the deficient goal, 380, only if they report that to be the case.

Due to lower expected response rates, the rates vary by the block group type. The rates by segment (at the bottom of the green tables), resulting from the BG type rates, indicate correlations. Targeted auto ownership rates were higher by design. Low income is oversampled because it is more common in block group types 1 and 2. The third type, which focuses on concentration of

Hispanic population, is not oversampled, but Hispanic households are oversampled owing to their prevalence in the first two BG types.

The BG type targeting produces resulting segment targets that do not match population shares, even for variables which are not related to the BG types. For example, 53% of households in the region have an income above $50,000, but this demographic comprises only 48% of the survey target. Three points should be taken into consideration regarding this.

- First, the survey will be weighted and expanded to the population totals. The segments used in expansion can be the same as those used here, or other segments may also be included to better represent regional population. This ensures that the model will consider respondents' behavior in proportion to the share of the population they represent.
- Second, households not designated hard-to-reach live in each of the BG types. They may be contacted at a lower rate, but their higher responsiveness often results in an excess of completed surveys above the targeted number for that segment.
- Finally, higher income households in an auto-centric area such as Phoenix are likely to have simplified travel decisions, and it is unlikely that any additional advantage may be gained by collecting a few additional surveys from these segments.

Early analysis of a portion of responses from the ongoing survey shows robust response from households with fewer vehicles. The share of zero vehicle households in the survey is 9%, on target and several points higher than the population. Other households with fewer vehicles than workers are responding at such a high relative rate that actively reducing their recruitment could be considered. Larger households and those with 2+ workers are responding at a rate lower than intended resulting in underrepresentation. This correlates with a skew towards the more wealthy that is common to household travel surveys. The dearth of larger and lower income households likely relates to lack of response from Hispanic households. Despite oversampling there has been very low participation from those who identify as part of this group – less than 10% of the sample in a region where they comprise almost 30% of the population. Through the remainder of the survey, the more Hispanic BG types will be targeted and monitored with the intention of closing this gap.

CONCLUSIONS

The paper presents a case study of using non-contiguous boundaries to target hard-to-reach demographics and capture critical-to-understand behaviors in support of an activity-based model development. This type of small area oversampling allows survey firms to purchase their sample purchase effectively. This can have cost implications – both during the purchase of the sample and then during the mail-out of the household recruitment letters as well. This method calls for oversampling and block-group based monitoring from the outset of the survey process. The objectives are threefold: first, to ensure that hard-to-reach or low responding populations are well represented in the data; second, to provide modelers with enough information on the choices of those with more complex behavioral patterns or choices; and third to meet all the targets efficiently. These are achieved by rating block groups and placing each one in a category based on the amount of transit activity or demographic make-up of households.

The difficulties of reaching certain groups will always be a part of household travel surveys. As it is not clear what demographics a household has until it is recruited, there is still the possibility of coming up short. This method gives the planners the option of prioritizing and oversampling groups they expect will be elusive. Starting with a sample frame based on this method that is set up to avoid this problem will help. Rates can be further adjusted during the survey to adapt to results.

This process produced four block group types, three of which were each just over a quarter of the population. By sampling the small set defined by its high level of transit activity at a rate more than double the overall rate, the survey will oversample those for whom transit is a chosen or at least viable option. The second BG type specifies places of high levels of vehicle deficiency (fewer cars than workers) which can have lower response rates, but is not nearly as oversampled. The focus for this group, as opposed to the first, is to represent the demographic, which is expected to be easier to find and have a narrow variety of behaviors. The last group is Hispanic, which was identified but not oversampled.

The BG types are set such that each one contains a sizeable share of the block groups. Aside from transit intense, each comprises of at least 760 (28%) block groups. Focusing on a narrower set of zones by using a higher threshold value can be considered. This would increase the likelihood of contacting the household type of interest. However, the overall sample sizes for such a custom zone set would be low and this would likely increase the risk of not achieving sample targets. The size and dispersion of the groups presented in this case study keeps this risk low. Future surveys in other regions may shape theirs differently to align with specific needs, such as: multiple small population niches of importance, less correlation between groups of interest, or more clustered block group types.

Another consideration might be the separation of segmentation targets from the oversampling of BG types. In this case the segment rates resulting from BG type rates were maintained. This could be considered more malleable, with segment targets being merely proportional to the population and disconnected from BG type rates. As previously discussed, underrepresentation is a problem for modeling, while overrepresentation is merely inefficient and fixable in expansion.

ACKNOWLEDGMENTS

The Authors would like to thank Petya Maneva and Lavanya Vallabhaneni at MAG; Arun Kuppam, Kimon Proussaloglou, Rachel Copperman and Cemal Ayvalik at Cambridge Systematics; and Josh DeLaRosa at AbtSRBI for their valuable inputs through the project's duration.

REFERENCES

1. Bradley, B., A. Bergman, M. Lee, E. Greene & S. Childress. Predicting and Applying Differential Response Rates in Address-Based Sampling for a Household Travel Survey. *Transportation Research Record*, Vol. 2526, Jan 2015, pp. 119-125.
2. Brown, J., O. Abbott and P. A. Smith. Design of the 2001 and 2011 Census Coverage Surveys for England and Wales. *Journal of the Royal Statistical Society. Series A (Statistics in Society)*, Vol. 174, No. 4 (Oct. 2011), pp. 881-906
3. FHWA NHTS Brief: Hispanics and Transportation. Federal Highway Administration. Washington, DC. http://nhts.ornl.gov/briefs/HispanicBrief.pdf. Accessed July 31, 2016
4. Metropolitan Council Travel Behavior Inventory Household Travel Survey. Metropolitan Council. St. Paul, Minnesota. http://www.metrocouncil.org/Transportation/Planning-2/Transit-Plans,-Studies-Reports/Other-Studies-Reports/Travel-Behavior-Inventory/TBI-Household-Survey-Report.aspx. Accessed July 20, 2016
5. Son, S., A. Khattak, X. Wang, P. Agnello and J. Chen. Quantifying Key Errors in Household Travel Surveys. *Transportation Research Record*, Vol. 2354, Dec 2013, pp. 9-18.
6. Stewart, O. T., and A. Moudon. Using the Built Environment to Oversample Walk, Transit, and Bicycle Travel. *Transportation Research Part D* 32, 2014, pp. 15-23.
7. Valley Metro System Fact Sheet. Valley Metro Regional Public Transportation Authority, Phoenix, Arizona. http://www.valleymetro.org/images/uploads/RPT2411-opt.pdf. Accessed July 20, 2016