ESTIMATION OF NONSAMPLING ERROR DUE TO SELECTED OFFICE OPERATIONS OF THE 1980 CENSUS

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I. BACKGROUND

It has been the practice during the past several decades to conduct evaluation studies as part of the decennial census program. These studies have provided measures of the quality of census data and have included assessments of the nonsampling variance present in the final statistics. By identifying the major contributors of nonsampling variability, estimates of the total variance of published census statistics can be provided to users of census results. In addition, the findings from these studies are useful in developing future censuses since they can help planners to gauge the effectiveness of the operations that have been studied.

Census data collection and processing procedures have grown more complex with each passing census, and opportunities for the introduction of nonsampling variance have increased correspondingly. Mail-returned questionnaires and enumerator-filled questionnaires from respondents who did not mail back their forms were processed in the district office. Spanish questionnaires were transcribed by bi-lingual clerks onto English forms. Each questionnaire was edited by an office clerk to flag items that were skipped by the respondent or answered incompletely or inconsistently. During this operation, entire questionnaires may have required transcription by the clerk to correct errors that made the form unreadable by processing equipment. Questionnaires for which the number of flagged items totaled more than a pre-determined amount were sent for followup by telephone clerks who attempted to complete the questionnaires and resolve any inconsistencies. If telephone followup efforts were unsuccessful, the questionnaires were returned to the field for followup by enumerators during personal visits with the respondent. Following the office operations, questionnaires will be sent to the processing centers where they will be prepared for machine processing. One part of this processing is clerical coding of certain items. In each of these operations, some amount of error is to be expected.

To consider all of the sources of nonsampling variability would require an experimental design so complex as to be technically impractical as well as prohibitively expensive in terms of both money and manpower needs. Thus this study, the Components of Variance Study (CVS), concentrates on the two office operations where the errors are expected to be most important and for which little previous information is available: the office edit and telephone followup operations. In the edit operations, the most common error we expect to find is failure of an editor to mark a question requiring followup as needing followup, thus allowing the questionnaire to reach the processing center with poor or missing information. Telephone followup clerks may also have failed to obtain the needed information, either by neglecting to ask some questions marked for followup or by accepting an inordinately large number of "don't know" responses or "refusals". Since the missing data will be imputed during the later processing stages, (i.e. the value for a "similar" unit will be substituted) bias is introduced into the final census results.

This paper describes the statistical planning and the field operations for the Components of Variance Study evaluation for the 1980 Decennial Census, and introduces the models that will be used to analyze the resulting data.

II. STATEMENT OF OBJECTIVES

There are two main objectives of the Components of Variance Study. They are: first, to provide separate estimates of the correlated components for both edit clerks and telephone followup clerks in centralized district offices for the long-form questionnaire items; and second, to provide an estimate of the interaction between the errors of the edit clerks and telephone followup clerks in centralized district offices for the long-form questionnaire items.

The estimation of these components can provide insight into the following questions:

First, do the edit clerks and telephone followup clerks contribute a significant amount of variability to the total variance of census estimates? It is already known that, for some items, the edit error rate is at a seriously high level; however, nothing is known about the edit clerks contribution to total variance. As shown in [5], the magnitude of the edit clerk variance component depends upon the variability of the individual edit clerk error rates - not upon the magnitudes of the error rates. So even though the overall error rate for editing is high, the edit variance component could be insignificant if individual error rates are homogeneous among the edit clerks.

Similarly, little is known about the variability due to telephone interviewers, although there have been several studies in previous census on personal visit interviewer (see, for example, [3] and [4]).

Second, what is the nature of edit error? In particular, this study will indicate whether edit clerks tend to make errors at about the same rate or whether edit error rates vary considerably among edit clerks. Suppose that for an item known to have a high edit error rate, an insignificant edit clerk variance component is observed. From [5], this indicates homogeneous error rates among edit clerks, hence, some factors which affect all edit clerks uniformly might be suspected as the dominating cause of edit error - for example, edit clerk training. Conversely, a significantly high edit component indicates that individual error rates vary among the edit clerks. This might suggest that the high overall error rate is caused by nonuniformity in the quality of personnel hired for the edit operation.

Third, does poor editing influence the work of the telephone followup clerks? A significant interaction variance component would indicate that edit clerks may be causing further errors during the telephone followup operation. This information could be very important as even further use of the telephone is being planned for future censuses.

Fourth, how does telephone interviewing compare with personal visit interviewing in terms of variances? Previous studies have provided information regarding the component of variance for personal visit interviewing in censuses (see, for example, [3] and [5]). Utilizing a model similar to the one proposed in [5], estimates of telephone interviewing variance can be computed which are comparable to the components of variance estimated from these other studies.

III. DESIGN OF THE STUDY

A. Sampling Plan

The first decision that had to be made was which questionnaires would be included in the sample to be studied. While there are more than four hundred decennial census district offices throughout the United States, only the "centralized" district offices, those serving areas having the greatest population density, have both the office edit and telephone followup operations conducted within the physical confines of the office. Thus, the sample was limited to centralized district offices. A simple random sample of the eighty-seven centralized offices yielded fourteen district offices in which the study would be made.

Within each selected district office, only long-form questionnaires were included in the study. Long-form questionnaires, which contain 115 questionnaire items, were completed by one-sixth of the households in the area covered by a centralized district office. Every questionnaire returned by mail to the district office, as well as every enumerator-filled questionnaire, that would normally undergo the office edit was examined for this study. Clearly, since all long-form questionnaires described above were part of the sample, every long form edit clerk and telephone followup clerk in the sample offices were included.

B. Methodology

The procedure for estimating the correlated components of variance for the error sources under investigation in the CVS, that is the edit and telephone followup operations, is based upon a technique called interpenetration of work assignments.

Consider only one source of error, say, edit clerk error, for example, and define a long form edit work assignment as all of the long-form questionnaires that are edited by a particular editor in a district office. The long form edit work assignment is interpenetrated when each assignment constitutes a simple random sample of long-form questionnaires from the population of long forms in the district. This implies that the average value of a characteristic for each edit work assignment is a valid estimate of the district population mean of the characteristic. So, by comparing these estimates, one could get an idea of the amount of variability among editors in the performance of the job.

If, for example, the average of one interpenetrated work assignment deviates considerably from the average of the other interpenetrated work assignments for a particular characteristic, the quality of the work in the atypical work assignment for that item could be questioned.

Based upon this concept, statistics have been derived using interpenetrated work assignment which measure the variance contributed by a particular error source. When two error sources are involved, as in the present study, the method of interpenetration is more complicated; however, this same basic principle is still applicable. Interpenetrating the joint edit clerk and telephone followup clerk work assignments is equivalent to partitioning the mail and enumerator returned long-form questionnaires in a district office into K roughly equal subsamples, K being the product of the number of edit clerks and the number of telephone followup clerks in the district office, and allocating each subsample to one of the K edit clerk/telephone followup clerk combinations.

The interpenetration scheme utilized for CVS is based upon interpenetrating the joint work assignments of editors and telephone followup clerks within small clusters within the district population rather than the entire district population. This is done both to improve the precision of the estimate and as a matter of operational convenience. Nevertheless, regarding these clusters as the populations under study, the concept described above is applicable.

C. Operational Planning of the Study

Once the methodology had been selected and developed, the task of operational planning began. In order to implement the study, a thorough understanding by the operational planners of the edit, telephone followup, and related office operations was necessary. This was accomplished by reading the operational manuals for all of the office operations that would be performed on the questionnaires from the time they were delivered to the district office until they left the telephone followup operation. In addition to the operational manuals, supervisors' manuals and training materials were studied to bring the procedures into focus. Discussions with census operations experts in Field Division were held to clarify the procedures and answer questions that were not fully covered in the written material. Following these discussions, a clear picture of the flow of long-form questionnaires processing in the district office emerged.

A major criterion to be met was the development of evaluation procedures that would cause as little disruption as possible to normal census district office procedures. In meeting this criterion, it was necessary to determine at what point in processing the questionnaires should be collected for interpenetration. It was decided that interpenetration could be achieved with the least impact on other operations if the questionnaires were intercepted immediately before the edit operation and returned to the normal census flow immediately after the telephone followup operation.

In centralized district offices where the CVS project was not being conducted, questionnaires were placed into "work units" by a questionnaire control clerk, a work unit being a set of fifty to eighty long-form questionnaires, approximately one day's work for an edit clerk. This work unit underwent a "pre-edit", a quality control procedure where a sample of questionnaires from the work unit was edited by a quality control edit clerk, and the results recorded on a special form rather than on the questionnaires themselves. The entire work unit was

then edited by an edit clerk who marked directly on the questionnaire. The editor corrected errors made by the respondent that would make the questionnaire unreadable by data processing equipment (e.g., erased stray marks, filled FOSDIC circles that had been checked instead of filled, filled appropriate FOSDIC circles for handwritten entries). In addition, the edit clerk marked questions that had not been answered, or that had been answered inconsistently, for followup by telephone followup clerks. Questionnaires which needed followup were marked "T"; questionnaires regarded as needing no followup were marked "C", for complete.

After being edited, the work unit was given to another quality control edit clerk, called a verification clerk, who compared the editing done by the editor to the editing done by the pre-editor for the sample of questionnaires that were pre-edited. Work units that passed this quality control check were released from the edit operation immediately. For those that failed, the entire work unit was re-edited by another edit clerk before it was released from edit.

The "C" questionnaires from a work unit were returned directly to the questionnaire control clerk. "T" questionnaires were taken to the telephone followup operation where clerks tried to complete the questionnaires with information obtained through telephone interviews with the respondents. Each questionnaire underwent a telephone followup quality control check before it was returned to the questionnaire control clerk.

For district offices in the CVS sample, an additional operation, CVS project control, was interwoven around the edit and telephone followup operations. The project control clerks obtained work units from the questionnaire control clerk and combined four work units into a "block". The questionnaires were regrouped into four new "editor work units," EWUs, which represented the interpenetrated work assignment. Each EWU in the block was edited by different edit clerk following the usual edit procedures.

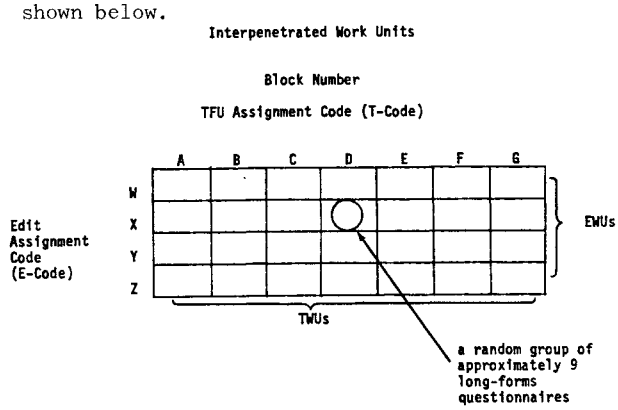
In order to keep the quality control effect constant for the block, every EWU in the block was pre-edited by the same pre-edit clerk and verified by the same verification clerk. (As in normal census procedures, the pre-editor, editor, and verifier for any given work unit were required to be different people.) In addition, any EWU that had to be re-edited was re-edited by a person who had not pre-edited, edited, or verified, any EWU in the block, or re-edited any other EWU in the block.

All questionnaires, whether complete after edit or requiring telephone followup, were returned to CVS project control in their EWU groupings. Project control clerks then separated all the questionnaires for a block into "C" or "T". "C" questionnaires were regrouped into their original work unit sets and returned to the central bin file. "T" questionnaires in a block were regrouped by project control clerks into seven interpenetrated telephone followup assignments, TWUs, and taken to the telephone followup operation. Within a block, a telephone followup clerk-pair was permitted to work on only one TWU assignment and a TWU assignment could be worked on by only one clerk-pair. (A clerk-pair was the pair of one day shift clerk and one night shift clerk who shared the same telephone followup assignment.) The telephone followup quality control was of such a nature that the effect of it could be assumed to be constant over the block.

Following telephone followup, the questionnaires were returned to project control where they were regrouped into the same form that the questionnaire control clerk would have received them in had CVS not been in the office.

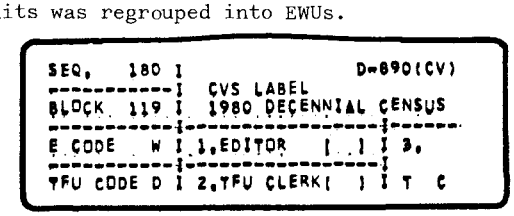
The decision to interpenetrate in blocks of four work units facilitated the flow of work through the operations. An earlier plan to interpenetrate in the district office without breaking the questionnaires into small "blocks" proved to be operationally unworkable if efficient use of manpower was considered to be a necessary constraint. The actual interpenetration scheme is described in the following paragraphs.

The configuration of the four EWUs and the seven TWUs for a block of four work units (approximately 252 long-form questionnaires) is shown below.



Each of the twenty-eight cells in this table contains a random group of approximately nine long-form questionnaires. The rows of the table correspond to EWUs and the columns correspond to TWUs.

This randomization was accomplished with the use of labels which were computer generated at census headquarters. (See illustration). One label was applied directly to the front of each long-form questionnaire before the block of work units was regrouped into EWUs.



The labels contained the block number, a sequence number (for control), an editor clerk assignment code, a telephone followup clerk assignment code, and spaces for recording other pertinent information.

The edit clerk assignment code was a capital letter W, X, Y, or Z. The telephone followup clerk assignment code was a capital letter A, B, ..., F, or G. The individual numerical codes of the edit and telephone followup clerks who actually worked on the questionnaire were

recorded in predesignated places on the label by the clerks themselves.

Prior to editing, four editors were selected based upon their relative workloads and were assigned to EWUs W, X, Y, and Z. Similarly, prior to telephone followup, seven telephone followup clerks were chosen and given TWUs A, B, C, D, E, F, and G. As described previously, only one pre-editor and one verifier were assigned in any given block.

By using interpenetration techniques in this way, simultaneous estimates of the effects of editor, telephone followup clerk, and their interaction can be computed for each block. The block estimates can then be combined to form estimates of the components that pertain to the entire district office. This interpenetration scheme also allowed problems such as attrition and assignment backlogs to be efficiently managed without sacrificing degrees of freedom for the estimates.

D. Setting of Controls

In order for proper control to be exercised during this study, a number of new forms were created. Some of these forms were similar to census forms used in all district offices and were used to replace the original forms while the questionnaires were in certain phases of the CVS project.

Two forms were designed to record critical data for the study. The first contained a summary of all information that pertained to a block. The code numbers of the clerks who worked on questionnaires in the block, notes on any breach of CVS procedures, and description of unusual occurances were written on this card. A second form was used to list each questionnaire in a work unit. So, for every questionnaire in the study, there exists a record of the CVS assignment codes as well as other identifying information. This form was also used to note problems relating only to specific questionnaires.

A second pair of forms was used as an aid to making assignments to edit and telephone followup clerks. On each form, assignments for one block were recorded on a single line. These forms were designed so that the person assigning the work could be assured, simply by checking for one thing, that no CVS restrictions were violated. The rule was: no clerk code number can appear more than once on a line.

Because new forms and procedures had been introduced into the edit and telephone followup operations, revisions to manuals and training guides were necessary. In most cases, the revisions were minor, since the substantive parts of the clerks' jobs were unchanged by the study. The materials used by the person who assigned EWUs to edit clerks, however, did require a good bit of supplementation.

It was felt that two supervisors would be needed in each district office to oversee the CVS activities, one for the day shift and one for the night shift. The project control supervisors, who worked days, also supervised the senior project control clerk, who was the night shift supervisor. The night supervisor's main job was to see that CVS assignment procedures were followed by the night shift telephone followup personnel and edit personnel in those district offices that had a night shift edit operation.

Both of these supervisors were recruited and hired by the district offices. Although knowledge of statistics was preferred, it was not a requirement for people filling these positions. An intensive three-day training session for all twenty-eight supervisors was held in Washington immediately prior to the start of CVS activities in the district offices. The supervisors were given a comprehensive manual that covered instructions for all activities they were expected to perform. In addition, they received copies of the CVS procedures manuals that would be the clerks' reference manual, plus verbatim guides for training project clerks and office supervisors in CVS procedures.

In order to maintain control over the operation, three levels of monitoring were devised. CVS supervisors were to call Washington with daily telephone progress reports. Notes from each call were kept in separate logs for each district office. A weekly written report to describe unusual situations or problems was also required. Finally, two observations of CVS operations in each office by trained headquarters personnel were planned. The first observation was scheduled for the very beginning of the operation, to try to keep small problems from becoming large. The second visit was to be at a later time when all phases of the operation would be in progress. The possibility that emergency visits might be needed was recognized and planned for.

IV. EXECUTION OF THE STUDY

CVS supervisors were in the district office just before Census Day, April 1st. According to the planned census schedule, the CVS activities in the offices should have ended on June 2. In a few offices, the schedule was closely adhered to. Most offices, however, experienced delays due to slow mail return of questionnaires and staffing problems. By the end of May, in some offices CVS was ready to end, while in others, telephone followup had barely begun.

The hiring and training of project control clerks went very well in most offices. Recruiting in the New York area was somewhat of a problem because of the transit strike. However, CVS project control was fully staffed in all offices by the time the questionnaires were available for processing. CVS training for both project control clerks and other district office personnel was done smoothly in most offices.

The CVS operations in general proceeded easily in nearly every office. While some problems were encountered, very few were serious enough to cause concern. The problems were routine and either solved by time or alleviated by a phone conversation with Washington. Some of the minor problems which plagued the study, but did not jeopardize the results, are discussed below.

Most of the offices were behind the originally planned schedule before the first questionnaire received a CVS label. The high volume of mail returns so overwhelmed the staff of clerks who performed check-in activities that several offices were weeks off of their schedule. In many cases, CVS clerks were drafted to help in other operations until the questionnaires were ready for CVS processing. The edit operation

was also slower than had been anticipated in many places and further delayed operations. It appears that the census schedule was overly optimistic in some places.

While supervisors in the majority of the district offices were cooperative with CVS activities, some supervisors were very unhappy to have the study in their offices and on occasion their communication with the CVS project control supervisors lapsed in matters relating to CVS procedure. When violation of CVS procedures seemed likely, Field Division intervened and most problems disappeared at that point. Conversations between district office supervisors and the CVS staff in Washington ironed out any remaining conflicts.

Manpower needs created some difficulties. In several offices, planned allocation of telephone followup clerks conflicted with minimum staffing requirements for CVS. In these cases a compromise was found which was satisfactory to both CVS and the district office involved. Sudden, unexpected decisions in a number of offices to initiate a night shift edit operations caused concern. In addition to bringing about a possible need for more project control clerks for an evening shift, certain quality control procedures were complicated by the fact that the day shift of edit was longer than the night shift. Alternative procedures for dealing with this problem were quickly developed.

In most offices there were occasional instances where CVS assignment rules were violated. Often the errors were discovered by the project control supervisor in time to be corrected. However, in cases where assignments were actually worked on by the wrong clerks, questionnaires will have to be deleted from the study. It is not expected, though, that this occurred frequently enough to invalidate the results.

Operations in a few offices were hampered by personnel problems. The temporary and political nature of the census jobs made it hard to recruit topnotch people for all positions. The difficulties, though, were less severe than had been expected, and all were overcome in time.

As a whole, the field operations for CVS were successful. The CVS supervisors were extremely capable. They were able to prevent most problems from happening by being constantly aware of what was going on in the CVS, edit, and telephone followup areas. While they took the initiative in keeping the project under control, they also knew when a conference with the Washington staff was necessary before making a decision. CVS was fortunate to have such a group of people in charge of the office procedures.

All of the control forms that were designed worked well. As had been planned, they became a permanent record of CVS operations for each district office. In addition, the forms were used to identify and locate missing questionnaires. More than once they helped supervisors to spot breaches in census procedures in time to correct the errors.

The CVS procedures were followed diligently in the offices. All information that was needed was recorded properly, and any deviations from expected activities were noted on appropriate forms. Written and verbal reports were received on schedule, for the most part, and became an important part of the documentation for the study. Written reports of the observation visits were also included in the documentation. Because of the care taken by the field staff, the data that will be available from the processing centers as well as the control data that is being examined in Washington should be of sufficiently good quality to use for analysis.

V. DATA ANALYSIS PLAN

This section presents a brief overview of the methodology for computing the estimates of the components of variance due to the edit and telephone followup operations in centralized district offices.

A simplifying device for estimating the target components is to postulate a linear additive model for the effects. Let y_{ijklm} denote the value of the characteristic for the m-th unit assigned to edit clerk k and telephone followup clerk l in block j within district office i. The following general model is assumed:

$$y_{ijklm} = \mu + \delta_i + \beta_{j(i)} + \epsilon_{k(i)} + \tau_{l(i)} + (\epsilon\tau)_{kl(i)} + (\beta\epsilon)_{jk(i)} + (\beta\tau)_{jl(i)} + (\beta\epsilon\tau)_{jkl(i)} + e_{ijklm} \quad (1)$$

where μ denotes the overall mean of the characteristic for centralized districts δ_i denotes the effect of the i-th district office, $\beta_{j(i)}$ denotes the effect of the j-th block with-in district office i, $\epsilon_{k(i)}$ denotes the effect of the k-th edit clerk within district office i, $\tau_{l(i)}$ denotes the effect of the l-th telephone clerk within district office i, $(\epsilon\tau)_{kl(i)}$, $(\beta\epsilon)_{jk(i)}$, $(\beta\tau)_{jl(i)}$, and $(\beta\epsilon\tau)_{jkl(i)}$ denote the interaction effects, and e_{ijklm} denotes the combined sampling and nonsampling elementary error.

All the components (except μ) are assumed to be random effects with zero means and the usual ANOVA assumptions of independence between the error terms are made. In the most general form of the model, the variances of the components $\epsilon_{k(i)}$, $\tau_{l(i)}$ and the interactions are not constant across district offices and Var (e_{ijklm}) varies across blocks within district offices.

Then the above model can be rewritten using the notation customary in variance component estimation methodology in the form

$$\underset{\sim}{y} = \mu \underset{\sim}{1} + \sum_q U_q \underset{\sim}{a}_q \quad (2)$$

where $\underset{\sim}{a}_q$ is a vector of random variables with zero mean, $\underset{\sim}{1}$ is a vector of all 1 elements, and U_q is the design matrix corresponding to error source q. The variance covariance matrix of $\underset{\sim}{a}_q$ is a block diagonal matrix of the form Λ_q = diagonal $(\psi_{qt}\ \sigma^2_{qt})$ where ψ_{qt} is a matrix of known constants. Hence, the variance components σ^2_{qt} can be estimated using standard estimation techniques for generalized mixed ANOVA models such as Minimum Norm Quadratic Unbiased Estimation (MINQUE).

In order to interpret the estimates of the variance components provided by this technique, a model similar to the one proposed in [5] for edit error will be adopted. It is shown in [5], assuming a survey error model which more practically describes the errors committed by edit clerks

than the model in (1), that the estimator of σ_ϵ^2 provided by the above technique is an estimator of

$$\hat{\pi}^2\sigma_\phi^2(1-\lambda)^2[(B_I - B_R)^2 + \rho_I\,\sigma_I^2 + \rho_R\,\sigma_R^2 - 2\rho_{IR}\sigma_I\sigma_R] \quad (3)$$

where B_I is imputation bias, B_R is response bias, $\rho_I\sigma_I^2$ is imputation error covariance, $\rho_R\sigma_R^2$ is response error covariance, $\rho_{IR}\,\sigma_I\,\sigma_R$ is the covariance between response errors and imputation errors, σ_ϕ^2 is the variance between edit clerks in their error rates, $\hat{\pi}$ is proportion of units in the sample that should be marked for followup and λ is the probability that a unit marked for followup is not successfully followed-up by the second phase followup operation. This latter term can be estimated by

$$1-\hat{\lambda} = \frac{\#\text{ of units successfully followed-up}}{\#\text{ of units marked for follow-up}} \quad (4)$$

If it is assumed that the bracketed term in (3) is large, then a small value of $\hat{\sigma}_\epsilon^2/[\hat{\pi}(1-\hat{\lambda})]^2$ indicates that σ_ϕ^2 is small, and likewise for large values. This estimator will be used to study the nature of the edit error as mentioned in Section II. A similar model applies to the telephone clerk analysis (see [5]).

The estimate of σ_ϵ^2 can also be used in studies comparing computer editing with human editing. This is also discussed in [5].

Because the data tapes will not be available for use for evaluation studies until 1982, the analysis of the data obtained for the Components of Variance Study will be delayed until that time. Release of a final report can be expected in 1983.

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APPENDIX

The CVS sample consists of the following fourteen district offices:

Hartford, CT	N. Detroit, MI
New Haven, CT	Gary, IN
N. Manhattan, NY	S.E. Chicago, IL
E. Bronx, NY	N.W. Chicago, IL
S. Bronx, NY	Central Houston, TX
N.W. Washington, DC	Downtown Los Angeles, CA
S.E. Washington, DC	Compton, CA