THE USE OF MICROCOMPUTERS FOR CENSUS PROCESSING IN DEVELOPING COUNTRIES

Vivian Toro and Thomas Melaney
U.S. Bureau of the Census [1]

1. Introduction

Processing population data with mainframe computers in developing countries is plagued with problems. These problems include limited access to scarce mainframe computer resources, high cost of leasing equipment for computer time, delays due to absence of replacement parts, lack of skilled personnel, and scarcity of adequate software. As a result, publication of census data often is delayed to the point that they are outdated, of questionable quality, or both.

Microcomputers offer potential solutions to many of these problems. Their low cost, in comparison to mainframe computers costs, enables national statistical offices (NSOs) to own and manage several microcomputers, thereby improving accessibility. Their simplified hardware design, allows the replacement of most parts to be done by the user, instead of by the highly skilled customer engineer that is needed to service mainframe computers. Replacement parts for microcomputers are cheaper than those for mainframe computers. Advances in software design and user interface have simplified training in and use of microcomputers.

To take advantage of this technology, NSOs that are processing census data need appropriate software, ideally an integrated system of microcomputer software. The International Statistical Programs Center (ISPC) of the Bureau of the Census has been developing such a system during the last several years.

This system is being implemented in several developing countries that are processing census data. Although problems still remain, the lessons learned so far from their experiences indicate that the microcomputer is a technologically sound and cost-effective tool for processing census data. Ongoing technological advances in hardware and refinement of microcomputer software should make the use of microcomputers even more advantageous in the future.

This paper focuses on the discussion and analysis of the practical experiences of three developing countries where this integrated system of microcomputer software is being used to process population census data: Senegal, the Federated States of Micronesia (FSM), and Burkina Faso (formerly Upper Volta). For each of these countries, the reasons for choosing microcomputers for census processing are examined. Where appropriate, the positive and negative results of their use are discussed, and alternative approaches are suggested. The paper concludes with some comments on trends for future use of microcomputers for census processing.

2. Considerations of Microcomputers as an Alternative to Traditional Mainframe Processing

Many developing country statistical offices have had expensive and frustrating experiences in using mainframe computers to process census data. Statistical offices renting computer time found themselves competing for computer time in government computer centers that were running time-consuming and high priority applications, such as payroll and national accounts. Inadequate management of these computer centers was often a problem. On the other hand, statistical offices that owned a mainframe computer (often bought by an international donor agency for the last population census) found themselves locked into a technology that had rapidly become outdated. The update of this hardware can be extremely expensive. For those statistical offices renting equipment, the rental costs often ran over $100,000 a year. In all of these situations, NSOs also had to deal with insufficient spare parts in the country, costly backup power systems, and environmental conditioning, such as raised floors and powerful air conditioners.

In addition to these problems, the use of the same mainframe computer for both data entry and census processing, considerably degraded performance so that very little or no concurrent program development could be accomplished.

Perhaps the biggest problem associated with mainframe computing is attracting, training, and retaining computer professionals. This is particularly true when appropriate generalized software is lacking, necessitating numerous customized programs.

Microcomputers are a natural alternative to consider in response to these problems. The computing capability of the microcomputer at an affordable price is extremely attractive to statistical offices whose budgets are often very limited. Increased accessibility and redundancy of equipment is a long-awaited dream for computer professionals. These computer professionals are willing to accept the greater degree of responsibility that the use of microcomputers places upon the individual, such as doing some of the system maintenance, in exchange for the added flexibility seldom obtainable in mainframes.

As the microcomputer hardware technology matured, more and more developing countries used this technology for other applications, including agriculture, health, and energy surveys. In spite of the successful implementation of many of these projects, the use of microcomputers for large-scale processing such as a population census was not considered feasible, mostly, because of limitations of mass storage, processing speed, and memory. The feasibility of large-scale processing was enhanced when technological developments provided faster processing units, expanded memory, and faster, more reliable mass storage units with higher recording densities.

3. Integrated Microcomputer Processing System

Until recently, the standard microcomputer software industry offerings have not addressed many of the processing needs of censuses and surveys. Therefore, ISPC embarked on a software project that attempts to meet these needs through the development of an Integrated Microcomputer Processing System (IMPS).

Since the 1970s, NSOs have successfully used ISPC's generalized editing and tabulation software packages, CONCOR and CENTS 4, respectively, on mainframes. The equivalent of these packages, as well as software to address

other processing tasks was needed for microcomputers. In designing an implementation strategy, the concept of "integrated software" came naturally since the processing of census data involves several clearly defined, but closely related, tasks.

Data entry, the first of these tasks, involves capturing the data in machine-readable form. This task is followed by the editing or cleaning of the data to eliminate inconsistencies. A series of statistical tables is then produced from the edited data. Tabulation is followed by analysis of the tabular results to determine mortality, fertility, migration trends, and other trends or characteristics of the population. Other associated tasks are operational and quality control, that allow for the monitoring of the processing cycle and for the identification of problem areas. Operational control becomes particularly important when processing a large volume of data.

The objective of ISPC's software project is to produce an integrated system to address the most important tasks in census and survey processing. This system would allow persons with only minimal computer experience to participate in processing the data. The overall design and objectives of the system, as listed in Barbara Diskin's paper (1986), are:

1. It should be designed for the standard configuration of the most common microcomputer hardware, running a well-accepted operating system.

2. At a minimum, it should address data entry, editing, tabulation, statistical analysis, demographic analysis, and operational control.

3. It should be modular to the degree that the user should be able to use one module or any number of modules.

4. The user should be able to interface with custom programs for specialized processing not provided for by the system.

5. A common data dictionary should be shared by at least the editing and tabulation modules.

6. The system should be menu-driven and offer the user additional support in the form of on-line "help" information.

7. The system should provide good error trapping and recovery routines.

8. It should automatically provide any reformatting necessary to move data from one module to another.

9. Comprehensive documentation should include written manuals and tutorials for user orientation.

10. The system should be designed in such a way that modules can be easily modified or swapped as software improvements are recognized. In addition, it should be written in a high-level language that allows it to migrate to other operating systems, since operating systems are evolving.

A project of this magnitude takes a considerable amount of time and resources. For this reason, ISPC has provided intermediate deliverables during the system development. At this time, the system is not totally integrated, although the transfer of data between modules is very simple. A description of the target microcomputer and of the modules for the integrated processing system follows.

3.1 Hardware Selection

The IBM Personal Computer (PC) is the microcomputer around which IMPS was designed. The basic hardware configuration required by most of the IMPS modules consists of an IBM PC model XT, AT, or 100-percent IBM PC compatible, with a minimum of 256 kilobytes of memory, a 10-megabyte hard disk, and a printer capable of printing 132 characters per line. This basic configuration, as well as the number of microcomputers to use, will vary according to the tasks they must perform.

3.2 Software Components

The basic modules of IMPS are: data entry, editing, tabulation, statistical analysis, demographic analysis, and operational control. A description of each of these modules follows.

3.21 Data Entry

ISPC evaluated commercially available data entry packages to identify the best software for census and survey data entry. The evaluation identified two packages with the proper balance of functionality and user friendliness: ENTRYPOINT from Datalex, Inc., and RODE/PC from DPX, Inc. Both packages are easy to learn and to set up, and have adequate documentation. However, both packages do not perform all of the functions equally well. RODE/PC's performance is good even on an IBM PC with 256 kilobytes of memory, whereas ENTRYPOINT's performance is not adequate on a microcomputer with this configuration. The cost of these packages varies according to the number of copies bought. Currently, RODE/PC has a slight advantage in cost. A more detailed discussion of the strengths and weaknesses of each of these packages is offered in an evaluation report available from ISPC.

3.22 Editing

ISPC's generalized editing system CONCOR (CONsistency and CORrection) was chosen as the editing module because of its successful use on mainframe computers in developing countries. CONCOR allows the user to perform range checking to ensure valid values of individual items, interrecord (within the same record) consistency checking, intrarecord (among multiple records) consistency checking, and automatic correction of data, using an English-like structural command language. CONCOR also produces comprehensive edit reports and has complete system documentation. It is fully supported by ISPC.

For reasons of portability and maintenance, CONCOR is written in COBOL. A COBOL compiler is needed to run CONCOR because CONCOR generates a COBOL program which must be compiled and linked. After examination of several microcomputer compilers, ISPC chose REALIA COBOL because of its speed of compilation, its generation of efficient code, and the product support available.

3.23 Tabulation

The proven record of ISPC's tabulation package CENTS 4 (CENsus Tabulation System version 4) on mainframe computers and minicomputers around the world was the reason for its selection as the tabulation module of IMPS. CENTS 4 offers the ability to produce publication-quality tables with geographic disaggregation. In addition, it offers flexibility of report formats and the ability to perform basic statistical

calculations. It is totally documented and fully supported by ISPC.

Similar to CONCOR, CENTS 4 requires the REALIA COBOL compiler in order to run. The execution speed of CENTS 4 on an IBM PC/AT exceeds that on some minicomputers.

3.24 Statistical Analysis

The statistical analysis module is the Iowa State University's PC-CARP (Cluster Analysis and Regression Package), which includes major algorithms for analyzing survey data and computing sampling error. This package has been redesigned to be more interactive and user-friendly than its mainframe predecessor SUPER-CARP in order to facilitate its use by analysts with little or no data processing experience. PC-CARP is currently being used for survey work in Haiti and the Philippines. System requirements include 512K bytes of memory, a math coprocessor, and a printer capability of producing 132 characters per line.

3.25 Demographic Analysis

The core of the demographic analysis module will be the Computer Programs for Demographic Analysis (CPDA). These programs were written by the Bureau of the Census in the early 1970s for mainframe computers. They were converted to run on an IBM PC microcomputer by Westinghouse Public Applied Systems under the sponsorship of the Agency for International Development (AID). The programs are designed to support the analysis of the quality of population data, as well as to calculate and estimate numerous demographic parameters. The subroutines can be used for such purposes as estimating levels and trends of fertility and mortality from census and survey data, projecting population by age and sex, constructing model or empirical life tables, and performing stable population analysis.

In addition to the routines from the CPDA, the demographic analysis module may draw on programs from the United Nations' mortality measure software, MORTPAK.

3.26 Operational Control

The CONTROL Census Management System will be offered as the module to complement the entry, editing, and tabulation processes. This system is designed to help monitor various activities of a census or a large survey by tracking each unit of data through the various processing phases. With this component, bottlenecks can be spotted and production schedules can be modified as needed. Information on the status of processing is presented by major phases of the project in tabular and graphic form. Another important function of CONTROL is the "check-in" of data by geographic unit to ensure the integrity of the data file. This function is essential when a large volume of data is being processed. Because of limited resources, the conversion of CONTROL to run on IBM PC microcomputers has been delayed. ISPC hopes to have this software available within the next year.

4. Case Studies

Several developing countries are using modules of the current integrated microcomputer processing system for their population census data. The different statistical offices are choosing to use this system in various ways.

The following three case studies, which represent typical implementations, illustrate the positive impact IMPS is having on the census processing activities of these countries.

4.1 Senegal

The Direction de la Statistique (DS) is preparing to take the second national population census of the Republic of Senegal in 1988; its estimated population is 7,500,000. The previous census (1976) was fraught with processing problems that caused the publication of the data to be delayed until February 1981.

During an assessment visit conducted in March 1985, it was agreed that the U.S. Bureau of the Census would provide technical assistance for data processing preparation and implementation. At that time, the DS considered renting IBM 3742 equipment for the data entry operation, as they did in 1976. This would have been costly and these machines, though adequate, are outdated technology. Alternatively, the Bureau of the Census recommended purchasing microcomputers for the data entry operation because of the reasonable cost of hardware, the availability of adequate data entry software, and the potential use of microcomputers for other projects after the keying operations are finished. The editing and tabulation of the data would be done using an IBM 370/145 at the Computer Center of the Ministry of Finance, a data production facility used by other government agencies.

Since it was agreed that the data would be edited using CONCOR and tabulated using CENTS 4, an added advantage to the purchase of microcomputers was that the development and testing of CONCOR and CENTS 4 programs could be done at DS instead of using the mainframe computer facilities at the Computer Center. The completed programs could then be transferred to the mainframe computer for production runs.

The microcomputer hardware was bought locally. Its configuration includes eighteen IBM PC microcomputers with 256 kilobytes of memory for data entry, two IBM PC/XT microcomputers with 10 megabytes of hard disk storage for program development, five printers, and a tape unit used for data backup. Uninterruptible power supply (UPS) units are used for power supply protection. The data entry software package chosen was RODE/PC because of its good performance on IBM PC microcomputers with 256 kilobytes of memory.

Members of the DS staff required training to use the newly acquired software. During a 3-week technical assistance visit to Dakar in January 1986, data processing advisors from the Bureau of the Census conducted a CENTS 4 workshop, installed CONCOR and CENTS 4 software on the IBM mainframe computer, and discussed tabulation plans and specifications with DS personnel.

The head of the data processing section and the head of the data entry section of the DS furthered their training during a work-study visit in early 1986 at ISPC in Washington, D.C. During a 6-week stay, the data entry supervisor, who had no programming experience, learned to use menu-driven RODE/PC and assisted in developing the data entry application for the census questionnaire. The editing done at data entry time was limited to range checks.

The data processing chief, an experienced systems analyst with prior CONCOR and CENTS 4 training, remained at ISPC for 3 months. In

addition to learning RODE/PC, she wrote the CONCOR program for the edit and imputation of data. She also completed much of the tabulation programming using CENTS 4. All the work was done on an IBM PC/XT.

How well is the system performing in Senegal? Because of funding problems, the Pilot Census is far behind schedule and, as of March 1987, the collected data had not yet been manually coded. However, the data processing component of the project remains healthy and the recommended software has shown adaptability. For example, when significant changes were made to portions of the questionnaire after the RODE/PC application had been designed, this application was redesigned within a single afternoon to conform to these changes. The same software adaptability is expected when updated edit and table specifications are prepared by demographers. The affected portions of the CONCOR and CENTS 4 programs should be easily revised.

As a result of their positive experiences with microcomputers, the data processing staff have indicated that they would prefer to process the pilot census data on the microcomputer instead of using mainframe computers. There are several advantages to this approach, among them ready access to microcomputers. In addition, the data processing staff find the interaction with the IBM PC operating system much friendlier than with the operating system of the IBM mainframe computer.

To upgrade the current microcomputer configuration to allow in-house processing, the data processing staff would like to acquire extended mass storage consisting of two 20 megabytes Bernoulli Boxes (removable cartridge based hard disk systems). File management will be a critical component of the processing since smaller batches of data will have to be physically handled. The data processing staff have considerable programming and processing expertise and have judged the file management problems less formidable than the inconveniences of working in the mainframe computer environment.

Although it has not yet been put to the test of live production, the microcomputer system in Senegal appears to be ready to meet the challenge.

4.2 Micronesia

In 1979, the Federated States of Micronesia (FSM) -Pohnpei, Kosrae, Yap, and Truk- that had previously been combined as the Trust Territory of the Pacific Islands administered by the United States for the United Nations, became independent. FSM is now in the process of independently taking its first census. The 1980 Census was directed and processed entirely by the US. Unfortunately, FSM experienced significant delays in getting results from the census because processing of domestic data took priority.

During a visit to the U.S. Bureau of the Census, in March 1985, the long-term advisor to the FSM attended a demonstration of IMPS. During subsequent discussions, ISPC agreed to work with the Office of Planning and Statistics (OPS) of the FSM to develop a system for processing census data from the Pohnpei State.

ISPC recommended a microcomputer configuration consisting of three IBM PC/AT microcomputers and related peripheral devices, including three 10 megabyte Bernoulli Boxes. ISPC also recommended the use of ENTRYPOINT, CONCOR, and CENTS 4. This hardware and software was procured in the U.S. and then shipped to Pohnpei.

Data processing training was required for members of the OPS staff since no one there had any previous experience working with computers. Another United Nations advisor working with the project had general data processing experience but had no previous knowledge of the hardware or the software to be used. In April 1986, a statistical analyst from OPS and the U.N. advisor came to ISPC for training in the use of the equipment and software. During her 7-week stay, the OPS staff member learned to use ENTRYPOINT and designed a data entry program that would edit individual records for valid values and intrarecord consistency checks. In a 4-week stay, the advisor learned to use the CONCOR and CENTS 4 packages and then wrote a CONCOR program that handled interrecord editing and prepared much of the CENTS 4 tabulation program. The Pohnpei State census enumeration took place in September 1985.

The actual data processing operations proceeded very smoothly, in large part because the census data consisted of only about 30,000 records. The census questionnaire had not been precoded, and it was decided that manual editing would be done during the coding process in order to reduce the number of errors to be handled during data entry. Data were entered by the two members of the data processing staff and by two part-time students, who were able to learn the data entry procedures with only several days' training. Thanks to the manual editing process, few consistency errors occurred. Those detected were corrected by the entry operators either by using information from the questionnaire or from personal knowledge of the individuals whose records were being entered. By November 1986, 21 tables were produced using CENTS 4. It took less than 15 minutes to process these tables.

The experience in Micronesia indicated that the use of microcomputers was efficient and effective in this situation. With technical assistance from ISPC and the U.N., the OPS staff was able to enter, edit, and tabulate the census data in Pohnpei. Processing went quickly and easily and the census data processing requirements were met. The census was completed in a timely, and cost-effective manner. Furthermore, the census of Pohnpei State has served as a pilot census for Kosrae, Yap, and Truk.

4.3 Burkina Faso

The National Institute of Statistics and Demography (INSD) of Burkina Faso, formerly Upper Volta, conducted the second national census in December 1985. The estimated population is 9,000,000. The Bureau of the Census involvement with the census began with a needs assessment conducted in 1984. At this time, it was found that the original projected budget was unrealistically low and failed to anticipate such costs as data entry equipment, data entry operator salaries, and computer time. Furthermore, INSD had essentially no in-house data processing resources.

INSD considered the use of CENATRIN, the governmental central computer facility used for the processing of the census in 1975, but

rejected this option because of access concerns and inadequate data entry facilities.

The US Agency for International Development provided funding for the purchase of either a WANG VS-65 minicomputer system, or a cluster of IBM PC and IBM PC/AT microcomputers. After extensive discussions of the advantages and disadvantages of each alternative, INSD chose to use the cluster of microcomputers. The most important factors influencing the INSD decision were the lower cost and ease of maintenance, and the decentralization offered by the microcomputers.

Three IBM PC/AT microcomputers with 512 kilobytes of memory, and 20 megabytes of hard disk storage are being used to process the data. The data entry configuration consists of 22 IBM PC microcomputers each having 512 kilobytes. Related peripherals include six printers, two tape drive units, and three Bernoulli Boxes. The tape drive units are used for backup and archival purposes, while the Bernoulli Boxes are used for processing the census data. RODE/PC, CONCOR and CENTS 4 are the software packages being used. All the hardware and software was bought in the U.S. and shipped to Burkina Faso.

The INSD data processing staff for the census project consists of two full-time programmers, one of whom had some previous experience using microcomputers, and a long-term United Nations advisor, who had previous experience in using microcomputers for census operations and a good working knowledge of CENTS 4.

A few problems were encountered in the areas of environmental conditioning and maintenance. Replacing some malfunctioning IBM microcomputer components, such as chips, was easily accomplished by INSD staff. However, when a major breakdown on one of the Bernoulli Boxes occurred, the equipment had to be shipped to the US for repairs. Operations were not seriously disrupted since they had two additional Bernoulli Boxes.

As a result of pressure from government agencies to obtain census results as soon as possible, and, because of concerns that funding problems might stop the project short of completion, INSD decided from the start to process a 10-percent sample while entering the remainder of the data.

In addition to the UN long-term advisor, data processing assistance has included three visits to Burkina Faso by Bureau of the Census data processing experts. These visits included training, program development, and monitoring of the data entry, CONCOR and CENTS 4 programs. CONCOR was used to perform interrecord checking and for the automatic correction of data.

Technically, the data processing operations have been reasonably successful. Data entry operations have proceeded more rapidly than anticipated. Two shifts of 22 operators began work in September 1986 after a week of training. Four months later, the entry of the 10-percent sample had been completed. By March 1987, 16 of the projected 40 tables were tabulated using CENTS 4 and two variance tables were run using the edited sample data. Entry of the remaining 90-percent data continued until April 1987, when it was suspended as a result of funding problems.

The use of Bernoulli cartridges for the storage of data is proving effective. Each 10 megabyte cartridge is used to hold one large or several small complete provinces. The edited sample occupy 11 Bernoulli cartridges.

Some file management problems arose during the processing of the variance tables because of the limited size of available memory of the microcomputer as compared to the memory on the mainframe computer. Production of the variance tables was possible but inconvenienced by the need to monitor closely the sizes of intermediate files. Since the variance calculations pertained to only a limited number of tables and were applicable only for the sample census, the difficulties could be tolerated.

The use of microcomputers is enabling INSD to process the census at its own facilities with a very limited budget. INSD now owns equipment and software that can be used for a variety of diverse projects, including surveys, for years to come.

5. General Prognosis

These three case studies are representative of the experiences that developing countries are having using the current version of IMPS for processing population census data. This system is offering solutions to some of the problems inherent in mainframe computing. The overall costs of hardware and software are far below those of mainframe computers. Maintenance of microcomputers is easier and does not need to be a problem if redundancy is provided and a maintenance plan is contemplated from the beginning. Environmental demands are not extreme, with a reasonably cool, dust-free environment sufficient for most microcomputers. The software has proven to be easy to learn and use, even for persons with little background in data processing. Computer accessibility is not a problem, provided there are sufficient microcomputers.

Controlling the flow of data through a decentralized processing system where data are treated in smaller work units will certainly be a challenge. In such cases, operational control and file management become crucial. This challenge is likely to be met in the immediate future by custom programming or by using commercially available data base programs to report on the status of processing.

Operational control and file management will become less problematic with improvements in the recording densities and access speeds of mass storage devices. As the price of such devices goes down, they will become more economically viable for developing country statistical offices.

It is encouraging to consider the fact that for the countries described in the case studies, the programs and procedures used for processing smaller volumes of data are the same as for processing larger volumes of data. This indicates that IMPS, even in its current state, is meeting successfully the needs of NSOs for processing census data.

Notwithstanding, ISPC is aware that improvements are needed. Finding a more cost-effective solution to the data entry software is one of them. Another is modifying CONCOR and CENTS 4 to take better advantage of the user-friendly environment on microcomputers. Work should be done on the demographic analysis software to make it more user-friendly.

Furthermore, one of the biggest gaps is the implementation of an operational control module and a user-friendly "umbrella" which integrates the modules.

Extensive efforts are being made by ISPC towards meeting these needs. Additional data entry packages are being examined. An interactive data dictionary for CONCOR and CENTS 4 has been developed. Its development has provided the facility to simplify the CENTS 4 and CONCOR user languages. CONCOR and CENTS 4 with their simplified user language, are now being integrated with the new data dictionary. As funding permits, ISPC will continue its commitment to reach the goal of a fully integrated and user-friendly system.

As enthusiasm increases in using microcomputers to process or complement the processing of population census data, one must not lose sight of what microcomputers cannot do or should not be expected to do. Microcomputers cannot compensate for poor planning or management. They cannot make up for inadequately designed questionnaires. They cannot replace skilled personnel nor reach conclusions on the significance of data. They cannot ensure adequate census coverage or make up for poorly written edit and tabulation specifications.

Finally, developing countries will continue to face in the immediate future some of the same general problems concerning the acquisition and use of microcomputers that they now face. Established dealerships are not plentiful, limiting the choice of vendors if local representation is desired. Servicing of hardware components is limited and expensive. Software and documentation in native languages are scarce. Microcomputer publications, when available, are expensive and often not available in native languages. Training facilities are limited and costly, or nonexistent. Power supply is unreliable, causing frequent and sudden power fluctuations.

6. Conclusions

Although problems still remain, the current use of microcomputers for population census processing in developing countries is encouraging. In many aspects, microcomputers are proving to be a viable alternative to mainframe computing. The experiences of developing countries who are currently using microcomputers to process their census data, accompanied by the technological advancements in hardware and the refinement of integrated systems of microcomputer software, indicate the microcomputer provide a technologically sound and cost-effective tool for processing census data.

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