Chapter 10.
Data Preparation and Processing for Housing Units and Group Quarters

10.1 OVERVIEW

Data preparation and processing are critical steps in the survey process, particularly in terms of improving data quality. It is typical for developers of a large ongoing survey, such as the American Community Survey (ACS) to develop stringent procedures and rules to guide these processes and ensure that they are done in a consistent and accurate manner. This chapter discusses the actions taken during ACS data preparation and processing, provides the reader with an understanding of the various stages involved in readying the data for dissemination, and describes the steps taken to produce high-quality data.

The main purpose of data preparation and processing is to take the response data gathered from each survey collection mode to the point where they can be used to produce survey estimates. Data returning from the field typically arrive in various stages of completion, from a completed interview with no problems to one with most or all of the data items left blank. There can be inconsistencies within the interviews, such that one response contradicts another, or duplicate interviews may be returned from the same household but contain different answers to the same question.

Upon arrival at the U.S. Census Bureau, all data undergo data preparation, where responses from different modes are captured in electronic form creating Data Capture Files. The write-in entries from the Data Capture Files are then subject to monthly coding operations. When the monthly Data Capture Files are accumulated at year-end, a series of steps are taken to produce Edit Input Files. These are created by merging operational status information (such as whether the unit is vacant, occupied, or nonexistent) for each housing unit (HU) and group quarters (GQ) facility with the files that include the response data. These combined data then undergo a number of processing steps before they are ready to be tabulated for use in data products.

Figure 10.1 **American Community Survey (ACS) Data Preparation and Processing**

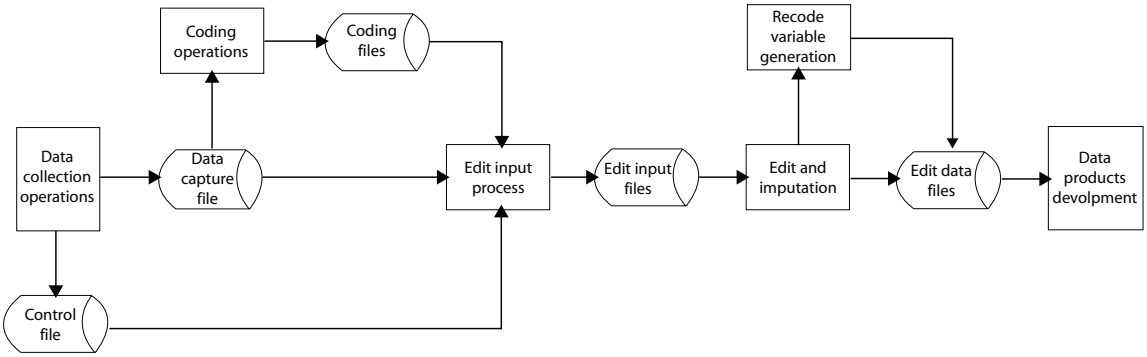


Figure 10.1 depicts the overall flow of data as they pass from data collection operations through data preparation and processing and into data products development. While there are no set definitions of data preparation versus data processing, all activities leading to the creation of the Edit Input Files are considered data preparation activities, while those that follow are considered data processing activities.

10.2 DATA PREPARATION

The ACS control file is integral to data preparation and processing because it provides a single database for all units in the sample. The control file includes detailed information documenting operational outcomes for every ACS sample case. For the mail operations, it documents the receipt and check-in date of questionnaires returned by mail. The status of data capture for these questionnaires and the results of the Failed-Edit Follow-up (FEFU) operation also are recorded in this file. Chapter 7 provides a detailed discussion of mail data collection, as well as computer-assisted telephone interview (CATI) and computer-assisted personal interview (CAPI) operations.

For CAPI operations, the ACS control file stores information on whether or not a unit was determined to be occupied or vacant. Data preparation, which joins together each case's control file information with the raw, unedited response data, involves three operations: creation and processing of data capture files, coding, and creation of edit input files.

Creation and Preparation of Data Capture Files

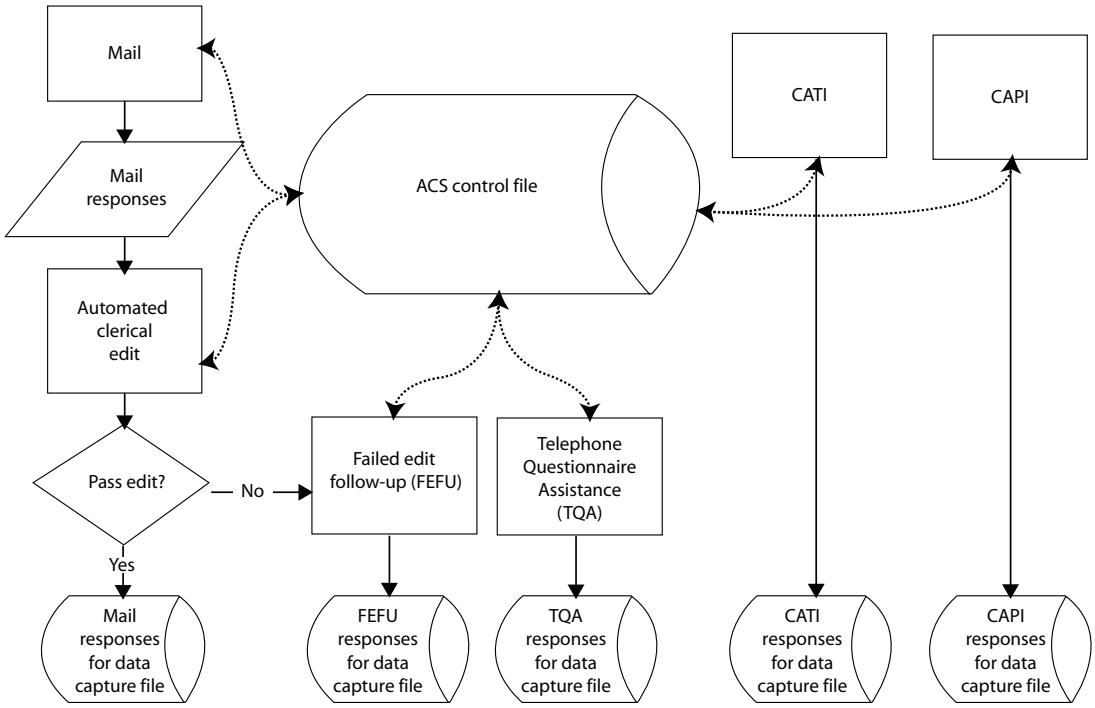
Many processing procedures are necessary to prepare the ACS data for tabulation. In this section, we examine each data preparation procedure separately. These procedures occur daily or monthly, depending on the file type (control or data capture) and the data collection mode (mail, CATI, or CAPI). The processing that produces the final input files for data products is conducted on a yearly basis.

Daily Data Processing

The HU data are collected on a continual basis throughout the year by mail, CATI, and CAPI. Sampled households first are mailed the ACS questionnaire; those households for which a phone number is available that do not respond by mail receive telephone follow-up. As discussed in Chapter 7, a sample of the noncompleted CATI cases is sent to the field for in-person CAPI interviews, together with a sample of cases that could not be mailed. Each day, the status of each sample case is updated in the ACS control file based on data from data collection and capture operations. While the control file does not record response data, it does indicate when cases are completed so as to avoid additional attempts being made for completion in another mode.

The creation and processing of the data depends on the mode of data collection. Figure 10.2 shows the monthly processing of HU response data. Data from questionnaires received by mail are processed daily and are added to a Data Capture File (DCF) on a monthly basis. Data received by mail are run through a computerized process that checks for sufficient responses and for large households that require follow-up. Cases failing the process are sent to the FEFU operation. As discussed in more detail in Chapter 7, the mail version of the ACS asks for detailed information on up to five household members. If there are more than five members in the household, the FEFU process also will ask questions about those additional household members. Telephone interviewers call the cases with missing or inconsistent data for corrections or additional information. The FEFU data are also included in the data capture file as mail responses. The Telephone Questionnaire Assistance (TQA) operation uses the CATI instrument to collect data. These data are also treated as mail responses, as shown in Figure 10.2.

Figure 10.2 **Daily Processing of Housing Unit Data**



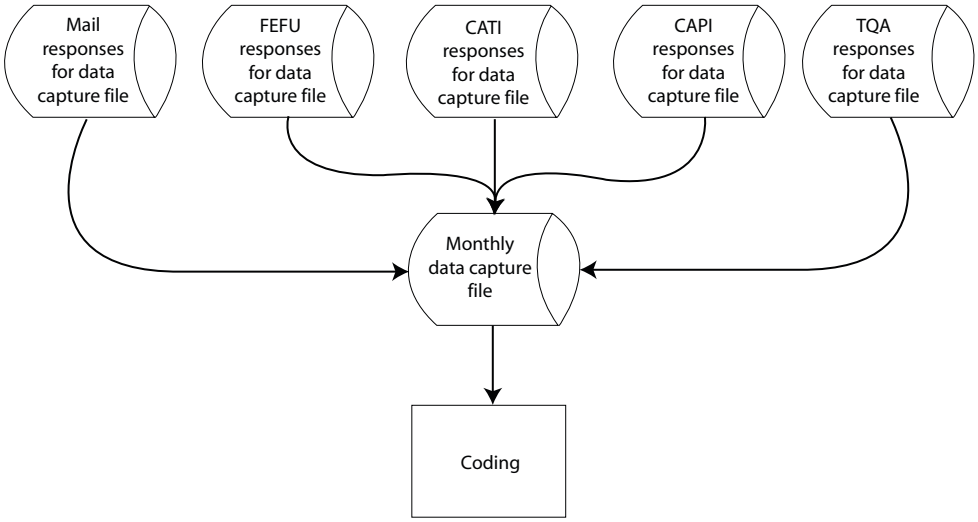
CATI follow-up is conducted at three telephone call centers. Data collected through telephone interviews are entered into a BLAISE instrument. Operational data are transmitted to the Census Bureau headquarters daily to update the control file with the current status of each case. For data collected via the CAPI mode, Census Bureau field representatives (FRs) enter the ACS data directly into a laptop during a personal visit to the sample address. The FR transmits completed cases from the laptop to headquarters using an encrypted Internet connection. The control file also is updated with the current status of the case. Each day, status information for GQs is transmitted to headquarters for use in updating the control file. The GQ data are collected on paper forms that are sent to the National Processing Center on a flow basis for data capture.

Monthly Data Processing

At the end of each month, a centralized DCF is augmented with the mail, CATI, and CAPI data collected during the past month. These represent all data collected during the previous month, regardless of the sample month for which the HU or GQ was chosen. Included in these files of mail responses are FEFU files, both cases successfully completed and those for which the required number of attempts have been made without successful resolution. As shown in Figure 10.3, monthly files from CATI and CAPI, along with the mail data, are used as input files in doing the monthly data capture file processing.

At headquarters, the centralized DCF is used to store all ACS response data. During the creation of the DCF, responses are reviewed and illegal values responses are identified. Responses of "Don't Know" and "Refused" are identified as "D" and "R." Illegal values are identified by an "I," and data capture rules cause some variables to be changed from illegal values to legal values (Diskin, 2007c). An example of an illegal value would occur when a respondent leaves the date of birth blank but gives "Age" as 125. This value is above the maximum allowable value of 115. This variable would be recoded as age of 115 (Diskin, 2007a). Another example would be putting a "19" in front of a four-digit year field where the respondent filled in only the last two digits as "76" (Jiles, 2007). A variety of these data capture rules are applied as the data are keyed in from mail questionnaires, and these same illegal values would be corrected by telephone and field interviewers as they complete the interview. Once the data capture files have gone through this initial data cleaning, the next step is processing the HU questions that require coding.

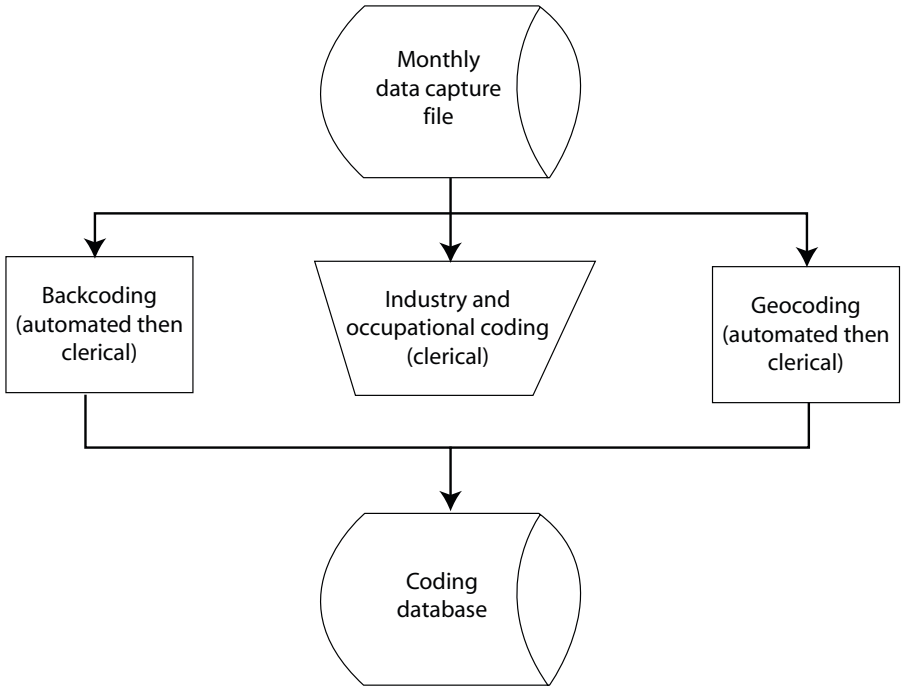
Figure 10.3 **Monthly Data Capture File Creation**



Coding

The ACS questionnaire includes a set of questions that offer the possibility of write-in responses, each of which requires coding to make it machine-readable. Part of the preparation of newly received data for entry into the DCF involves identifying these write-in responses and placing them in a series of files that serve as input to the coding operations. The DCF monthly files include HU and GQ data files, as well as a separate file for each write-in entry. The HU and GQ write-ins are stored together. Figure 10.4 diagrams the general ACS coding process.

Figure 10.4 **American Community Survey Coding**



During the coding phase for write-in responses, fields with write-in values are translated into a prescribed list of valid codes. The write-ins are organized into three types of coding: backcoding, industry and occupation coding, and geocoding. All three types of ACS coding are automated (i.e., use a series of computer programs to assign codes), clerically coded (coded by hand), or some combination of the two. The items that are sent to coding, along with the type and method of coding, are illustrated below in Table 10.1.

Table 10.1 **ACS Coding Items, Types, and Methods**

Item	Type of coding	Method of coding
Race	Backcoding	Automated with clerical follow-up
Hispanic origin	Backcoding	Automated with clerical follow-up
Ancestry	Backcoding	Automated with clerical follow-up
Language	Backcoding	Automated with clerical follow-up
Industry	Industry	Clerical
Occupation	Occupation	Clerical
Place of birth	Geocoding	Automated with clerical follow-up
Migration	Geocoding	Automated with clerical follow-up
Place of work	Geocoding	Automated with clerical follow-up

Backcoding

The first type of coding is the one involving the most items—backcoding. Backcoded items are those that allow for respondents to write in some response other than the categories listed. Although respondents are instructed to mark one or more of the 12 given race categories on the ACS form, they also are given the option to check "Some Other Race," and to provide write-in responses. For example, respondents are instructed that if they answer "American Indian or Alaska Native," they should print the name of their enrolled or principal tribe; this allows for a more specific race response. Figure 10.5 illustrates backcoding.

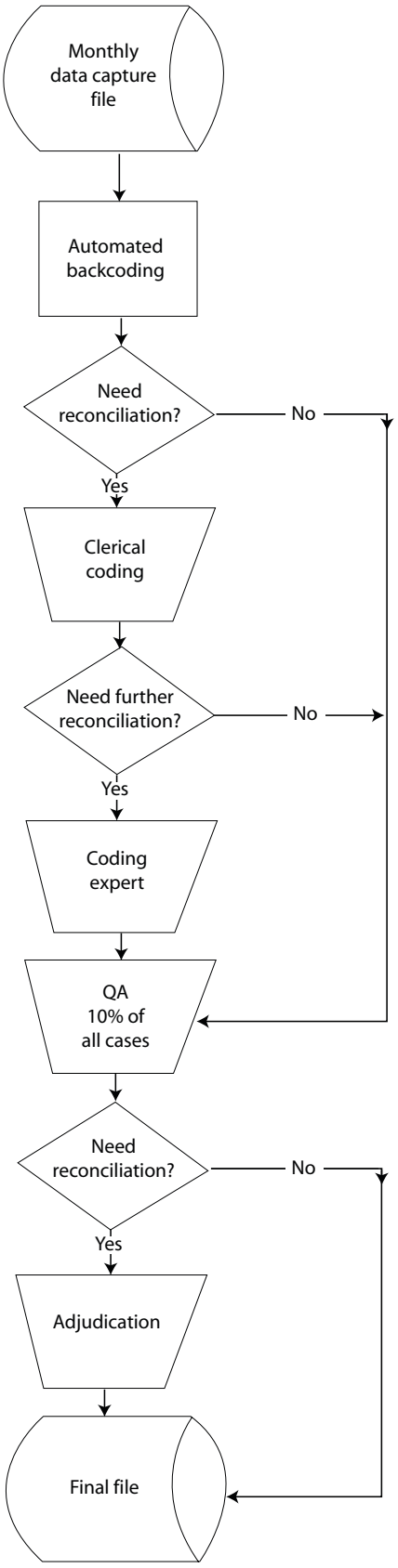
All backcoded items go through an automated process for the first pass of coding. The written-in responses are keyed into digital data and then matched to a data dictionary. The data dictionary contains a list of the most common responses, with a code attached to each. The coding program attempts to match the keyed response to an entry in the dictionary to assign a code. For example, the question of language spoken in the home is automatically coded to one of 380 language categories. These categories were developed from a master code list of 55,000 language names and variations. If the respondent lists more than one non-English language, only the first language is coded.

However, not all cases can be assigned a code using the automated coding program. Responses with misspellings, alternate spellings, or entries that do not match the data dictionary must be sent to clerical coding. Trained human coders will look at each case and assign a code.

One example of a combination of autocoding and follow-up clerical coding is the ancestry item. The write-in string for ancestry is matched against a census file containing all of the responses ever given that have been associated with codes. If there is no match, an item is coded manually. The clerical coder looks at the partial code assigned by the automatic coding program and attempts to assign a full code.

To ensure that coding is accurate, 10 percent of the backcoded items are sent through the quality assurance (QA) process. Batches of 1,000 randomly selected cases are sent to two QA coders who independently assign codes. If the codes they assign do not match one another, or the codes assigned by the automated coding program or clerical coder do not match, the case is sent to adjudication. Adjudicator coders are coding supervisors with additional training and resources. The adjudicating coder decides the proper code, and the case is considered complete.

Figure 10.5 **Backcoding**



Industry and Occupation Coding

The second type of coding is industry and occupation coding. The ACS collects information concerning many aspects of the respondents' work, including commute time and mode of transportation to work, salary, and type of organization employing the household members. To give a clear picture of the kind of work in which Americans are engaged, the ACS also asks about industry and occupation. Industry information relates to the person's employing organization and the kind of business it conducts. Occupation is the work the person does for that organization. To aid in coding the industry and occupation questions, two additional supporting questions are asked—one before the industry question and one after the occupation question. The wording for the industry and occupation questions are shown in Figures 10.6, 10.7, and 10.8.

Figure 10.6 **ACS Industry Questions**

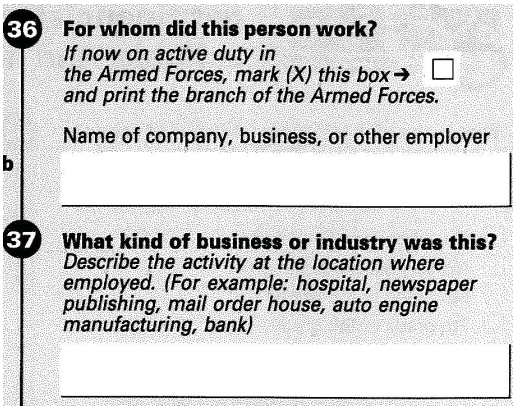


Figure 10.7 **ACS Industry Type Question**

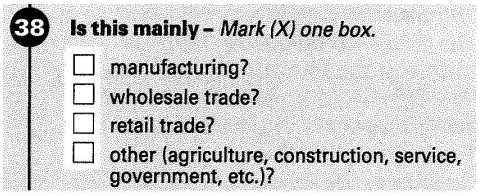
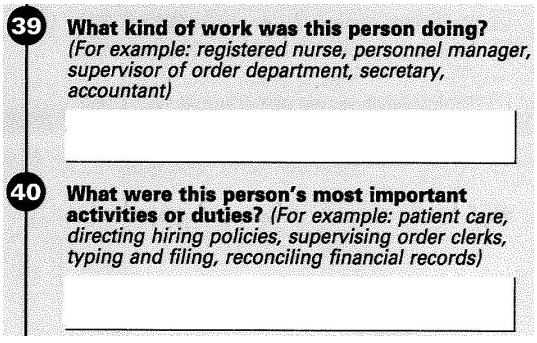
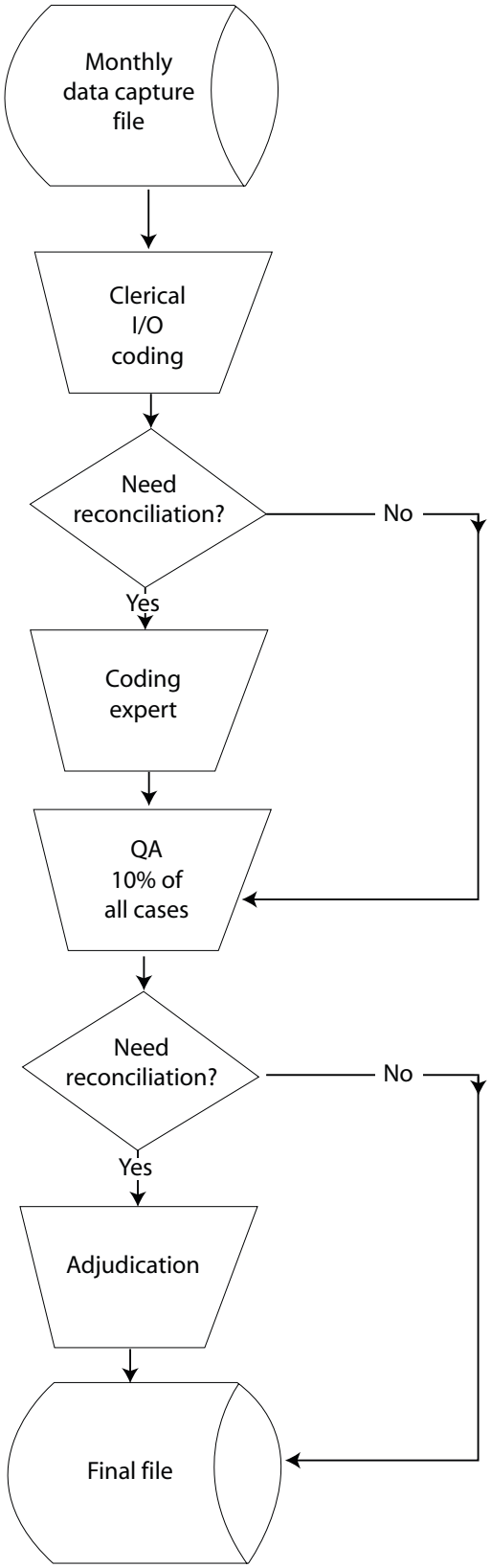


Figure 10.8 **ACS Occupation Questions**



From these questions, the specialized industry and occupation coders assign a code. Unlike back-coded items, industry and occupation items do not go through an automated assignment process. Automated coding programs were used for these items for the 2000 Decennial Census, but it was determined that using trained clerical coders would prove more efficient (Kirk, 2006). Figure 10.9 illustrates industry and occupation coding.

Figure 10.9 **Clerical Industry and Occupation (I/O) Coding**



Industry and occupation clerical coders are trained to use the Census Classification System to code responses. This system is based on the North American Industry Classification System (NAICS) and the Standard Occupational Classification (SOC) Manual. Both industry and occupation are coded to a specificity level of four digits. The Census Classification System can be bridged directly to the NAICS and SOC for comparisons (Kirk, 2006). The NAICS groups businesses into industries based upon their primary activity (U.S. Census Bureau, 2006a, pp. 52–53). The occupation system consists of 23 major occupational groups and 509 specific occupational categories.

To aid in the assigning of industry and occupation codes, coders are given access to additional responses from the respondent. The computer program displays responses to key items that can be used to assist coders in assigning the numeric industry or occupation codes. For example, along with the responses to both the industry and occupation questions, the program also displays the respondent's reported education level, age, and geographic location, all of which may be useful to coders in selecting the most accurate industry or occupation code. The software also includes an alphabetical index on the screen that coders can use for help in assigning codes. Codes are assigned directly into a computer database program. In addition, if respondents provide the name of the company or business for which they work, coders can compare that response with the Employer Name List (ENL), formerly known as the Company Name List, to see if the company name is listed. The Census Bureau developed the ENL from a publication that contains businesses and their NAICS codes. The ENL converts a company's NAICS designation to a Census Classification Code. Using this computerized system, as opposed to coding on the paper instrument itself, has greatly reduced the amount of resources needed to accomplish coding.

When industry and occupation clerical coders are unable to assign a code, the case is sent to an expert, or coding referralist, for a decision. Industry and occupation coding referralists receive an additional 16 hours of training, and are given access to more resources, including hardbound copies of the SOC and NAICS manuals, access to state registries, and use of the Internet for finding more information about the response. Approximately 18 percent of all industry and occupation responses are sent to coding referralists (Earle, 2007). Once these cases are assigned codes, they are placed in the general pool of completed responses.

From this general pool, a fixed percentage of cases are sent through an internal quality assurance verification process, also called the "weighted QA." Coders independently assign a code to a previously coded case; the codes then are reconciled to determine which is correct. Coders are required to maintain a monthly agreement rate of 95 percent or above and a 70 percent or above production rate to remain qualified to code (Earle, 2007). A coding supervisor oversees this process.

Geocoding

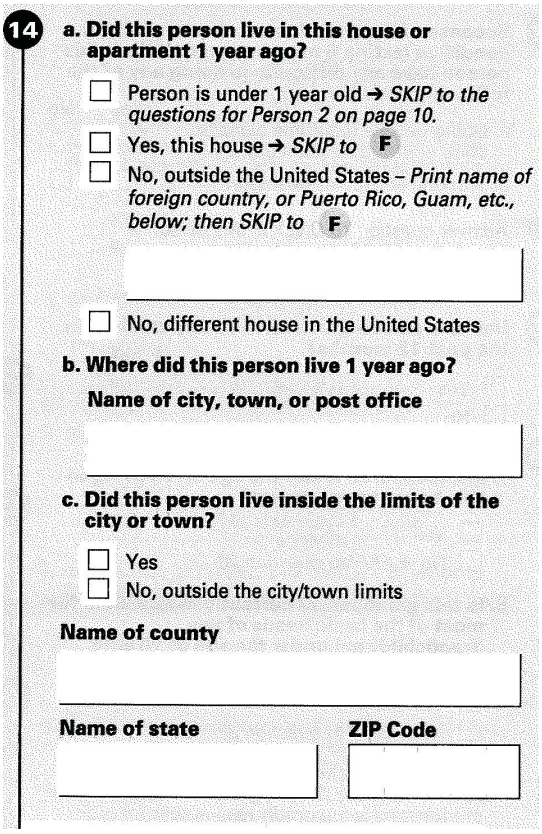
The third type of coding that ACS uses is geocoding. This is the process of assigning a standardized code to geographic data. Place-of-birth, migration, and place-of-work responses require coding of a geographic location. These variables can be as localized as a street address or as general as a country of origin (Boertlein, 2007b).[1]

The first category is place-of-birth coding, a means of coding responses to a U.S. state, the District of Columbia, Puerto Rico, a specific U.S. Island Area, or a foreign country where the respondents were born (Boertlein, 2007b). These data are gathered through a two-part question on the ACS asking where the person was born and in what state (if in the United States) or country (if outside the United States).

The second category of geocoding, migration coding, again requires matching the write-in responses of state, foreign country, county, city, inside/outside city limits, and ZIP code given by the respondent to geocoding reference files and attaching geographic codes to those responses. A series of three questions collects these data and are shown in Figure 10.10. First, respondents are asked if they lived at this address a year ago; if the respondent answers no, there are several follow-up questions, such as the name of the city, country, state, and ZIP code of the previous home.

[1] Please note: The following sections dealing with geocoding rely heavily on Boertlein (2007b).

Figure 10.10 **ACS Migration Question**



The goal of migration coding is to code responses to a U.S. state, the District of Columbia, Puerto Rico, U.S. Island Area or foreign country, a county (municipio in Puerto Rico), a Minor Civil Division (MCD) in 12 states, and place (city, town, or post office). The inside/outside city limits indicator and the ZIP code responses are used in the coding operations but are not a part of the final outgoing geographic codes.

The final category of geocoding is place-of-work (POW) coding. The POW coding questions and the question for employer's name are shown Figure 10.11. The ACS questionnaire first establishes whether the respondent worked in the previous week. If this question is answered "Yes," follow-up questions regarding the physical location of this work are asked.

The POW coding requires matching the write-in responses of structure number and street name address, place, inside/outside city limits, county, state/foreign country, and ZIP code to reference files and attaching geographic codes to those responses. If the street address location information provided by the respondent is inadequate for geocoding, the employer's name often provides the necessary additional information. Again, the inside/outside city limits indicator and ZIP code responses are used in the coding operations but are not a part of the final outgoing geographic codes.

Each of the three geocoding items is coded to different levels of geographic specificity. While place-of-birth geocoding concentrates on larger geographic centers (i.e., states and countries), the POW and migration geocoding tend to focus on more specific data. Table 10.2 is an outline of the specificity of geocoding by type.

Figure 10.11 **ACS Place-of-Work Questions**

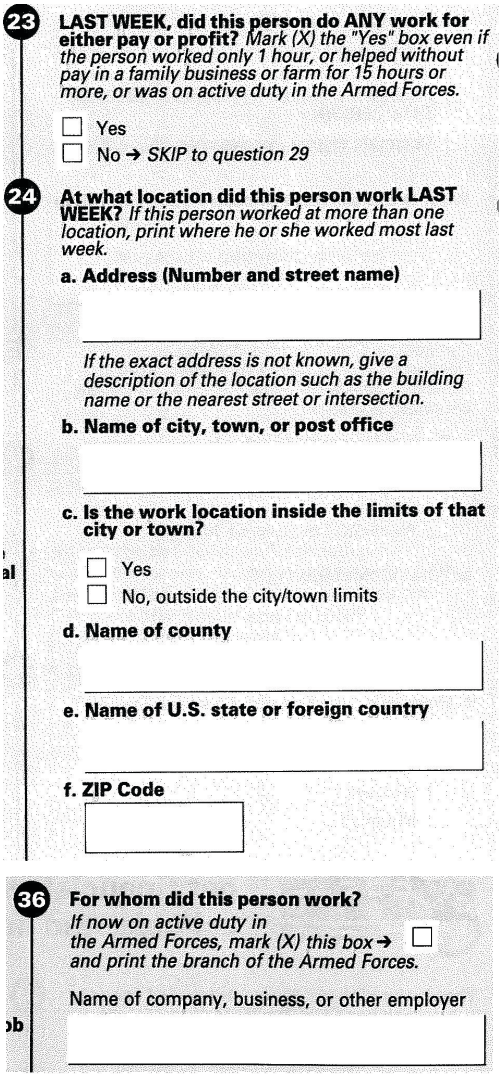


Table 10.2 **Geographic Level of Specificity for Geocoding**

Desired precision—geocoded items	Foreign countries (including: provinces, continents, and regions)	States and statistically equivalent entities	Counties and statistically equivalent entities	ZIP codes	Census designated places	Block levels
Place of birth	X	X				
Migration	X	X	X	X		
Place of work	X	X	X	X	X	X

The main reference file used for geocoding is the State and Foreign Country File (SFCF). The SFCF contains two key pieces of information for geocoding. They are:

- The names and abbreviations of each state, the District of Columbia, Puerto Rico, and the U.S. Island Areas.
- The official names, alternate names, and abbreviations of foreign countries and selected foreign city, state, county, and regional names.

Other reference files (such as a military installation list and City Reference File) are available and used in instances where "the respondent's information is either inconsistent with the instructions or is incomplete" (Boertlein, 2007b).

Responses do not have to match a reference file entry exactly to meet requirements for a correct geocode. The coding algorithm for this automated geocoding allows for equivocations, such as using Soundex values of letters (for example, m=n, f=ph) and reversing consecutive letter combinations (ie=ei). Each equivocation is assigned a numeric value, or confidence level, with exact matches receiving the best score or highest confidence (Boertlein, 2007b). A preference is given for matches that are consistent with any check boxes marked and/or response boxes filled. The responses have to match a reference file entry with a relatively high level of confidence for the automated match to be accepted. Soundex values are used for most types of geocoding and generally are effective at producing matches for given responses. Table 10.3 summarizes the properties of the geocoding workloads by category of codes that were assigned a code automatically.

Table 10.3 **Percentage of Geocoding Cases With Automated Matched Coding**

Characteristic	Percentage of cases assigned a code through automated geocoding
Place of birth	99
Migration	97
Place of work	53

The remaining responses that have not been assigned a code through the automated system are processed in computer-assisted clerical coding (CACC) operations. The CACC coding is separated, with one operation coding to place-level and one coding to block-level responses. Both the place- and block-level CACC operations involve long-term, specially trained clerks who use additional reference materials to code responses that cannot be resolved using the standard reference files and procedures. Clerks use interactive computer systems to search for and select reference file entries that best match the responses, and the computer program then assigns the codes associated with that geographic entity. The CACC operations also generally are effective at assigning codes.

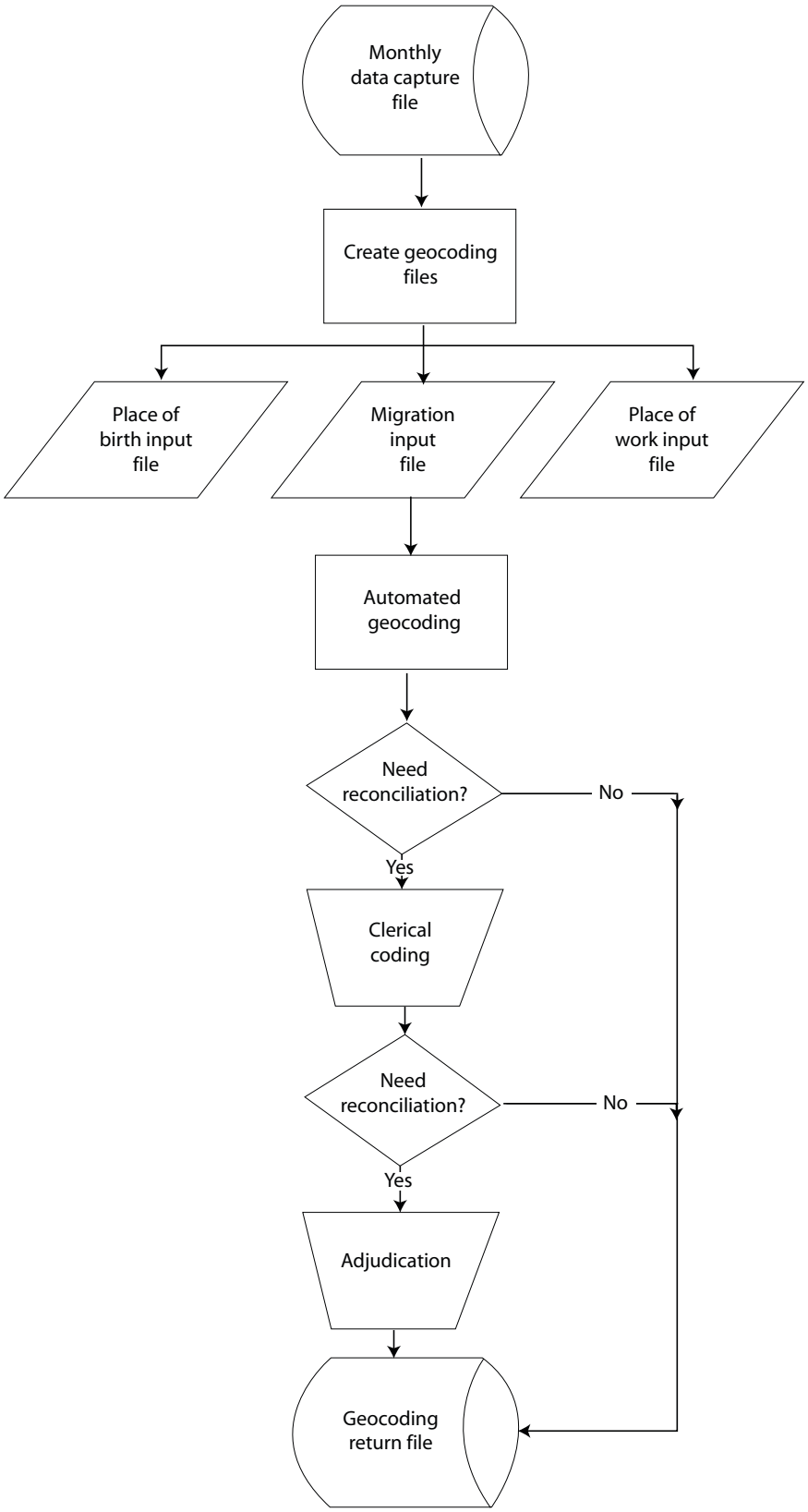
All three geocoding items—place of birth, migration, and place of work—require QA to ensure that the most accurate code has been assigned. The first step of assigning a geocode, the automated coding system, currently does not have a QA step. In both the 1990 and 2000 Decennial Censuses, the automated coding system had an error rate of less than 2.4 percent of all cases (Boertlein, 2007a); since then, the automated coder software has undergone revisions and has been shown to have an even lower error rate.

Among the place-of-birth, migration, and place-of-work cases that were not assigned geocodes by the automated coding system and that subsequently are sent to CACC, 5 percent will be sent to three independent clerical coders. If 2 out of 3 coders agree on a match, the third coder is assigned an error for the case. Coders must keep below a 5 percent error rate per month (Boertlein, 2007a).

For POW block-level coding, the QA protocol is slightly different. Block-level coders must maintain an error rate at or below 10 percent to continue coding. These coders also are expected to have 35 percent or less uncodeable rates. If block-level coders do not maintain these levels, 100 percent of their work is reviewed for accuracy, and additional training may be provided (Boertlein, 2007a).

The QA system for ACS geocoding also includes feedback to the coders. Those with high error rates or high uncodeable rates, as well as those who have low production rates or make consistent errors, may be offered additional training or general feedback on how to improve. Figure 10.12 illustrates automated geocoding.

Figure 10.12 **Geocoding**



10.3 PREPARATION FOR CREATING SELECT FILES AND EDIT INPUT FILES

The final data preparation operation involves creating Select Files and Edit Input Files for data processing. To create these files, a number of preparatory steps must be followed. By the end of the year, the response data stored in the DCF will have been updated 12 times and will become a principal source for the edit-input process. Coding input files are created from the DCF files of write-in entries. Edit Input Files combine data from the DCF files and the returned coding files, and operational information for each case is merged with the ACS control file. The resulting file includes housing and person data. Vacant units are included, as they may have some housing data.

Creation of the Select and Edit Input Files involves carefully examining several components of the data, each described in more detail below. First, the response type and number of people in the household unit are assessed to determine inconsistencies. Second, the return is examined to establish if there are enough data to count the return as complete, and third, any duplicate returns undergo a process of selection to assess which return will be used.

Response Type and Number of People in the HU

Each HU is assigned a response type that describes its status as occupied, temporarily occupied, vacant, a delete, or noninterview. Deleted HUs are units that are determined to be nonexistent, demolished, or commercial units, i.e., out of scope for ACS.

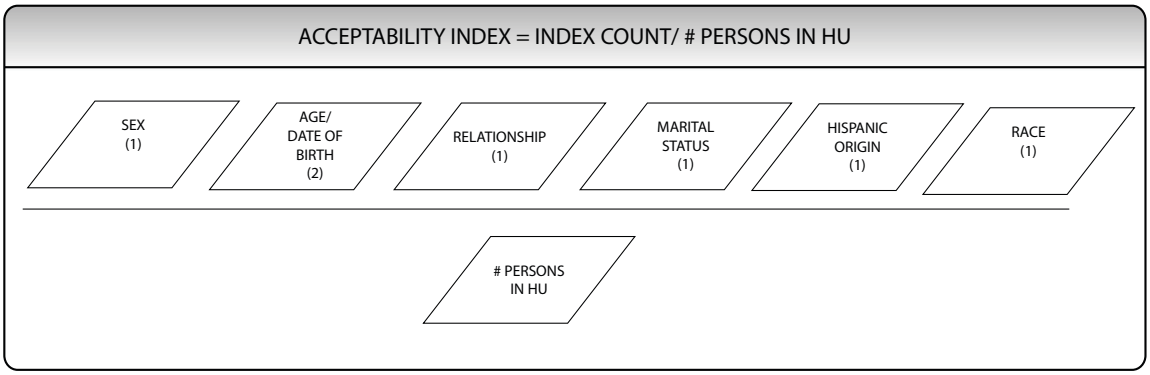
While this type of classification already exists in the DCF, it can be changed from "occupied" to "vacant" or even to "noninterview" under certain circumstances, depending on the final number of persons in the HU, in combination with other variables. In general, if the return indicates that the HU is not occupied and that there are no people listed with data, the record and number of people (which equals 0) is left as is. If the HU is listed as occupied, but the number of persons for whom data are reported is 0, it is considered vacant.

The data also are examined to determine the total number of people living in the HU, which is not always a straightforward process. For example, on a mail return, the count of people on the cover of the form sometimes may not match the number of people reported inside. Another inconsistency would be when more than five members are listed for the HU, and the FEFU fails to get information for any additional members beyond the fifth. In this case, there will be a difference between the number of person records and the number of people listed in the HU. To reconcile the numbers, several steps are taken, but in general, the largest number listed is used. (For more details on the process, see Powers [2006].)

Determining if a Return Is Acceptable

The acceptability index is a data quality measure used to determine if the data collected from an occupied HU or a GQ are complete enough to include a person record. Figure 10.13 illustrates the acceptability index. Six basic demographic questions plus marital status are examined for answers. One point is given for each question answered for a total of seven possible points that could be assigned to each person in the household. A person with a response to either age or date of birth scores two points because given one, the other can be derived or assigned. The total number of points is then divided by the total number of household members. For the interview to be accepted, there must be an average of 2.5 responses per person in the household. Household records that do not meet this acceptability index are classified as noninterviews and will not be included in further data processing. These cases will be accounted for in the weighting process, as outlined in Chapter 11.

Figure 10.13 **Acceptability Index**



If the Acceptability Index is $\geq$ than 2.5, the person record is accepted as a complete return.

If the Acceptability Index is < than 2.5, the person record is not accepted as a complete return.

Unduplicating Multiple Returns

Once the universe of acceptable interviews is determined, the HU data are reviewed to unduplicate multiple returns for a single HU. There are several reasons why more than one response can exist for an HU. A household might return two mail forms, one in response to the initial mailing and a second in response to the replacement mailing. A household might return a mailed form, but also be interviewed in CATI or CAPI before the mail form is logged in as returned. If more than one return exists for an HU, a quality index is used to select one as the final return. This index is calculated as the percentage of items with responses out of the total number of items that should have been completed. The index considers responses to both population and housing items.

The mode of each return also is considered in the decision regarding which of two returns to accept, with preference generally given to mail returns. If two mail returns are received, preference generally is given to the earliest return. For the more complete set of rules, see Powers (2006).

After the resolution of multiple returns, each sample case is assigned a value for three critical variables—data collection mode, month of interview, and case status. The month in which data were collected from each sample case is determined and then used to define the universe of cases to be used in the production of survey estimates. For example, data collected in January 2007 were included in the 2007 ACS data products, even if the returns were sampled in 2006, while ACS surveys sent out in November 2007 were included in the 2007 ACS data products if they were received by mail or otherwise completed by December 31, 2007. Surveys sent out in November 2007 that were received by mail or otherwise completed after December 31, 2007, will be included in the 2008 ACS data products.

10.4 CREATING THE SELECT FILES AND EDIT INPUT FILES

Select Files

Select Files are the series of files that pertain to those cases that will be included in the Edit Input File. As noted above, these files include the case status, the interview month, and the data collection mode for all cases. The largest select file, also called the Omnibus Select File, contains every available case from 14 months of sample—the current (selected) year and November and December of the previous year. This file includes acceptable and unacceptable returns. Unacceptable returns include initial sample cases that were subsampled out at the CAPI stage,[2] returns that were too incomplete to meet the acceptability requirements. In addition, while the "current year"

[2]See Chapter 7 for a full discussion of subsampling and the ACS.

includes all cases sampled in that year, not all returns from the sampled year were completed in that year. This file is then reduced to include only occupied housing units and vacant units that are to be tabulated in the current year. That is, returns that were tabulated in the prior year, or will be tabulated in the next year, are excluded. The final screening removes returns from vacant boats because they are not included in the ACS estimation universe.

Edit Input Files

The next step is the creation of the Housing Edit Input File and the Person Edit Input File. The Housing Edit Input file is created by first merging the Final Accepted Select File with the DCF housing data. Date variables then are modified into the proper format. Next, variables are given the prefix "U," followed by the variable name to indicate they are unedited variables. Finally, answers that are "Don't Know" and "Refuse" are set as missing blank values for the edit process.

The Person Edit Input File is created by first merging the DCF person data with the codes for Hispanic origin, race, ancestry, language, place of work, and current or most recent job activity. This file then is merged with the Final Accepted Select File to create a file with all person information for all accepted HUs. As was done for the housing items, the person items are set with a "U" in front of the variable name to indicate that they are unedited variables. Next, various name flags are set to identify people with Spanish surnames and those with "non-name" first names, such as "female" or "boy." When the adjudicated number of people in an HU is greater than the number of person records, blank person records are created for them. The data for these records will be filled in during the imputation process. Finally, as with the housing variables, "Don't Know" and "Refuse" answers are set as missing blank values for the edit process. When complete, the Edit Input Files encompass the information from the DCF housing and person files but only for the unduplicated response records with data collected during the calendar year.

10.5 DATA PROCESSING

Once the Edit Input Files have been generated and verified, the edit and imputation process begins. The main steps in this process are:

- Editing and imputation.
- Generating recoded variables.
- Reviewing edit results.
- Creating input files for data products.

10.6 EDITING AND IMPUTATION

Editing

As editing and imputation begins, the data file still contains blanks and inconsistencies. When data are missing, it is standard practice to use a statistical procedure called imputation to fill in missing responses. Filling in missing data provides a complete dataset, making analysis of the data both feasible and less complex for users. Imputation can be defined as the placement of one or more estimated answers into a field of a data record that previously had no data or had incorrect or implausible data (Groves et al., 2004). Imputed items are flagged so that analysts understand the source of these data.

As mentioned, the blanks come from blanked-out invalid responses and missing data on mail questionnaires that were not corrected during FEFU, as well as from CATI and CAPI cases with answers of "Refusal" or "Don't Know." The files also include the backcoded variables for the seven questions that allow for open-ended responses. As a preliminary step, data are separated by state because the HU editing and imputation operations are completed on a state-by-state basis.

Edit and imputation rules are designed to ensure that the final edited data are as consistent and complete as possible and are ready for tabulation. The first step is to address those internally inconsistent responses not resolved during data preparation. The editing process looks at internally contradictory responses and attempts to resolve them. Examples of contradictory responses are:

- A person is reported as having been born in Puerto Rico but is not a citizen of the United States.
- A young child answers the questions on wage or salary income.
- A person under the age of 15 reports being married.
- A male responds to the fertility question (Diskin, 2007a).

Subject matter experts at the Census Bureau develop rules to handle these types of responses. The application of such edit rules help to maintain data quality when contradictory responses exist. Some edits are more complex than others. For example, joint economic edits look at the combination of multiple variables related to a person's employment, such as most recent job activity, industry, type of work, and income. This approach maximizes information that can be used to impute any economic-related missing variables. As noted by Alexander et al. (1997),

> Editing the ACS data to identify for obviously erroneous values and imputing reasonable values when data were missing involved a complex set of procedures. Demographers and economists familiar with each specific topic developed the specific procedures for different sets of data, such as marital status, education, or income. The documentation of the procedures is over 1,000 pages long, so only a very general discussion will be given here.

As Alexander et al. (1997) note, edit checks encompass range and consistency. They also provide justification for the edit rules:

> The consistency edit for fertility ('how many babies has this person ever had') deletes response from anyone identified as Male or under age 15. In setting a cutoff like this, a decision must be made based on the data about which categories have more 'false positives' than 'true positives.' The consistency edit for housing value involves a joint examination of value, property taxes, and other variables. When the combination of variables is improbable for a particular area, several variables may be modified to give a plausible combination with values as close as possible to the original.

Another edit step relates to the income components reported by respondents for the previous 12 months. Because of general price-level increases, answers from a survey taken in January 2007 are not directly comparable to those of December 2007 because the value of the dollar declined during this period. Consumer Price Index (CPI) indexes are used to adjust these income components for inflation. For example, a household interviewed in March 2007 reports their income for the preceding 12 months—March 2006 through February 2007. This reported income is adjusted to the reference year by multiplying it by the 2007 (January–December 2007) CPI and dividing by the average CPI for March 2006–2007.

Imputation

There are two principal imputation methods to deal with missing or inconsistent data—assignment and allocation. Assignment involves looking at other data, as reported by the respondent, to fill in missing responses. For example, when determining sex, if a person reports giving birth to children in the past 12 months, this would indicate that the person is female. This approach also uses data as reported by other people in the household to fill in a blank or inconsistent field. For example, if the reference person and the spouse are both citizens, a child with a blank response to citizenship is assumed also to be a citizen. Assigned values are expected to have a high probability of correctness. Assignments are tallied as part of the edit output.

Certain values, such as whether a person has served in the military, are more accurate when provided from another HU or from a person with similar characteristics. This commonly used approach of imputation is known as hot-deck allocation, which uses a statistical method to supply responses for missing or inconsistent data from responding HUs or people in the sample who are similar.

Hot-deck allocation is conducted using a hot-deck matrix that contains the data for prospective donors and is called upon when a recipient needs data because a response is inconsistent or blank. For each question or item, subject matter analysts develop detailed specification outlines

for how the hot-deck matrices for that item are to be structured in the editing system. Classification variables for an item are used to determine categories of "donors" (referred to as cells) in the hot-deck. These donors are records of other HUs or people in the ACS sample with complete and consistent data. One or more cells constitute the matrix used for allocating one or more items. For example, for the industry, occupation, and place-of-work questions, some blanks still remain after backcoding is conducted. Codes are allocated from a similar person based on other variables such as age, sex, education, and number of weeks worked. If all items are blank, they are filled in using data allocated from another case, or donor, whose responses are used to fill in the missing items for the current case, the "recipient." The allocation process is described in more detail in U.S. Census Bureau (2006a).

Some hot-deck matrices are simple and contain only one cell, while others may have thousands. For example, in editing the housing item known as tenure (which identifies whether the housing unit is owned or rented), a simple hot-deck of three cells is used, where the cells represent responses from single-family buildings, multiunit buildings, and cases where a value for the question on type of building is not reported. Alternatively, dozens of different matrices are defined with thousands of cells specified in the joint economic edit, where many factors are used to categorize donors for these cells, including sex, age, industry, occupation, hours and weeks worked, wages, and self-employment income.

Sorting variables are used to order the input data prior to processing so as to determine the best matches for hot-deck allocation. In the ACS, the variables used for this purpose are mainly geographic, such as state, county, census tract, census block, and basic street address. This sequence is used because it has been shown that housing and population characteristics are often more similar within a given geographic area. The sorting variables for place of work edit, for example, are used to combine similar people together by industry groupings, means of transportation to work, minutes to work, state of residence, county of residence, and the state in which the person works.

For each cell in the hot-deck, up to four donors (e.g., other ACS records with housing or population data) are stored at any one time. The hot-deck cells are given starting values determined in advance to be the most likely for particular categories. Known as cold-deck values, they are used as donor values only in rare instances where there are no donors. Procedures are employed to replace these starting values with actual donors from cases with similar characteristics in the current data file. This step is referred to as hot-deck warming.

The edit and imputation programs look at the housing and person variables according to a predetermined hierarchy. For this reason, each item in a response record is edited and imputed in an order delineated by this hierarchy, which includes the basic person characteristics of sex, age, and relationship, followed by most of the detailed person characteristics, and then all of the housing items. Finally, the remainder of the detailed person items, such as migration and place of work, are imputed. For HUs, the edit and imputation process is performed for each state separately, with the exception of the place of work item, which is done at the national level. For GQ facilities, the data are processed nationally by GQ type, with facilities of the same type (e.g., nursing homes, prisons) edited and imputed together.

As they do with the assignment rules, subject matter analysts determine the number of cells and the variables used for the hot-deck imputation process. This allows the edit process to apply both assignment rules to missing or inconsistent data and allocation rules as part of the edit process.

In the edit and imputation system, a flag is associated with each variable to indicate whether or not it was changed and, if so, the nature of the change. These flags support the subject matter analysts in their review of the data and provide the basis for the calculation of allocation rates. Allocation rates measure the proportion of values that required hot-deck allocation and are an important measure of data quality. The rates for all variables are provided in the quality measures section on the ACS Web site. Chapter 15 also provides more information about these quality measures.

Generating Recoded Variables

New variables are created during data processing. These recoded variables, or recodes, are calculated based on the response data. Recoding usually is done to make commonly used, complex variables user-friendly and to reduce errors that could occur when users incorrectly recode their own data. There are many recodes for both housing and person data, enabling users to understand characteristics of an area's people, employment, income, transportation, and other important categories.

Data users' ease and convenience is a primary reason to create recoded variables. For example, one recode variable is "Presence of Persons 60 and Over." While the ACS also provides more precise age ranges for all people in a given county or state, having a recoded variable that will give the number and percentages of households in a region with one or more people aged 60 or over in a household provides a useful statistic for policymakers planning for current and future social needs or interpreting social and economic characteristics to plan and analyze programs and policies (U.S. Census Bureau, 2006a).

Reviewing Edit Results

The review process involves both review of the editing process and a reasonableness review. After editing and imputation are complete, Census Bureau subject matter analysts review the resulting data files. The files contain both unedited and edited data, together with the accompanying imputation flag variables that indicate which missing, inconsistent, or incomplete items have been filled by imputation methods. Subject matter analysts first compare the unedited and edited data to see that the edit process worked as intended. The subject analysts also undertake their own analyses, looking for problems or inconsistencies in the data from their perspectives. When conducting the initial edit review, they determine whether the results make sense through a process known as a reasonableness review. If year-to-year changes do not appear to be reasonable, they institute a more comprehensive review to reexamine and resolve the issues. Allocation rates from the current year are compared with previous years to check for notable differences. A reasonableness review is done by topic, and results on unweighted data are compared across years to see if there are substantial differences. The initial reasonableness review takes place with national data, and another final review compares data from smaller geographic areas, such as counties and states (Jiles, 2007).

These processes also are carried out after weighting and swapping data (discussed in Chapter 12). Analysts also examine unusual individual cases that were changed during editing to ensure accuracy and reasonableness.

The analysts also use a number of special reports for comparisons based on the edit outputs and multiple years of survey data. These reports and data are used to help isolate problems in specifications or processing. They include detailed information on imputation rates for all data items, as well as tallies representing counts of the number of times certain programmed logic checks were executed during editing. If editing problems are discovered in the data during this review process, it is often necessary to rerun the programs and repeat the review.

Creating Input Files for Data Products

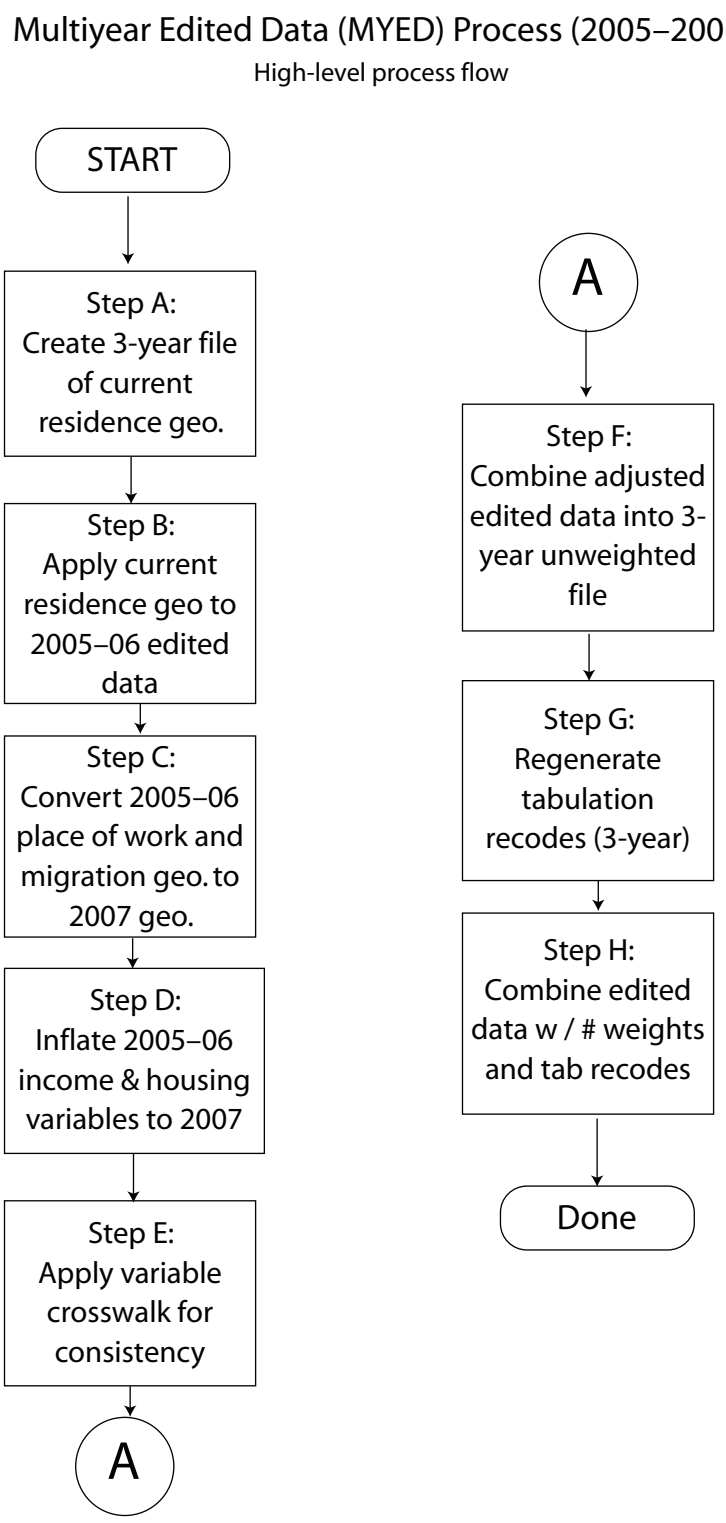
Once the subject matter analysts have approved data within the edited files, and their associated recodes, the files are ready to serve as inputs to the data products processing operation. If errors attributable to editing problems are detected during the creation of data products, it may be necessary to repeat the editing and review processes.

10.7 MULTIYEAR DATA PROCESSING

ACS multiyear estimates will be published for the first time in 2008 based on the 3-year combined file from the 2005 ACS, 2006 ACS, and 2007 ACS. To do this, multiyear edited data (or microdata) are needed as the basis for producing the 3-year ACS tabulated estimates for the multiyear period. This discussion will focus on this first 3-year tabulation period, the data collection years 2005–2007. A number of steps must be applied to the previous year's final edited data to make it consistent for multiyear processing. The first step is to update the current residence geography for

2005 and 2006 data to 2007 geography. The most involved step in the process pertains to how the vintage of geography in the "Place of Work" and "Migration" variables and recodes are updated to bring them up to the current year (2007). This step is necessary due to the fact that for the 2005 edited data for these variables and recodes would be in 2005 vintage geography, and in 2006 vintage geography for the 2006 edited data. The geocodes in these variables and recodes from prior years need to be converted in some way to current geography. This transformation was accomplished using a matching process to multiyear geographic bridge files (Boertlein, 2008) to update these variables to 2007 geography. Inflation adjustments also must be applied to monetary income and housing variables and recodes to inflate them up to a constant reference year of 2007 for the 2005–2007 edited file. Yet another step is needed to deal with variable changes across years, so that a consistent 3-year file may be created. A crosswalk table for the multiyear process attempts to map values of variables that changed across years into a consistent format. For the creation of the 2005–2007 file, only two recode variables were identified whose definition had changed over the period: Veteran's Period of Service (VPS) and Unmarried partner household (PARTNER). To make them consistent for the 3-year file, both recodes were recreated for the 2005 and 2006 data using the 2007 algorithm. When all of these modifications have been applied to the prior year's data, these data are combined with the 2007 data into an unweighted multiyear edited dataset. Tabulation recodes are then recreated from this file, and the outputs of that process joined with the 3-year weights and edited data to create the multiyear weighted and edited file. At this point the 3-year ACS edited and weighted data file will be suitable for input to the data products system. See Figure 10.14 for a flowchart showing high-level process flow.

Figure 10.14 **Multiyear Edited Data Process**



10.8 REFERENCES

Alexander, C. H., S. Dahl, and L. Weidmann. (1997). "Making Estimates From the American Community Survey." Paper presented to the Annual Meeting of the American Statistical Association (ASA), Anaheim, CA, August 1997.

Bennett, Aileen D. (2006). "Questions on Tech Paper Chapter 10." Received via e-mail, December 28, 2006.

Bennett, Claudette E. (2006). "Summary of Editing and Imputation Procedures for Hispanic Origin and Race for Census 2000." Washington, DC, December 2006.

Biemer, P., and L. Lyberg. (2003). *Introduction to Survey Quality*. Hoboken, NJ: John Wiley & Sons, Inc.

Boertlein, Celia G. (2007a). "American Community Survey Quality Assurance System for Clerical Geocoding." Received via personal e-mail, January 23, 2007.

Boertlein, Celia G. (2007b). "Geocoding of Place of Birth, Migration, and Place of Work—an Overview of ACS Operations." Received via personal e-mail, January 23, 2007.

Diskin, Barbara N. (2007a). Hand-edited review of Chapter 10. Received January 15, 2007.

Diskin, Barbara N. (2007b). Telephone interview. January 17, 2007.

Diskin, Barbara N. (2007c). "Additional data preparation questions—ACS Tech. Document," Received via e-mail January 30, 2007.

Earle, Katie. (2007). Edited review of Chapter 10. Received January 30, 2007.

Griffin, Deborah. (2006). "Question about allocation rates." Received via e-mail July 3, 2006.

Groves, R. M., F. J. Fowler, M. P. Couper, J. M. Lepkowski, E. Singer, and R. Tourangeau, (2004). *Survey Methodology*. Hoboken, NJ: John Wiley & Sons, Inc.

Jiles, Michelle. (2007). Telephone interview. January 29, 2007.

Kirk, Mary. (2006). Telephone interview. July 12, 2006.

Powers, J. (2006). U.S. Census Bureau Memorandum, "Specification for Creating the Edit Input and Select Files, 2005." Washington, DC. Draft of 2006-10-02.

Raglin, David. (2004). "Edit Input Specification 2004." Internal U.S. Census Bureau technical specification, Washington, DC.

Tersine, A. (1998). "Item Nonresponse: 1996 American Community Survey." Paper presented to the American Community Survey Symposium, March 1998.

U.S. Census Bureau. (1997). "Documentation of the 1996 Record Selection Algorithm." Internal U.S. Census Bureau memorandum, Washington, DC.

U.S. Census Bureau. (2000). "Census 2000 Operational Plan." Washington, DC, December 2000.

U.S. Census Bureau. (2001a). "Meeting 21st Century Demographic Data Needs: Implementing the American Community Survey." Washington, DC, July 2001.

U.S. Census Bureau, Population Division, Decennial Programs Coordination Branch. (2001b). "The U.S. Census Bureau's Plans for the Census 2000 Public Use Microdata Sample Files: 2000." Washington, DC, December 2001.

U.S. Census Bureau. (2002). "Meeting 21st Century Demographic Data Needs: Implementing the American Community Survey: May 2002." Report 2, Demonstrating Survey Quality. Washington, DC.

U.S. Census Bureau. (2003a). "American Community Survey Operations Plan Release 1: March 2003." Washington, DC.

U.S. Census Bureau. 2003b. “Data Capture File 2003.” Internal U.S. Census Bureau technical specification, Washington, DC.

U.S. Census Bureau. 2003c. “Technical Documentation: Census 2000 Summary File 4.” Washington, DC.

U.S. Census Bureau. 2004a. “American Community Survey Control System Document.” Internal U.S. Census Bureau documentation, Washington, DC.

U.S. Census Bureau. 2004b. “Housing and Population Edit Specifications.” Internal U.S. Census Bureau documentation, Washington, DC.

U.S. Census Bureau. 2004c. “Housing Recodes 2004.” Internal U.S. Census Bureau data processing specification, Washington, DC.

U.S. Census Bureau. 2004d. “Hispanic and Race Edits for the 2004 American Community Survey.” Internal U.S. Census Bureau data processing specifications. Washington, DC.

U.S. Census Bureau. 2006a. “American Community Survey 2004 Subject Definitions.” Washington, DC, <www.census.gov/acs/www/Downloads/2004/usedata/Subject_Definitions.pdf>.

U.S. Census Bureau. 2006b. “Automated Geocoding Processing for the American Community Survey.” Internal U.S. Census Bureau Documentation.

U.S. Census Bureau, May 21, 2008. “Issues and Activities Related to the Migration and Place-of-Work Items in the Multi-Year Data Products.” Celia Boertlein, Kin Koerber, Journey to Work and Migration Staff, Housing and Household Economics Statistics Division.