Department of Economic and Social Affairs
Statistics Division

Guidelines on the use of electronic data collection technologies in population and housing censuses

United Nations
New York, January 2019

Acknowledgments

The Guidelines on the Use of Electronic Data Collection Technologies in Population and Housing Censuses was prepared by the United Nations Statistics Division (UNSD), Department of Economic and Social Affairs (DESA) administered by Mr. Stefan Schweinfest, Director, UNSD. The publication is the outcome of collective efforts involving a wide range of contributors.

The production of the Guidelines was initiated by Keiko Osaki-Tomita, Chief of the Demographic and Social Statistics Branch (former). Srdjan Mrkic, Chief of the Demographic Statistics Section, provided overall substantive guidance.

UNSD expresses its appreciation to the members of the Task Force established to guide the drafting of the Guidelines for their contribution. The Task Force consisted of the following national statistical offices and international and regional organizations: Department of Statistics of Jordan; Instituto Brasileiro de Geografia e Estatística (IBGE); Statistics Canada; Statistics Estonia; Statistics Poland; Statistics South Africa; United States Census Bureau; Environmental Systems Research Institute (ESRI); United Nations Economic Commission for Africa (ECA); United Nations Economic Commission for Europe (ECE); United Nations Economic Commission for Latin America and the Caribbean (ECLAC); United Nations Economic and Social Commission for Asia and the Pacific (ESCAP); United Nations Economic and Social Commission for Western Asia (ESCWA); United Nations Population Fund (UNFPA); United Nations Statistics Division (UNSD); and, the World Bank.

Special gratitude goes to the following census experts for contributing written input towards the drafting of the Guidelines: Marcos Rodrigues Pinto, Instituto Brasileiro de Geografia e Estatística (IBGE); Patrice Mathieu, Statistics Canada; Diana Beltadze, Statistics Estonia; Qasem Al Zoubi, Department of Statistics of Jordan; Janusz Dygaszewicz, Statistics Poland; Linda Peters, Environmental Systems Research Institute (ESRI); and, Sergiy Radyakin, World Bank. Due acknowledgement is also given to documentation of national experience contributed by Ximena Clark, National Institute of Statistics of Chile (INE); Tomoaki Ogawa and Fumika Akutsu, Statistics Bureau, Ministry of Internal Affairs and Communications, Japan; Lei Vai Peng, Statistics and Census Service of Macao, China; Ola Awad, Palestinian Central Bureau of Statistics; and, Arona Pistiner, United States Census Bureau.

Sincere appreciation goes to the following experts who reviewed and/or provided technical advice: Hussein Abu Al Hassan and Amany Sobhy Elia, Central Agency for Public Mobilization and Statistics (CAPMAS), Egypt; Luqmaan Omar and Calvin Molongoana, Statistics South Africa; Oliver P. Fischer and Sarveswara Rao Surumpudi, United States Census Bureau; Phil Bright, The Pacific Community (SPC); Godheart Mbiydzenyuy Ayenika, United Nations Economic Commission for Africa; Samson Lamlenn, consultant to the United Nations Economic Commission for Africa; Paolo Valente, United Nations Economic Commission for Europe; Paulo Saad and Lenin Aguinaga, United Nations Economic Commission for Latin America and the Caribbean; Ismail Lubbad, United Nations Economic and Social Commission for Western Asia; Tapiwa Jhamba and Sabrina Juran, United Nations Population Fund; Mikhail Lokshin and Zurab Sajaia, World Bank; and, Abdulla Gozalov and Mark Iliffe, United Nations Statistics Division.

A noteworthy acknowledgment is given to UNSD staff Meryem Demirci and Seiffe Tadesse for their coordination, research, compilation of inputs and drafting of individual chapters of the Guidelines. The publication benefited from the vital contribution of, and comprehensive review by, Ian White, consultant to UNSD.

Executive Summary

Population and housing censuses provide a wide range of information on population and housing units. They allow detailed disaggregation of data by small geographic areas and small population groups. However, it is widely recognised that conducting a population and housing census is one of the most expensive and complex data collection operations, comprising of a series of many interrelated activities. As widely recognised, the traditional census approach using paper questionnaires exposes census data to different types of human errors throughout the census processes, especially during mapping, enumeration and data processing. In order to decrease such errors, the census operation usually includes additional procedures for monitoring and controlling errors. More importantly, dependency on manual input creates pressure on the timeliness of the dissemination of census data.

National Statistical Offices (NSOs) are increasingly facing a number of challenges in conducting population and housing censuses, particularly decreasing response rates, timely dissemination of census results and increasing data collection costs. These challenges are compelling NSOs to investigate alternative ways of implementing the census. Recent technological developments have offered NSOs many opportunities to modernize their census operations, especially with regard to constructing census maps, capturing and validation of census data and dissemination of census results.

The use of technology has become an integral part of many census processes critical for improving the cost, quality (coverage, accuracy, timeliness) and efficiency of the census. The rapid expansion in mobile connectivity, and rapid progress in technological innovation more broadly (such as cloud computing, smart mobile devices, GPS, web GIS), provide new opportunities for increasing the quality and speed with which census data can be collected. Data collection with computer-assisted self-interview (CASI) with the use of the Internet and with computer-assisted personal interviewing (CAPI) on tablets or laptops have become an increasingly attractive substitute to using paper questionnaire, administered by an interviewer (PAPI) or self-administered (PASI).

The *Guidelines on the Use of Electronic Data Collection Technologies in Population and Housing Censuses* is intended to serve as a reference document for countries which are planning to use electronic data collection technologies, CAPI and CASI methods. The Guidelines emphasize the benefits of using electronic data collection technologies, particularly for improving the census coverage, data quality and timeliness of census results. The Guidelines also discuss new operational aspects and considerations that need to be made in planning, designing and managing census operations. It also discusses new challenges and risks that can be introduced when paper questionnaires are replaced with electronic questionnaires.

There are many drivers for the adoption of electronic data collection technologies in censuses. Widely recognised key drivers include:

(i) Demand for improving census coverage;
(ii) Demand for improving the quality of data collected for each person or housing unit (improving item response);
(iii) Demand for timely dissemination of data;
(iv) Demand for minimizing burden on respondents;
(v) Vision for modernisation of national statistical offices and paperless data collection.

As with the adoption of any new technology, understanding of the value of electronic data collection technologies is a critical step in making an informed decision on whether or not to use these technologies in censuses. As the introduction of these technologies can be an expensive and risky exercise, it is important for any country to ensure that there is sufficient value in its introduction in a census by taking into account the particular national circumstances.

The Guidelines provides detailed discussions on planning, designing and managing census operations with electronic data collection technologies, principally via handheld electronic devices and the

Internet. The Guidelines also emphasis the necessity of building sufficient capacity for making a decision and maximizing the benefits and minimizing the risks of using such technologies.

The Guidelines is expected to help countries in achieving an improved understanding of the process of adopting electronic data collection technologies in conducting population and housing census. The Guidelines underlines the importance of ensuring the cost-effectiveness of the selected technology and maximizing the benefits derived from this investment.

The guide document would be useful for countries which are planning to use CAPI and/or CASI in conducting the census, especially in:

(i) **Making a sound decision** on whether to use or not to use a particular technology based on a good understanding of the value of introducing such technology and the requirements and potential risks of its, taking into account the national context in terms of factors such as technological infrastructure, operational, institutional, socio-cultural and economic;

(ii) **Designing census operations with the use of CAPI** - its requirements, advantages and challenges, selection criteria for handheld devices, basic features of the data collection application, data transfer from field to the headquarter, and field operation management;

(iii) **Designing census operations with the use of Internet** - its requirements, advantages and challenges, contact and communication strategies, identification and authentication of respondents, development of data collection and portal, methods of supporting respondents in completing online questionnaire, and operational management;

(iv) **Adoption of multi-mode data collection** - benefits and challenges of using multiple modes of data collection, and its implication for data quality;

(v) **Determining key managerial considerations** for planning and managing the adoption of electronic data collection technologies, including the management of IT investment, building institutional capacity, management of IT acquisition, development and testing of IT systems and processes, and considerations for information and system security.

The Guidelines makes several recommendations to NSOs in planning and designing their censuses with the use of handheld devices and/or the Internet. The Guidelines conveys the following key messages to census managers:

- Decision making as to whether to use a particular technology or not should be organised as a process with the objectives of understanding the value of introducing the new approach, evaluating its cost-effectiveness and making the choice on the basis of the information gathered during this process;
- A step-by-step decision-making process should be applied for making a more deliberate decision on the feasibility of introducing a new approach, taking into consideration the potential risks of doing so and factors related to institutional, operational, social/cultural contexts of the country;
- Given the fact that the adoption of electronic data collection requires a certain amount of capacity at the institutional and national levels, factors that are important for a successful adoption of new technology should be determined in the early stages of census planning;
- Total cost of ownership, referring to the estimate of the direct and indirect costs of developing and applying a particular product/system, should be calculated using three key components: software/hardware costs, operational costs, and personnel and training costs;
- Decision on the use of CAPI or CASI in censuses should be made with the involvement of all stakeholders/partners based on detailed analysis of the requirements, benefits, risks and the total cost of ownership;
- Early decision is necessary for the use of CAPI and/or CASI in order to have enough time to be able to build capacity, redesign census processes and undertake extensive testing for every component individually and in whole in an integrated way to ensure that the new approach will be implemented efficiently as planned;
- The adoption of CAPI or CASI in censuses requires strong project management expertise and capacity for planning, designing and implementing census operations;

- Establishing a well-designed management structure is key for the successful management of census processes highly dependent on technology. Therefore, management of census operations should be redesigned considering all aspects of the new technology, including aspects related to data transfer, outsourcing and procurement of hardware/software and services;
- Real time monitoring of field enumeration is necessary for a successful adoption of CAPI, CASI or a multi-mode data collection method to ensure full coverage of population and housing units during the enumeration. To implement real time monitoring during enumeration, it is desirable to transfer data immediately after completing the enumeration of each household. The data should be transferred to headquarters at least on a daily basis;
- It is widely recognised that gaining prior experience is crucial for successful adoption of CAPI or CASI. Therefore, NSOs are encouraged to test and apply these technologies in other statistical operations such as agricultural censuses, business censuses and/or household surveys. Prior experience also allows NSOs to make the appropriate decision and to improve capacity for developing contingency plans and dealing with risks related to IT issues;
- NSOs should have a plan for collecting geographic information during the mapping operation so as to ensure effective and efficient enumeration with electronic data collection technologies and to support real-time monitoring of field operations during the enumeration;
- It may be necessary to consider the use of multi-mode approach (combining electronic collection with paper questionnaire) to ensure full census coverage and improve the overall quality of the census;
- A centralised management information system should be established for the effective management and monitoring of operational activities including staff recruitment, logistical issues (distributing and returning handheld devices and other census materials) and operational intelligence;
- The successful adoption of electronic data collection technologies requires a well-designed programme for testing software applications and systems in an integrated way. The data collection applications and supporting IT systems should be subjected to functionality testing, usability testing, scenario-based testing, integration testing, accessibility testing, infrastructure stress testing and security testing;
- For countries planning to use CASI, the development of an optimal contact and communication strategy is critical for attaining high Internet self-response rates. The contact strategy should include three phases: i) solicit households to complete their questionnaire by Internet; ii) send reminder to complete the questionnaire; and, iii) non-response follow up by census enumerators or telephone.

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Chapter A - Introduction to the Guidelines

1. Introduction

A.1. Population and housing censuses provide a wide range of statistical information on the population – persons, households and housing units. They allow detailed disaggregation of data by small geographic areas and small population groups. However, it is widely recognised that conducting a population and housing census is one of the most expensive and complex data collection operations, comprising of a series of many interrelated activities. The logistical effort required, and the difficulties encountered in contacting and collecting information on the whole population within a limited period of time, adds to the complexity.

A.2. National Statistical Institutes (NSIs) are increasingly facing a number of challenges in conducting population and housing censuses, ranging from falling participation to increasing data collection costs. Response rates have declined as citizens become increasingly concerned about information security and privacy and the confidentiality of information given to the government. Households are becoming more diverse, dynamic and mobile, making it a challenge to reach people and assign them to a single unique location. These societal, demographic and budgetary trends are making it harder and more expensive to locate individuals and solicit their participation through traditional data collection methods. Moreover, each of these trends threatens the ability of NSIs to deliver high-quality, timely and cost-effective census results.

A.3. These challenges are compelling NSIs to investigate alternative ways of implementing the census, and ultimately, to modernise and transform the traditional method of conducting a census. Today's information and communication technologies offer NSIs unprecedented opportunities to innovate and transform their census operations, dramatically improving performance and census results while reducing costs. Moreover, they can enhance the quality and accessibility of census results. With proper planning, governance and vision, modern technology can help to improve the efficiency (as measured in terms of cost and time savings, productivity gains, increased accuracy) and effectiveness (by, for example, providing better products and service, improved analysis) of census processes.

A.4. Recent advances in information and communication technology have changed how routine statistical business processes. such as enumeration area (EA) design, data capture and validation, data processing, and data dissemination, are being carried-out. The use of such technology has become an integral part of many census processes critical for improving the cost, quality (coverage, accuracy, timeliness) and efficiency of the census. The rapid expansion in mobile connectivity, and rapid progress in technological innovation more broadly (such as cloud computing, smart mobile devices, GPS, web GIS), provide new opportunities for increasing the quality and speed with which census data can be collected and the statistics produced. Hardware and software as well as mobile data networks are becoming cheaper and better, and infrastructure and capacity that enables effective deployments is increasingly available in all parts of the world. This means that the immense progress in connectivity (in terms of both speed and magnitude) and technology adoption has a large potential for modernizing and complementing traditional statistical collection. New approaches are allowing the collection of data with handheld electronic devices, the Internet and the telephone in a manner that is better, faster and potentially cheaper.

A.5. Data collection with a computer-assisted personal interviewing (CAPI) methodology on tablets, PDAs (personal digital assistants) or laptops is becoming an increasingly attractive substitute for using a paper questionnaire with personal interviewing (PAPI) approach in most parts of the world. The ability of CAPI systems to instantly transmit data over mobile data networks provide a substantial advantage over more traditional procedures and allows data to be captured, inspected and validated shortly after it is collected, thus improving data quality. A CAPI system integrated with digital mapping and

operational management applications can improve the monitoring of census data collection operations, and the coordination of field operations, logistics, and communications.

A.6. The CAPI technology is continuously improving and should be embraced, improved and tailored by NSIs to strengthen data collection activities. The reduction in costs and improvements in technology will likely see increased usage of CAPI in the 2020 round of population and housing censuses. Similarly, the Internet has immense potential to improve the speed and quality of statistical data collection and dissemination and is feasible in many parts of the world.

2. Purpose and scope

A.7. The *Guidelines* is intended to assist NSIs and census officials to effectively plan and implement their censuses with electronic data collection technologies, principally via handheld electronic devices and the Internet. The publication focuses on some of the key considerations that should be taken into account when planning the use electronic data collection technologies.

A.8. The *Guidelines* emphasise the importance of having in place a sound decision-making process for understanding the value of introducing a particular technology solution, evaluating its cost-effectiveness and viability on the basis of key institutional, operational and social factors, and making such a decision on the basis of the information gathered during this process. As census information technology (IT) projects could become costly, risky, and unproductive, the *Guidelines* highlight the importance of an effective and efficient management process for maximizing the value of IT investments and minimize the risks, including in IT acquisitions and systems development.

A.9. To assist the NSI in its reorganization and capacity building efforts in order to carry out a census that makes use of electronic data collection technologies, the *Guidelines* presents a range of recommended actions. The document discusses, for example, the geospatial information and systems that are considered as being critical for seamlessly integrating the census mapping, enumeration and data analysis phases as well as for improving the efficiency and effectiveness of field work operations. Another key issue addressed is effective security for IT systems and electronic data to prevent inappropriate disclosure of sensitive information and disruptions in critical operations.

A.10. The *Guidelines* are meant to be a supplement to, and to be read in conjunction with, the *Principles and Recommendations for Population and Housing Censuses*, *Revision 3* and the *Handbook on the Management of Population and Housing Censuses, Revision 2*. The latter two publications discuss and elaborate general issues associated with planning out and managing census data collections, while the present *Guidelines* focuses on a set of selected, essential and critical planning, management and implementation issues and processes specific to the use of electronic handheld devices and the Internet in census data collection.

A.11. The treatment of alternative sources to the traditional census is not in the scope of these *Guidelines*. Information on the use of registers and administrative sources for censuses may be found in the *Principles and Recommendations for Population and Housing Censuses, Revision 3* and the UNECE's *Guidelines on the use of registers and administrative data for population and housing censuses* (forthcoming).

A.12. These *Guidelines* were developed reflecting the practices and experience of countries that have deployed electronic data collection technologies in recent censuses. However, it is recognized that the material in this publication is not inclusive of the whole gamut of national experience. Success in adopting technology depends on a wide variety of contextual and operational factors as well as institutional strengths and weaknesses. It is suggested that countries should use the information in this publication only to the extent that is relevant to their particular situation. Each NSI needs to evaluate how available technology options fit into the context of its own census programme and organizational structure and mission. Such issues as the availability of resources (human, financial, technological) and

the time frame allocated for census tasks as well as the goals of the census will determine the best mix of technology and approaches.

3. Target audience

A.13. This publication aims to serve as a reference for NSIs and their census officials. It has two main target audiences:

(i) census managers responsible for decision-making, planning and providing overall oversight to ensure technology investments meet organizational needs and are implemented to predefined cost and schedule expectations; and,

(ii) census operational and technical staff tasked with implementing aspects of the census plan, including those staff responsible for program and project management, information system development, and information and system security.

4. Structure

A.14. The remainder of the *Guidelines* is laid out in five chapters:

A.15. **Chapter B** provides an overview of the drivers of technological innovation in census data collection as well as of the various data collection methods, including both interviewer-administered data collection methods—consisting of paper questionnaire with face-to-face interview (PAPI), computer-assisted personal interviewing (CAPI), computer-assisted telephone interviewing (CATI)—and self-administered data collection—comprising paper questionnaire with self-enumeration (PASI) and computer-assisted self-interviewing (CASI). Multi-mode data collection is also briefly discussed. The chapter also emphasises the importance of having in place a sound process for introducing technology solutions, evaluating the cost-effectives and viability of solutions on the basis of key institutional, operational and social factors, and making decisions on the basis of the information gathered and analysed during this process.

A.16. **Chapter C** presents the considerations to be taken when collecting census data with handheld electronic devices (such as tablets, PDAs and laptops). The chapter weighs both the advantages and challenges to using CAPI on handheld electronic devices. It discusses critical factors in planning data collection with handheld electronic devices. An overview of handheld electronic devices, along with important features, evaluating requirements for selection of devices and options for acquisition, are elaborated. A section is dedicated to the discussion of the data collection application, including the essential functional features of CAPI, evaluating requirements, acquisition/development options, and questionnaire design and performance considerations. Another section deals with the testing of the data collection application and systems. The section on data transfer details the means of data transmission and some of the technical considerations that have to be made for data transfer via cellular networks. Given the importance of transferring data collected in the field back to the head office quickly and securely, a section on security provides an overview of the security threats and vulnerabilities in data collection with handheld electronic devices along with measures that can be taken to overcome security threats and vulnerabilities. The use of geospatial technology during enumeration is also described in the chapter. Field operation management and monitoring is elaborated in the chapter. This section elaborates on such topics as the organization of field enumeration, the roles and responsibilities of the field staff and IT support teams, recruitment and training of field staff and the provision of technical support to enumerators and supervisors during field operations. The importance of an efficient management and monitoring system is also discussed as a key factor for a successful field enumeration using CAPI. The chapter also discusses the need to have a device use policy and considerations for the re-use and disposition of handheld electronic devices.

A.17. **Chapter D** details the considerations that have to be taken into account when collecting census data with the Internet. It summarizes the main advantages of Internet data collection as well as the challenges and risks. Based on the experience and lessons learned from countries that adopted this

method of collection, the chapter presents the requirements that are essential for Internet based data collection. The section on planning the implementation process of Internet-based data collection also includes a discussion on the importance of setting reasonable and reachable targets for Internet take-up rate. The development of an optimal contact and communication strategy, which is an important element in the enumeration phase, is discussed in detail. Also discussed is questionnaire design for Internet self-response, as this plays a key role in ensuring a positive experience for respondents. The identification and authentication of respondents is crucial to maintain the integrity of an Internet-based data collection system and the security and confidentiality of the information supplied. Successful conduct of a large-scale Internet-based self-response enumeration requires developing, testing and refining a proper IT infrastructure and business rules to ensure the system has the capacity to handle the anticipated response loads. These and related issues, including security measures to protect information and IT systems, are covered in this chapter. Also covered is the provision of support to respondents—for technical problems and on the content of the census questionnaire—which is an important consideration when implementing Internet-based data collection. Additional topics discussed include those pertaining to monitoring, controlling and tracking Internet response as well as the information needed for monitoring and non-response follow-up.

A.18. **Chapter E** discusses considerations for using multi-mode methods for data collection.

A.19. **Chapter F** covers selected, critical planning and management issues to consider when adopting electronic data collection technologies (handheld electronic devices and/or Internet). It includes a section dealing with management structures and processes necessary to provide effective oversight to ensure that the technology investments meet organizational needs and are implemented within planned costs and schedule expectations. It discusses organizational restructuring, institutional capacity development and management of IT systems acquisition to support electronic data collection. Topics covered include considerations for use of geospatial information in support of census operations. IT systems development, including IT systems testing, is covered to underscore the importance of IT systems in meeting the functional and business requirements of a census operation. To emphasize the need to ensure adequate protection for the integrity, confidentiality and availability of the NSI's data and systems, sections are allotted to information and system security, risk assessment and mitigation as well as contingency planning. The evaluation of investment in IT, including key focus areas for the evaluation as well as information requirements and decisions from the evaluation are also covered.

Chapter B - Decision-making in the adoption of electronic data collection

1. Introduction

B.1. A population and housing census is perhaps the single most complicated and expensive exercise that a statistical agency can undertake, consisting of a series of extensive operations in terms of the numbers of people involved and records processed. Numerous processes have to be carried out in a prescribed and very limited time period, involving the employment of large numbers of persons covering a wide range of activities such as mapping, enumeration and data processing. Due to high dependency on manual intervention, census data is exposed to different types of human error. In order to decrease such errors, the census operation usually includes additional procedures for monitoring and controlling errors to produce good quality data. More importantly, a dependency on manual input creates pressure on the provision of timely dissemination of census data.

B.2. It is therefore always going to be a matter of some interest to census managers in seeking to benefit from the use of modern technology to basically replace manual labour for a variety of reasons, but especially for improving the quality and timeliness of the resulting statistical outputs. Recent developments in technology and subsequent access to electronic devices and the Internet more generally has created much interest in the use of these technologies for electronically collecting and capturing census data and monitoring such processes. While on the one hand, the use of technology has largely eased the way in which the business of a population and housing census is undertaken, on the other hand it has also introduced new challenges and risks.

B.3. As in the adoption of any other new technology, the understanding of the value of electronic data collection technologies is a critical step in making an informed decision on whether or not to use these technologies in censuses. As the introduction of these technologies can be an expensive and risky exercise, it is important for any country to ensure that there is sufficient value in its introduction in a census by taking into account the particular national conditions prevailing.

2. Overview of data collection methods

B.4. The *United Nations Principles and Recommendations for Population and Housing Censuses, Revision 3* describes two major methods for enumerating populations and housing units in a traditional census. In the face-to-face (or enumerator) method, information for each individual (in a population census) and for each set of living quarters and the occupants thereof (in a housing census) is collected and entered in the questionnaire by a census official designated to perform this operation in a specified area. In the self-enumeration method, the major responsibility for entering the information is given to a person in the unit being enumerated (usually the reference person of the household), although the questionnaire may be distributed, collected and checked by a census official.

B.5. Until recent years, the face-to-face and/or self-enumeration methods were applied with paper questionnaire across most countries. However, as a result of advances in technology, new ways of enumerating populations have been introduced. The traditional method of enumerating the population with face-to-face interviews can now be applied with the use of handheld electronic devices or the telephone to automatically capture data during the interview. On the other hand, the self-enumeration method can now also be applied using the Internet. These approaches can either substitute or complement the traditional face-to-face, pen-and-paper interviews (PAPI) as well as be used in a variety of combinations (multi-mode method).

B.6. The mode of data collection includes the way in which respondents are contacted and how their responses are obtained. The modes of data collection used by national statistical offices vary across

countries. One mode of data collection or a combination of two or more methods may be used in a census operation. Each mode of data collection has inherent advantages and disadvantages, and there is no one best data collection mode for all situations. The mode of data collection has implications in terms of logistical requirements for the survey operations, number and qualifications of the enumerators, training needs, and, consequently, the cost of the data collection operation. Therefore, a decision on the mode of data collection should be made by countries early in the planning stage of the census, based on the strategic objectives the census (e.g. improving coverage), previous experience in data collection, available resources, characteristics of the population such as literacy rates and coverage of phone and internet services, and availability of frames (e.g. address frame for mailed questionnaires). When selecting mode(s) for data collection, NSOs should specifically consider to number of factors, both statistical (coverage, response rates and measurement errors) and non-statistical (timeliness, cost, population of interest).

B.7. This section provides an overview of commonly used data collection modes and describes their key characteristics along with some of the strengths and limitations of each mode.

2.1 Interviewer-administered data collection

1.1.1 Paper questionnaire with face-to-face interview (PAPI)

B.8. Face-to-face paper-and-pencil personal interviewing (PAPI) is a mode of data collection in which an enumerator typically visits a respondent at their home and collects data through an interview using a paper questionnaire. Face-to-face interviews are the most common method of census data collection, particularly in developing countries and in population groups with significant illiteracy rates. Given adequate time and numbers of contact attempts, in-person interviews typically have the highest response rates. Data obtained in face-to-face interviews are also more complete and accurate because of the potential for interaction between the enumerator and the respondent, and the opportunity to clarify some of the questions and probe for more adequate answers. However, face-to-face interviews require highly trained enumerators and are likely to be more costly than other data collection modes, mostly due to traveling to respondents' residences.

B.9. The primary disadvantage of in-person interviews is the high cost associated with sending an interviewer to households to collect the data. Also, the data collection phase of the survey may take longer (or require a larger interviewing force) compared to other modes of collection. In-person interviewers may also face barriers in completing their assignments because some addresses may be less accessible to interviewers, e.g., high rise buildings and gated communities, or be in high crime areas with greater risk to interviewer safety. Because in-person interviewers typically operate alone with much less supervision and control, there may be greater interviewer variance in in-person interviews and there are also greater opportunities for interviewer falsification of some questionnaire items or entire interviews. As a result, some re-interviews or independent verification of interviewers' work to detect and minimize falsification may be needed.

1.1.2 Computer-assisted personal interviewing (CAPI)

B.10. In computer-assisted personal interviewing (CAPI), the enumerator obtains information from one or more household members through an interview using an electronic questionnaire (CAPI software application) loaded on a tablet or other handheld electronic device (e.g. PDAs and laptops). The enumerator asks the respondent questions in a face-to-face interview and the responses are recorded by the enumerator directly into the electronic device. Following the interview, the data are sent to a central computing network electronically via internet or other means of data transfer. CAPI offers several advantages over the traditional paper-and-pencil method. These benefits translate into cost savings in data processing, improved quality of data, and shorter timelines for completion of data processing. Additionally, CAPI can capture a range of operational information that can be used to monitor operations and analyse responses. For example, use of CAPI allows for a detailed analysis of the time

duration for completing the questionnaire. CAPI also enables more efficient management of interviewers, including updating enumerators' assignments and checking of the completed questionnaires by the supervisors.

B.11. However, there are also costs and risks associated with using CAPI instead of a paper questionnaire. When considering the CAPI method, the cost of providing all interviewers with the electronic device used to administer the questionnaire must be incorporated into the project budget. Each interviewer must have her or his own tablet computer for data collection, which can represent a substantial initial investment. Less expensive tablets and notebooks are becoming widely available, however, meaning that computer costs may be offset by savings derived from eliminating the printing, editing and transport of the questionnaires and the transfer of data from paper forms to an electronic database. These devices can also be reused on future surveys. Additional costs when using CAPI may refer to the human resources and time related to programming, additional training on CAPI for interviewers, field supervisors and headquarters staff; cost of access to server hardware, software and server maintenance; and technical support. Furthermore, more preparation time is needed before starting data collection in the field. The additional time to be allocated to field preparation activities should not be underestimated. It also should be emphasized that when not enough time is allocated to the development and testing of the CAPI questionnaire data quality may be severely compromised.

1.1.3 Computer-assisted telephone interviewing (CATI)

B.12. Computer-assisted telephone interviewing (CATI) is a mode of data collection in which the interviewer records the respondent's answers to questions asked over the telephone (either a fixed-line telephone or mobile phone). The responses are recorded directly into a computer. Compared to paper-and pencil methods, CATI system offers a number of advantages. Telephone interviewing can provide lower costs and shorter data collection times compared to in-person interviews. CATI based data collection are often conducted in large, centralized facilities that include careful supervision and monitoring of interviewers (although with advances in technology, CATI systems could be employed in a decentralized manner enabling interviewers to plug into the CATI system and conduct interview with respondents remotely). In CATI calling centres, interviewer variance is likely to be less than for in-person interviews. Social desirability concerns may also be less than is the case for in-person surveys. Just like CAPI systems, CATI capabilities include branching, skips, and real-time validation of data based on in-built logic checks and other advanced features that enhance data quality.

B.13. There are also disadvantages to telephone interviewing. Even when telephone coverage is high, some groups, such as those with low incomes, are more likely to be excluded from the frame. Cell phones may not be covered by existing frames, and there are some legal restrictions on calling these phones. The number of households with only mobile phones is growing and may present further coverage problems for telephone surveys. Increasing use of technologies including answering machines, voice-mail, and caller ID is making it harder to reach households. Conducting an interview over the telephone also imposes more constraints on the length of the questionnaire and complexity of the questions compared to some other modes. Some response effects, such as response order, are more likely to occur in telephone surveys than self-administered surveys. For example, respondents are more likely to select the last response option (recency effect) in a telephone survey than a mail survey.

2.2 Self-administered data collection

1.1.4 Paper questionnaire with self-enumeration (PASI)

B.14. In the paper questionnaire with self-enumeration (PASI) approach, paper questionnaires are handed or mailed to respondents and completed without interviewer involvement. Filled questionnaires are retuned by mail or handed to enumerators. Self-administered questionnaires are more often used in developed countries, as a high level of literacy is a requirement for this mode of data collection to succeed. This method is most appropriate when there is a good address list for a frame, especially if the

questionnaires are mailed. It also requires a longer data collection phase than other modes. PASI by mail have relatively low cost, and self-administration of the questionnaire improves response to sensitive questions, minimizing social desirability and interviewer biases.

B.15. There are a number of disadvantages of PASI by mail. Mail based collections could suffer from low response rates, therefore, they are often used in mixed mode collection deign with follow-ups done via telephone or in-person. It is important that mail questionnaires have clear instructions, easy to follow layouts, and clear question wording because there is no interviewer present to provide clarification. The items on PASI questionnaires are more likely to be incomplete than those on questionnaires that employ other modes (higher item nonresponse).

1.1.5 Computer-assisted self-interviewing (CASI)

B.16. Computer-Assisted Self Interviewing (CASI) is a data collection technology where respondents access the electronic questionnaire by means of an internet browser application. The questionnaire is self-administered by respondents who read the questions on the computer screen and enter the responses without interviewer involvement.

B.17. CASI has several benefits over CATI and CAPI. CASI provides respondents with more privacy and anonymity and allow respondents to report sensitive information, such as household income, with more comfort. Self-administration eliminates interviewers' ability to influence responses or register them according to personal biases. This removes the effect of interviewer bias that is often associated with CATI and CAPI surveys. Some studies also suggest that data collected using CASI is of higher quality than CATI or CAPI methods due to the flexibility of completion at convenient times and elimination of time pressure giving the respondents more time to think through the questions before answering. Like other modes that use computer administration, data processing time and cost may be reduced compared to paper and pencil surveys because data can be uploaded or captured directly into databases without additional keying. Data quality may also be higher because the instrument can contain built-in edits and prompts.

B.18. There are a number of disadvantages to Internet surveys. Respondents need to be "computer literate" and have access to the Internet. Self-administered questionnaires can successfully be used only with populations with high literacy. Low household coverage rates for Internet access and differences between households with access and those without access means that the Internet could not be used as the sole mode for census data collection.

2.3 Multi-mode data collection approaches

B.19. A multi-mode approach to data collection entails the use of two or more data collection modes. The two main reasons to consider using more than one mode of collection simultaneously are cost and response rates. The typical multi-mode approach is to use a less costly method for initial contact and a more-costly mode for follow-up with non-respondents, such as using a PAPI, CAPI or PASI method with telephone nonresponse follow-up (this is known as sequential design). Using multiple modes often yields a higher response rate by offering alternative means to respond, so respondents may choose the mode that is most convenient for them; for example, some households may prefer to respond via the Internet rather than complete a paper questionnaire. Mixed-mode designs can be either sequential or concurrent (where different collection modes are offered simultaneously). Which option is best depends on the situation. In general, the sequential design might be preferable, where one mode is offered, and another used only if needed.

B.20. Data collection modes vary with respect to factors such as the cost and speed of fieldwork, and their impact on data quality. Mixing modes could minimise both the costs and errors associated with using any given single-mode approach. Mixed-mode designs are, therefore, becoming increasingly popular as a means to tackling the problem of coverage, nonresponse and measurement errors, as well

as a way of reducing costs. For example, an additional mode can help provide access to a group of respondents that would otherwise be hard or impossible to contact using the principal collection mode. NSOs planning mixed mode collections should carefully design their questionnaires to minimize potential mode effects—the bias caused by the mode of the data collection. Section 6 in Chapter F discusses in detail the considerations that have to be made when using of mixed-mode data collection.

3. Key drivers of technological innovation in census data collection

B.21. Among the main driving forces behind the adoption of new technologies by NSOs are the potential savings to be realised and the possibility for automating laborious, repetitive manual tasks. However, technology plays a far broader role than those and is critical for improving statistical business processes and the effectiveness and efficiency of census operations. A review of recent country experience with new technological approaches to data collection finds that new technologies can substantially advance statistical capacity to produce data. Despite some limitations and risks, electronic data collection technologies can improve the speed and quality of census data. With the use of these technologies, data will be available for analysis much faster because data are transferred to a central database immediately or soon after collection. Electronic forms reduce the amount of material (such as questionnaires) to be printed, distributed and returned, and reduce data entry costs and errors. Electronic forms can improve data quality by implementing validation rules.

B.22. Drivers of technological innovation in census data collection are many, although those that have significant impact may vary from one county to another. However, there are certain drivers (see list below) that motivate most countries to adopt modern technologies for improving the efficiency and effectiveness of their census operations. The drivers are key to enhancing census operational capability and data quality as well as to contributing to organisational transformation and modernization of NSO business processes. Some of the key drivers include:

B.23. **Demand for timely data**: The timing of the release of census results is a main consideration for both data producers (NSOs) and users alike. There are several reasons for why census data is not available to users timely including capacity, budget resources and even politics. However, a key reason is the relative slowness of the traditional method of collection and production system. The process of data capture, coding, editing, imputation and validation for Pen and Paper Interviewing (PAPI) takes a long time. With the use of scanners for automatic data entry, there has been some improvements in the data processing stage. Timeliness can be further improved through the adoption of electronic data collection methods which allow for a significant decrease in processing time through the use of automatic data capture and real-time consistency control during the interview.

B.24. **Demand for quality data**: The population and housing census is one of the most complex and costly data collection operation due to the involvement of a large number of people and a multitude of activities, many of which are conducted simultaneously. The requirement to enumerate the whole population within a short period of time also lends to its complexity. Due to these factors, it is a challenge to produce good quality data (in terms of coverage and item response). The adoption of new technologies (for example for mapping, data collection, transmission and processing, and operational management) has the potential to substantially improve the efficiency of the operations and the quality of the outputs. The use of multiple modes of data collection (for example, face-to-face interview followed by telephone interview) can improve coverage and response as this would give respondents the option to be reached and provide information in the form which best suits them.

B.25. **Demand for improving efficiency**: The process burden is the effort, including in terms of time and cost, required for statistical agencies to design census operations and carry out field operations, especially activities related to mapping, enumeration and data processing. Designing census operations using traditional approaches which are mostly dependent on manual work creates many challenges, including for controlling the quality of the work done by the census staff. The use of modern technology for these operations will improve the effectiveness and efficiency of census processes.

B.26. **Demand for cost reduction and cost-effectiveness**: Population and housing census is a costly operation and census planners are always looking for ways to carry out a census as inexpensively as possible without compromising other strategic objectives. A substantial portion of costs associated with taking a census is due to field operations and the direct interview method which is more costly. Costs can be minimized in several ways including by replacing direct collection of data with use of administrative data, contracting out appropriate parts of the operation and through cost recovery and income generation. However, one key way to reduce cost is the adoption of technologies that lead to more efficient data collection, data capture and data-processing approaches. The use of electronic means to conduct the census could reduce the costs. For example, the use of Internet-based collection would result in employing fewer enumerators, and automating processes could lead to savings from manually intensive collection and data entry operation.

B.27. **Demand for minimizing respondent burden**: The reasons for declining participation in survey and censuses include the concerns citizens have about information security and the confidentiality of information given to the government as well as the burden of lengthy and complex questionnaires and discouragement place on respondents feel. This impacts the response rate and undermines the quality of the data. It is in the interest of both data producers and respondents to minimize the burden associated with providing information through data collection activities. The adoption of technology for data collection can contribute to minimizing respondent burden.

B.28. **Availability of cheaper and better technology**: A wide range of data collection methods and sources have become available as a result of recent advances in information and communication technology. Hardware and software as well as mobile data networks are becoming cheaper and better, allowing newer and faster data collection approaches that either substitute or complement the traditional pen-and-paper interviews (PAPI). For example, personal interviews carried out by an interviewer using tablets for recording answers and direct data entry provides improvements to traditional methods.

B.29. **Stakeholder and user expectations**: Data producers strive to serve the needs of their users and to retain the support and trust of stakeholders (comprising those that advise, oversee, and provide data to the NSO) and the public at large. Engagement with stakeholders and users is crucial to understand their requirements and to determine the range of data products and services. Increasingly stakeholders expect the census to use technology innovation and data users demand advanced tools for data delivery and data analysis (e.g. mapping tools based on a GIS database). To meet this demand NSOs will need to assess and strengthen their internal operational capabilities and business processes. In this context, the adoption of advanced technologies can provide operational capabilities to NSOs so that they can be responsive to new demands and changing conditions and continue to deliver quality data products.

B.30. **National and global commitments to modernise statistical systems**: National legal and political factors (e.g. digital government or e-Government initiatives) as well as global commitments made by countries are important driving forces for the modernisation of statistical systems. Several international initiatives—for example, the 2030 Agenda with the Sustainable Development Goals (SDGs) at its centre and the National Strategies for the Development of Statistics (NSDS)—make statistical capacity-building and modernization endeavours a key priority for the production of data for evidence-based policy- and decision-making.

4. The decision-making process

B.31. Decision making on whether to use a particular technology or not should be organised as a process with the objectives of understanding the value of introducing such a new approach, evaluating its cost-effectives and making the choice on the basis of the information gathered during this process. A step-by-step decision-making process will help to make more deliberate and thoughtful decisions on the feasibility of introducing any new approach and potential risks of doing so. The following steps are suggested for this process:

(i) Developing strategic objectives
(ii) Identifying key factors affecting decision
(iii) Gathering information required for decision making
(iv) Analysis of information
(v) Decision making
(vi) Documenting decisions and evaluation

3.1 Developing strategic objectives

B.32. Establishing a set of strategic objectives can be used to set success criteria and a rationale for adoption of new technology in censuses. The starting point for developing such objectives should be a combination of: an evaluation of information derived from previous census experience (both national and international); an understanding changes in a society and technology; and from assessing the cost-benefits of the use of the technology in censuses. Strategic objectives would also help to inform stakeholders and the Government about the success criteria for the use of electronic data collection methods to be used in any consultations about the benefits of adoption of these technologies in censuses.

B.33. The specific strategic objectives will differ from one country to another depending on their local circumstances. However, among the most important, common to most countries, would be:
(i) Improving census coverage and data quality
(ii) Reducing costs
(iii) Disseminating census results more timely
(iv) Modernisation of business processes of other statistical operations
(v) Meeting public expectations

3.2 Identifying key factors affecting decision

B.34. In making the decision a number of key factors will need to be considered in order to determine whether a particular technological solution is viable and cost-effective. There are many factors that may affect the successful adoption of any new technology in a census. Given the fact that a very large number of people are involved in data collection, either as enumerators or face-to-face interviewers, or, of course, as respondents, the institutional and operational factors, as well as environmental and social, cultural conditions, will have an impact on the successful use of these technologies in the field, and should be considered during decision making process.
Key factors can be categorised into the following five groups:

(i) ***Institutional factors*** refer the capacity and capability of the statistical agency to adopt the new technology and to apply it more strategically. These should be examined to determine if there are any barriers to the agency meeting the internal requirements for adoption of technology such as handheld devices and/or Internet in a timely manner. Therefore, these factors should encompass a range of aspects including the technical and technological capacity of staff, the scope of statistical legislation to allow the use new technology, the commitment of the government and potential stakeholders, and the extent to which the census methodology will be impacted by the introduction of new technology. For example, adoption of CASI would be much easier in case of having an experience on self-enumeration method. It should be kept in mind that the investment required for the adoption of electronic data collection will differ depending on the agency's existing capacity including its experience in using these technologies in other statistical areas. It is important therefore to carefully evaluate this capacity to fully assesses the resource and other requirements for establishing a new system. Moreover, the past experiences of other agencies in transferring to a new technology would provide a good base for understand the institutional capability for change management. Furthermore, it is likely that there will be insufficient knowledge and culture with the agency to provide a fully in-house solution to the challenge of electronic data collection, in which case outsourcing parts (or the whole) of the operation will be

an option. Good knowledge of contract management for appointing and working with suppliers will be necessary.

(ii) ***Technological factors*** are those that have a direct effect on establishing the infrastructure needed for the use new technology more widely, particularly for data transfer and the use of Internet. General availability and use of Information and Communication Technology (ICT) in a country is one of key considerations for evaluating the feasibility of this technology. Therefore, the technological infrastructure within a country should be assessed carefully based on relevant indicators such as the proportion of population who can access the Internet and have exclusive use of ICT devices. Moreover, a widely available and reliable supply of electricity and broadband coverage in a country are also important environmental factors for ensuring the effective use of devices in the field. These indicators should be disaggregated by geographical area and by sex and age category where possible, to assess if these technologies are universally available or applicable only in some parts of the country such as metropolitan areas and cities.

(iii) ***Economic factors*** refer to those that have to be considered for securing the financial resources for establishing a system for the use of the new technology - be it handheld devices and/or Internet. Close cooperation with government and stakeholders is essential for ensuring resource mobilisation, therefore there is a need to carefully study the benefits of adoption of technology against its associated costs. If there is a pressure for purely reducing census costs, the relatively high initial cost of purchasing the hardware and establishing a technological infrastructure might be a major concern of funding providers. However, for the purposes of a cost-benefit analysis, a comparison with the costs of the current census methodology should not be undertaken without a similar comparison of the benefits of the new technology in terms of its long-term advantages in modernisation of statistical system and meeting users' needs and expectations.

(iv) ***Operational factors*** refer to the parameters that specify the necessary conditions for adoption of electronic data collection technologies in terms of time required and the workforce needed. Adoption of new technology in conducting a census usually requires additional time for planning and redesigning of new systems and testing appropriately. Operational factors are critically important for making a decision since any deficiencies in the required conditions will create a risk which may not be resolved until after making the decision. Analysis of the operational factors should be carried out taking into consideration any diversity within a country in the ability to apply the technology to every part of the country. This assessment would also help to understand if there is a necessity to adopt a multi-mode data collection approach.

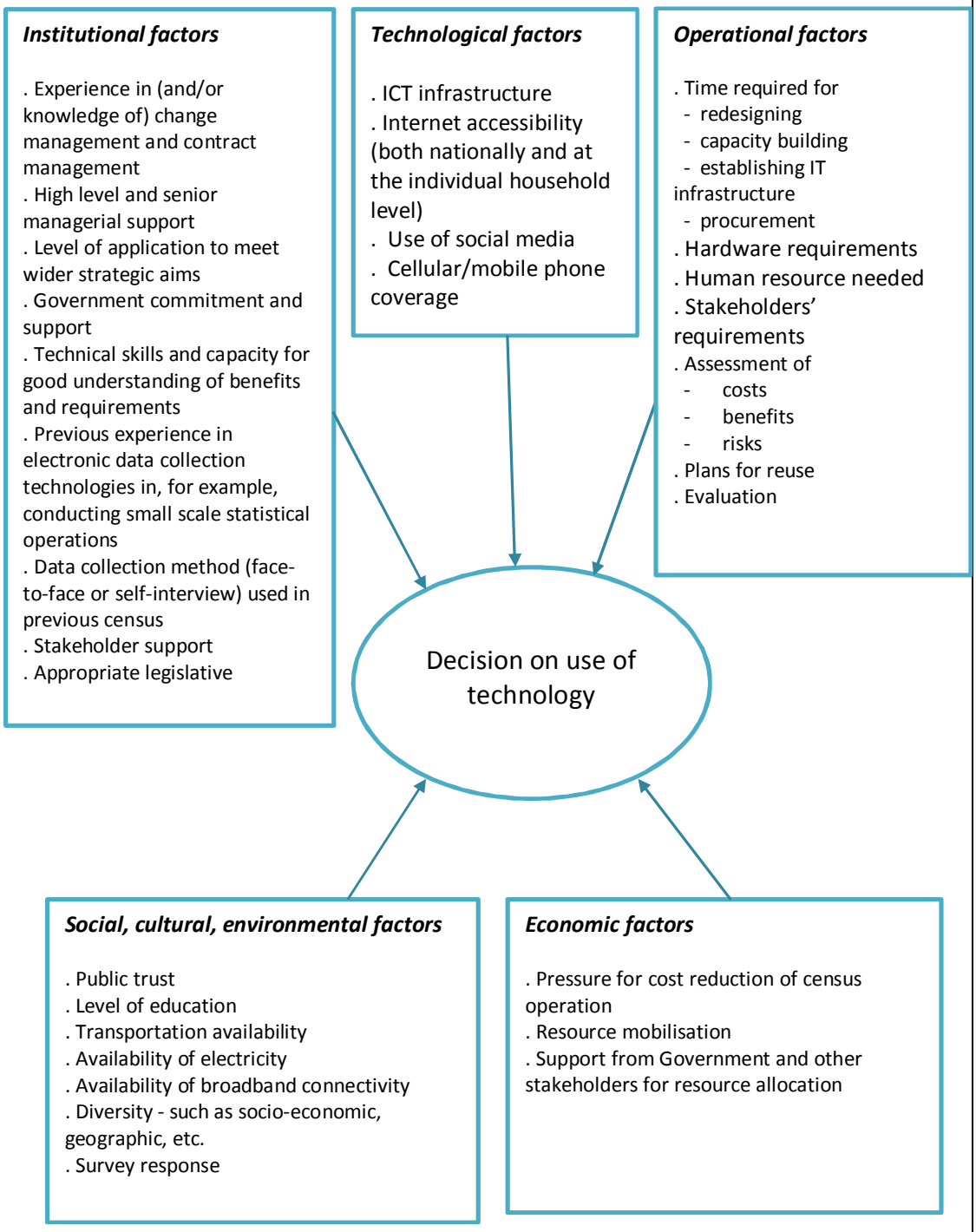
(v) ***Social, cultural and environmental factors*** refer to those that are related both to public`s general exposure to, and acceptance of, new technology, and the perception of the impact of its specific application to the census itself. These would influence the levels of acceptance and capability of a society to use such technology within their own environment. The education level of population, its experience in the use of ICT devices, the availability of electricity, level of public trust and confidence, and response rates to other official surveys would be among the most important factors. For example, the education characteristics of population (particularly its literacy rate) will have a significant impact on the level of use of Internet for self-response and on the recruitment of enumerators and supervisors with the basic skills required for the use of electronic devices. More generally, self-enumeration as a method of data collection (whether or not by electronic means) creates a potential risk of increasing levels of non-response. Also, a lack of public trust in government generally may have negative impact on the use of technology due to confidentiality concerns. The perception of increasing levels of cybercrime raises the level discomfort amongst respondents as technology is often seen as easy target for personal information theft. Ideally, having a well-established e-government[1] system in a country for

[1] E-government can be broadly defined as the use of information and communication technologies (ICTs) and the Internet to enhance the access to, and delivery, of many facets of government services and operations for the benefit of citizens, businesses, employees, and other stakeholders

providing services would have positive impact on public acceptance, particularly for the use of Internet.

B.35. Figure 1 presents general framework for determining key factors affecting decision making on the use of new technology. It should be noted that there may be other factors that are equally relevant in the national context that might also need to be taken into consideration.

Figure 1. Key factors affecting decision on the use of new technology



3.3 Information required for decision making

B.36. As noted above, there are many factors that should be considered in making a sound decision on whether new technology should be adopted in conducting the census. Information can be generated in different formats such as quantitative data, qualitative data, assumptions, good country practices and international experience (and even anecdotal experience and the occasional hunch). All sources of information are important. However, as the basis for a sound judgment on existing capacity and possible risks, more emphasis should be given to clearly documented quantitative and qualitative information. On the other hand, other types of information are also necessary especially for understanding the feasibility of electronic data collection technologies and risks of using these technologies.

(i) Quantitative and qualitative information

B.37. Qualitative and quantitative information can be generated for some factors described before. This guideline provides some examples of the type of data that can be used for assessing whether or not national circumstances are conducive to the option of using electronic data collection technologies.

B.38. The following data/indicators are given as examples of *quantitative* information:

- Population size and density
- Literacy rate
- Proportion of population with highest level of education
- Proportion of persons living alone
- Proportion of population having basic computer skills
- Proportion of population using social media
- Percentage of population living in urban/rural areas
- Percentage of population living in multi-occupied dwellings
- Number and proportion of population who can access to the Internet
- Number and percentage of households with Internet connection
- Proportion of households with electricity
- Cellular/mobile phone coverage
- Pattern of non-response rates for previous censuses and surveys

B.39. Such indicators should be disaggregated by geographical area to illustrate local variations, and also (where it is appropriate) by sex, age and special population groups (such as ethnic communities). The main objective of collecting this information is to assess whether or not the adoption of the new data collection technology would not be viable in any particular parts of the country or population.

B.40. *Qualitative* information can be collected through cognitive research, user and other stakeholder consultations, individual interviews, observation, market and academic research, and other expert opinion. Information on the following questions might be considered as examples of qualitative information:

- What is the public's reaction to adoption of Internet as the medium for self-response?
- How ready is the statistical agency to adopt new technology for enumeration?
- How will Government and main stakeholders (particularly data users) react to the use of new technology?
- Does existing legislation allows for a change in the method of enumeration, and, if not, is a requisite change practicable?
- What are main expected challenges? What would be strategies to achieve these challenges?
- What are the risks in procuring hardware and outsourced services?

(ii) Information needed for operational aspects

B.41. In the same way that the census agency needs to decide on the number of Enumeration Areas in order to determine staffing requirements, so must it consider the type of technology that will be required in any electronic data collection to meet the needs of enumerators, supervisors, regional and HQ staff as well as respondents throughout the enumeration process. Particularly with the adoption of handheld devices, the key questions to be answered are what are the number and type of devices needed, while on the other hand, the key question for adoption of the Internet is to answer what will be the size of the infrastructure needed for adoption of the Internet such as servers, storage devices and communication vehicles.

B.42. It should be noted that components of estimating total cost for adoption of handheld devices and Internet differ significantly especially for building necessary IT infrastructure. However, there are also some common areas with regard to organisation of the field work considering that adoption of the Internet requires multi-mode data collection approach in an integrated way with other methods such as PAPI and/or CATI and/or CAPI.

B.43. In general, the agency needs to consider several factors including:

- the extent of the geographic area to be covered (square kilometres or miles and constraints to accessibility -terrain/elevation, security, weather, etc.)
- number of days/weeks estimated to complete the enumeration
- total population (in terms of person and households) to be counted
- number of Enumeration Areas (EAs)
- size of field force (enumerators and all supervisory staff) depending on method of data collection including multi-mode approach
- Availability and the quality of address frame or address registers
- technology constraints (online/offline, bandwidth, power access)
- outsourcing

B.44. By understanding the size and scope of the work needed, as well as the characteristics of the geography and households, the census agency can begin to determine the number and type of handheld devices that will be required in case of adoption of CAPI and specifications of the infrastructure necessary for the CASI.

B.45. For example, in a country of, say, 1m square kilometers, with a population of 100 million, the agency might estimate that it would need 150,000 enumerators based on a total number of 30 days to complete the fieldwork with an estimated 15,000 supervisory staff needed to manage the operation at the local area level, giving a total field force of 165,000. However, this does not necessarily help to determine the type of device(s) needed. Would a smart phone be appropriate, or would a tablet be more suitable, for field personnel?

B.46. On the other hand, for adoption on CASI, the agency should consider the important factors for determining the cost of IT infrastructure such as: (i) the average number of pages/questions, (ii) average time spent for self-interview, (iii) number of simultaneous users and (iv) total number of persons expected to use the Internet.

B.47. In addition, census agencies need to factor in other considerations such as:

- The physical environment: Are ruggedized devices needed (that is, does any account need to be taken of temperature extremes, heavy rainfall or screen brightness for example?
- Variations in geography: What are the percentages in urban and rural. The degree of remoteness and inaccessibility is important as this may impact on battery charging and storage needs, travel time and transportation costs.
- Issues of device distribution: What types of devices will be used for field operation such as for enumeration and supervisions and in case of failures what will be replacement plans.

- Outsourcing opportunity: What tasks or activities can be outsourced to increase efficiency of the use of new technology? What extent total cost can be reduced through a competitive selection process?
- Issues of connectivity: the capacity to upload data/download work assignments.
- Data storage: the capacity to handle online and offline work requirements.
- Connectivity: the degree of broadband coverage and speed of response
- Workforce and respondent characteristics: How familiar are field staff with the technology? This will largely depend on the extent of training/support provided. What is the level of educational attainment (particularly the level of literacy) of the population being enumerated?
- Respondent attitudes: To what extent should the publicity specifically address issues of concern such as safety/security/privacy of data submitted electronically?
- Survey characteristics: How long is the question and how complex are the questions?
- Non-response follow-up: What is the anticipated level of non-response and how many re-visits will be required.

B.48. By better understanding these factors the specification of IT infrastructure -for CAPI, number and type of devices and specification- may become clearer. But there are other issues that should also be understood in order to get a clear estimate of total cost involved of adopting to the new technology. These include:

- Support needs: What investment is needed to provide a technical support call center to assist enumerators (and respondents) during data collection? What skill and training does that staff need? What technology is required for the support center? Is there a requirement for staff with different specializations to be more effective in assisting different callers (for example, in responding to queries about the questionnaire on the one hand and about specifications of the hardware or connectivity issues on the other)?
- Security needs: What type of security will need to be implemented both in downloading and uploading the data, in ensuring confidentiality of data on the device, in transferring data and in protecting the hardware itself?
- Training needs: What additional investment needs to be made to train not only the field staff (the regional managers, supervisors and enumerators) but also the staff of the agency in the use of new technology.

B.49. Such costs – referred to here as the 'total cost of ownership' - are discussed in more detail in the following section.

(iii) Estimate of Total Cost of Ownership (TCO)

B.50. The concept of the 'total cost of ownership' (TCO) refers to the estimate of the direct and indirect costs of developing and applying a particular product or system. There are three key components to calculate TCO: software/hardware costs, operational costs and personnel costs.

B.51. To make a true total cost of ownership (TCO) comparison, agencies should assess the full costs in both the existing or previous census workflow and the proposed new workflow. It should be noted that some fixed costs will be offset by reductions in some of the variable costs.

Fixed costs cover:

- Tablets/Handheld/Mobile devices
- Servers
- Global Positioning System (GPS)
- Capacity development (training, hiring temporary staff, etc.)
- Building technological infrastructure
- Maintenance

While variable costs cover:

- Double data entry (relevant when a PAPI methodology is adopted – see Chapter B)
- Paper questionnaire costs:
    - Paper storage (PAPI)
    - Printing costs (PAPI)
- Data transfer

B.52. An example of a template for calculating total cost of ownership for possible alternatives methods for data collection methods and data collection method(s) used in previous census is shown below:

Items	Method of Data Collection 2010			Method of Data Collection 2020				
	PAPI	PASI		PAPI	PASI	CAPI	CASI	CATI
Number of EAs								
Number of questions								
Number of households								
Fixed costs:								
Hardware								
Software								
Technical support/services								
Other Electronic equipment								
Maintenance Fees								
Variable costs:								
Recruitment of temporary staff								
Training/workshops, etc.								
Enumerator salaries								
Supervisor salaries								
Data entry (PAPI/PASI only)								
Data cleaning								
Printing paper questionnaire (PAPI/PASI only)								
Data transfer fees (CAPI/CASI only - cost of data plan from carrier)								
Logistics costs								
Other (describe)								
Total cost per household:								

B.53. The total costs of the multi-mode data collection method can be simply assessed by adding the cost estimate of each possible method. To reliable estimate of the total costs of ownership, there should be a clear understanding of what types of data collection methods are feasible and what is the estimated number of households that are expected to be enumerated through a specific method of data collection.

(iv) Benefits

B.54. One of the main benefits of CAPI/CASI over PAPI/PASI is an improvement in data quality. It has been found that the percentage of interviews containing erroneous data for CAPI interviews is lower than PAPI (*Zhang et al, 2012; King et al, 2013; Caeyers et al, 2010*), and that this might be also similar for CASI. Improvements in coverage and timeliness of delivery of census outputs can also be achieved, together with reductions in manpower requirements and respondent burden with its concomitant cost savings. In utilizing CAPI/CASI, agencies can also expect some other positive impacts such as reduction in interview duration which, in turn, will results in further savings in field costs.

B.55. The CAPI mode also offers benefits for field staff, including:

- less weight to carry around
- reduced concern on correctly following skip patterns
- more effective organization, including real time analysis of data to inform any necessary change in workload allocation or follow-up visits
- less risk of damage to completed questionnaires in bad weather conditions

B.56. A key benefit in adopting an Internet-based solution for self-enumeration is that respondents generally prefer the flexibility offered in filling out the questionnaire both in terms of when, and the time taken, to do so, and the greater level of privacy provided in submitting personal and sometimes sensitive c information. A more detailed discussion of the benefits of Internet-based data collection is set out in Chapter F.

(v) Risks and challenges

B.57. Whenever considering a change of field methodology, and particularly when adopting new technologies, the risks and challenges must also be taken into consideration. A full assessment of the impact (both positive and negative) on existing systems and workflows must be undertaken. The activities particularly prone to risk often include procurement, IT, recruitment, operations, and training and support, as well as the technical, managerial and statistical processes.
The most common risks and challenges might be:

- Building a capacity for planning, designing and implementation of field operation
- In case of using multi-mode data collection (a combination of use of handheld devices and/or Internet-self response, with or without paper questionnaire) the linkage of data collected from different modes, and creating a reliable link with household addresses in order to prevent double counting and follow up non-response
- Resource mobilisation
- Loss of/damage to handheld devices and/or loss of the data itself
- The training of staff skilled enough to use handheld devices for data collection
- Reliance on power supply and sufficient network/broadband coverage
- Public trust in data security and confidentiality

(vi) Timetable

B.58. The necessary revisions (usually extensions) to the timetable required for planning and decision-making also need to be well understood in order to allow sufficient time for procurement, system development and integration, the training of all necessary staff at the various operational and

geographic levels, conducting various types of tests throughout development of census operations including pilot census, and evaluation.

(vii) Reuse of technology

B.59. Consideration also needs to be given to the potential for the reuse, for other applications, of hardware devices and associated software once the census fieldwork has been completed. Such re-use becomes practicable if there is potential for statistical agency to adopt corporate strategic solutions for a variety of data collection operations, and particularly if a directory of standardised questions with common definitions and concept can be adopted across a range of national surveys. This helps to increase the cost-benefit of the initial purchase of (usually) large quantities of hardware for initial use in the census.

B.60. However, re-use need not be restricted solely to within the statistical agency itself. Consideration should also be given to the use of the hardware by other organisations in the public sector, such as schools. This provides the opportunity of such organisations to acquire much needed equipment at lower costs. For such external reuse, however, a number of issues need to be addressed, in particular:

- understanding which devices can be effectively re-used or refurbished and which need to be recycled or disposed
- monitoring the location of all assets using bar-code technology or similar structure logging of the devices
- the removal all stored data and software, including operating systems and applications, in accordance with all relevant commercial agreements and statutory requirements

(viii) Best practices of other international statistical agencies

B.61. Many countries have made the progression from a paper questionnaire methodology to an electronic data capture technology. Best practices and valuable lessons can therefore be learned from those statistical agencies that have already gained much experience from such a move, particularly where countries have similar demographic, geographic and cultural characteristics.
Census agencies may have already established either formal or informal links with those in neighbouring or regional countries, and these can be utilised as a forum for discussion of best practices and an exchange of ideas and experiences on technological solutions – not only for data collection but other census operations as well. Meetings of the UN's regional member states can provide similar opportunities for benefiting from the experience of electronic data collection gained by the member states.

3.4 Decision making

B.62. The decision on what data collection methodology to adopt and how it will be implemented will only be one of many to made in planning and carrying out the census. Similar processes will usually be adopted for each of these so that there is a consistency of approach. Thus, the methods described in this section may already be familiar in other applications but, it should be noted, are particularly relevant where a change in census methodology is being considered.

(i) Analysis of information

B.63. The analysis of existing census/demographic and contextual data is a critical step in the decision-making process, and several types of approach may need to be conducted. Two key approaches are described here either (or both) of which can be used as the basis for making a decision on new technology. The results would also provide valuable information for preparing a justification for transferring to new technology, and especially for convincing the government and stakeholders about the value of the new approach.

a. SWOT (Strengths, Weaknesses, Opportunities and Threats) Analysis

B.64. SWOT analysis is commonly undertaken and is a widely recognised tool for gaining a better understanding of the balance between the benefits, risks and challenges present in the introduction of a new process, and one that is particularly relevant when faced with the rapid changes taking place today in technology. The four elements of the analysis encompass the concepts of:

- *Strengths:* those characteristics of the new process or methodology that give it an advantage over others
- *Weaknesses:* those characteristics which put the process or methodology at a disadvantage compared to others
- *Opportunities:* those elements of the process or methodology that can be exploited to its advantage or the advantage of others
- *Threats:* those elements that create risks, or present challenges, to the process or methodology

B.65. In applying this analysis, agencies should identify the strengths and weaknesses of the adoption of either handheld devices or an Internet-based approach on the basis on the information collected of the type described in the previous section. Also, the potential opportunities and threats that could arise from either internal or external factors should be identified in order to assess if the new technology is viable and practicable, and what challenges and risks are incurred.
SWOT analysis might be the most appropriate method for evaluating the pros and cons of the adoption of electronic data collection technologies compared to the current data collection mode. This analysis should give a clear idea about comparative advantages and disadvantages of adoption of new technology throughout whole census processes by considering its impact on cost and time required for each phase of the census operation. This analysis should also take into consideration the benefits of such technological investment in modernizing the national statistical system more generally and its possible impact on other government programmes and services.

b. Cost-benefit analysis

B.66. Cost-benefit analysis is very useful method to compare the total costs of a project with its benefits. This method is often used when different options are being appraised and compared, as a means for choosing the best approach. The method assumes that a monetary value can be placed on all the costs and benefits of a programme, including tangible and intangible returns to other people and organisations (stakeholders) in addition to those immediately involved. As such, a major advantage of cost-benefit analysis lies in forcing decision makers to explicitly and systematically consider the various factors which will influence the strategic choice. Cost Benefit analysis take into consideration other factors beyond just monetary such as societal benefit, risk, impact on participants as well as survey result.

B.67. Cost-benefit analysis can be used as a tool for explaining the benefits of adopting an electronic data collection technology by comparing its cost with the costs of current data collection mode but also including an assessment of benefits and risks. If a multi-mode data collection methodology is an option, the cost estimates, benefits and risks should be determined for each type of data collection method under consideration.

B.68. Cost-benefit analysis can be undertaken based on the information collected or generated in the way described in the previous section. While some of the benefits generated through the use of a technology - or multi-mode option - can be readily quantified such as the reduction in questionnaire printing costs, the improvement in data quality and timeliness, the value of other benefits (such as the positive impact on the agencies reputation) can be more difficult to measure but are nonetheless important and should also be assessed.

B.69. Countries can use a variety of items for calculation of costs. An example from the 2017 Ethiopian census case is shown in Box 1 below.

Box 1. Cost-benefit analysis for conducting a digital census: The Ethiopian Case

Box II.14 Cost-benefit analysis for conducting a digital census: The Ethiopian case

The Central Statistical Agency of Ethiopia (CSA) is in the process of preparations for the fourth population and housing census scheduled for November 2017. The census results are eagerly awaited by government and the private sector for informed decision making. To cater to the demands for timely census data, CSA is contemplating to conduct a digital census. The tables provide a summary of the cost and benefit assessment prepared to aid decision-making. Reflecting the situation existing in the country at the time of drawing up of census plans, the first table presents information on estimated direct costs and benefits while the second table provides information on indirect costs and benefits vis-à-vis paper-based and digital censuses.

Table 1: Estimated direct costs for scanning and digital data capture in the 2017 PHC of Ethiopia (in US Dollars)[1]

Cost components	Scanners	Handheld devices	Remarks
Capital cost of software and hardware, including spare parts	3,798,000	28,000,000	140,000 tailor made device
Printing scannable questionnaires	3,783,000	-	Printing questionnaire, manuals
Vendor support costs	1,142,000	130,000	Local & international consultants/firms
3G dongles	-	2,300,000	46,000 dongles; one per supervisor
Telephone and Internet airtime	74,000	460,000	Flat fee of USD 10 per device
Salary of processors needed	2,187,000	200,000	Staff training, salary and allowance
Payment for enumerators and supervisors	26,000,000	17,300,000	Daily subsistence allowance
Stationary, bags, etc for enumerators	2,057,000	-	
Transport /freight cost	392,000	120,000	Distribution and collection
Storage and documentation	955,000	250,000	
Total	**40,388,000**	**48,760,000**	

(ii) The components of decision making

B.70. Based on the results of the analyses above, once all the facts have been assessed, the decision can be made on the technological option(s) that provides the most appropriate and cost-effective solution for the country.

B.71. Main components of the decision are:

(i) **Data collection mode(s)**: Understanding the data collection mode (or modes if a multi-mode approach is decided) is one of the first considerations. Where the data is to be collected via a household interview, will PAPI, CAPI, CASI, CATI or some combination of these be adopted? And, what devices will be most suitable for each mode (for more information about data collection modes, see Chapter B).

(ii) **Selection of hardware and software**: Types of hardware (such as servers, handheld devices, tables or smartphones) needed for census operations should be decided. Hardware will usually be acquired from external suppliers through a procurement process, but agencies may wish to build appropriate software and applications in house rather outsourcing. Commercial off-the shelf (COTS) or open source software is, today, typically configurable to particular work flow requirements and may be a more cost-effective that an in -house solution. Agencies may wish to weigh the pros and cons of alternative solutions for data collection application. In doing so they should consider the following questions before making their decision:
- Can COTS or open source software meet the needs?
- Can the COTS or open source solutions integrate with existing systems?

- Is the COTS or adoption of open source applications within budget?
- Does the staff have sufficient technical proficiency?
- What are time constraints? Remember building software takes time.
- Does custom-built software offer increased productivity compared with COTS or open source software?
- Will the system be scalable?

Building customized software can unlock benefits, but agencies should only pursue this strategy if they can spread the cost of a proprietary system over a large number of users, have the ability to maintain the system and be able to provide appropriate security, stability and scalability needed for the organization.

(iii) **System development**: Understanding and balancing an investment in refreshing or updating existing systems compared to modernizing and replacing these with a new system will be a key to success. Also, consideration should be given to the method of application development and the capacity to take on technology work such as building customized applications from scratch to suit census purposes that are not otherwise available. It is important to consider modern IT architectures and platforms that offer configurable application environments which can often help avoid costly customized application development (For more information, see section 4 on IT systems and development in Chapter F).

(iv) **Organisational structure**: In this stage, there should be decision on how to manage census project. Is there a need for restructuring organisation? What would be management structure of census project? What new skills are needed? How can the existing capacity be developed (For more information, see section 2 on Institutional Capacity Development in Chapter F).

3.5 Documenting decisions and evaluation

B.72. Decision-making is a fundamental part of adoption of any new technology in the census, as the overall census design will be affected and other processes necessarily reconfigured and implemented as a result of the decision made. Therefore, statistical agencies should clearly document the discussions and procedures followed at each stage during the whole of the decision- making process from start to finish. Each stage of this process should be described by linking all decisions with relevant documents. For more information about documentation of census experience, see UN Principles and Recommendations (UN, 2015, paragraphs 3.468-3.472)

B.73. Systematic recording of this process will be very useful document for designing and implementation other census operations affected by the decisions, and crucial if there is a need for revising the decisions during later stage of census planning if the conditions/requirements underlying particular decisions change. As important (if not more so), such documentation provides a vital component in the subsequent evaluation of overall census operation, and for recording the lessons learned for the next census.

5. Management structure for decision making

B.74. Another important issue to settle during the decision-making process is to determine how and by whom the decisions on new technology will be made. These should never be the sole responsibility of a single person or single group of people. Instead such decisions should be reached after discussion and consultations both with managers within the agency and with a variety of external stakeholders including technical experts, subject specialists and end users (both in the public and private sectors) who can offer diverse strengths and expertise. With this approach, multiple individuals/teams will participate actively in assessing the current situation, in evaluating the needs, and in determining the costs and benefits of the use of electronic data collection technologies.

B.75. The adoption of new technology in censuses requires strong project management expertise and capacity for change management. Therefore, adequately competent, experienced, motivated and knowledgeable staff should lead discussions on the benefits of such technology weighted against its costs and risks.

B.76. Managing the decision-making process is a challenge in any census, but particularly so when it involves technological decisions being made for the first time, and even more so if there is no experience in other statistical operations. Managing this process with staff who themselves have never had experience using handheld devices and Internet for data collection purpose will require a significant amount of time to determine whether this option is viable. Thus, there is a strong need for the agency to develop both the capacity to understand the needs for the adoption of new technology and the means for establishing a good collaboration with external stakeholders.

B.77. The management structure will vary significantly from one country to another depending on the existing organisational structure of the national statistical agency. A generic management and administrative structure of a typical census operation is set out in some detail in the UN Handbook on the Management of Population and Housing Censuses, Revision 2 (see paragraphs 2.92-2.176). This highlights that it is important that the management structure for the decision-making process should be based around a small group of experienced or knowledgeable senior staff. Preferably, there should be a three-level structure consisting of a high-level decision-making body, an advisory board, and technical working groups consisting of specialists in different areas. Their composition should include:

(i) **The high-level management group** would be responsible body for making the decision whether or not to use handheld devices and/or Internet and/or paper questionnaire. This group should consist of managers/specialists on IT, census methodology, field operation, mapping, procurement/outsourcing, budget, logistics and representatives from related stakeholders.

(ii) **An advisory board** on technology would be responsible for reviewing types of technology available in respect of both hardware and software, good practices in the use of such technology, and market research for possible technological options and costs.

(iii) **Technical working groups** would be formed for specific areas such as IT, census methodology and field operation, census legislation, budget, procurement/outsourcing, logistics, etc. These groups would be responsible for undertaking the more detailed research for possible alternatives, evaluating the impacts of using handheld devices and/or Internet on census procedures, testing, estimating costs, evaluating challenges/risks, making suggestions to high level management group.

B.78. Another issue that might be relevant to the management structure of the census is to decide if there is a need to change organisational structure itself. It is sometimes the case that the adoption of a radically different methodology offered by the application of new technology has a significant influence on organisational structure because of change in job description and roles of staff involved. Therefore, a need for reorganisation of the statistical agency – or at least the census office components of this - and how to structure it should be discussed in good time for any necessary implementation.

B.79. It should also be highlighted that having a vision at the high level for the modernisation of the statistical system in a country is likely to exert a positive influence on any decision to adopt the use of electronic data collection technologies in its population and housing census. It is generally accepted that use of new technology is a strategic enabler of all modernization activities, such as process automation, method innovation, and information and data-management capabilities. In this context, building a vision for paperless data collection would help to develop a sustainable programme for the national statistical office including its census programme. This could then provide a good opportunity for building infrastructure and capacity for the adoption of advanced technology in all relevant statistical areas, bearing in mind that whatever method is used in the census operation requires a big budget.

Chapter C - Data Collection with Handheld Electronic Devices[2]

1. Introduction

C.1. Rapid advances in information and communication technologies are revolutionizing the way data, and particularly census data, are collected in the field. Recent advances, particularly in handheld computing devices and mobile connectivity, have resulted in new approaches for collecting data in ways that are faster and collect data that is of higher quality than traditional paper-based methods, offering a large potential for integrating these new methods to strengthen national statistical data collection programmes. Handheld electronic devices, such as tablets, PCs, smartphones and Personal Digital Assistants (PDAs), have demonstrated potential to improve data quality and reduce data collection time. These technologies show promise for improving data quality and timeliness even in environments with challenging institutional capacity and with limited infrastructure in terms of electricity and mobile connectivity. They are rapidly becoming the standard in field-based data collection.

C.2. The transition from the traditional data collection method of using paper and pencil (PAPI) to Computer-Assisted Personal Interviewing (CAPI)—which entails the use of electronic questionnaires administered via handheld electronic devices in face-to-face interviews—is motivated by the advantages derived from the use of these technologies in terms of efficiency, effectiveness and data quality. Compared to the traditional paper-based process with subsequent transcription to a centralised computer system, the use of handheld electronic devices offers immediate digitization of data at the point of collection. This allows for faster and automated data aggregation.

C.3. For statistical agencies planning large scale data collection operations such as the census, CAPI has become an alternative with sizeable benefits to the traditional PAPI techniques in terms of improving the quality, relevance and timeliness of the census. However, the introduction of CAPI will have an impact on the entire census process, and its implementation will create various challenges in census operations. The benefits associated with the successful introduction of CAPI-based data collection in the census cannot be realized without a strong commitment from the statistics agency to move tactically and strategically towards technological systems. As has been noted in Chapter C, the decision to use CAPI instead of PAPI is an important one and should not be taken lightly. The decision should begin in the initial census planning stages and be made in consultation with all stakeholders and with a clear understanding of the technology and assessment of the operating environment in terms of institutional capacity, infrastructure and terrain. Census agencies should undertake an evaluation well in advance of the census to determine whether these technologies are appropriate for their own situation. To the extent possible, the determination as to whether this technology meets the needs of a census operation should be based on information generated by hands-on experience and field tests.

C.4. There are both advantages and challenges to using CAPI which should be weighed carefully. It is important to consider the practicalities of using handheld electronic devices, such as cost, institutional readiness, electricity supply, Internet availability and speed, and how much time is available for the census enumeration. Preparations for a census using handheld electronic data capture may require more time than for a paper-based census, especially if the technology is being used for the first time.

[2] Note: Presently we are using the term “handheld electronic devices” but the use of the term “mobile devices” is also under consideration. A decision as to which term to use will be made after additional consultation.

1.1. Advantages of using handheld electronic devices for data collection

C.5. There are many benefits to using CAPI via handheld electronic data collection devices. First and foremost is the improvement of data quality due to such factors as the ability to apply internal validation checks and automated routing. When data are readily available for assessment by field supervisors and the data processing team at headquarters immediately after collection, errors in fieldwork can be corrected and changes in procedures, if needed, can be implemented quickly. The most important benefit to using tablets or PCs for data collection is that the software guides the interview and generally improving the interview experience for both interviewer and respondent primarily because it is easier to administer the questionnaire and ensures better data quality. Experience has shown that CAPI enhances the quality of data and delivers benefits in several ways including through:

(i) *Validation checks in the questionnaire*. Internal validation checks lead to more accurate data capture as the real-time checks enable errors and inconsistencies to be resolved with the respondent at the time of the interview. They also enforce basic business rules for data collection by ensuring all compulsory fields are captured and violations of the questionnaire's routing scheme are rectified through error messages that allow the interviewer to investigate inconsistencies.

(ii) *Automated routing*. This leads to a more accurate and speedy progression through the questionnaire and to the reduction of errors due to missed responses, the avoidance of irrelevant questions or incorrect skip patterns, and reduces the time spent correcting data after the fieldwork. With each enumerator being able to conduct more consistent interviews following the same sequence of questions, a more consistent set of responses will result.

(iii) *Automated coding*. The provision of response options, where appropriate, in the form of pre-coded drop-down menus can speed up the interview time as well as lead to the capture of more precise responses. Drop-down menus that are altered dynamically, depending on previous responses, can ensure that the interviewer is never presented with an impossible response ~~code~~.

(iv) *Customisation of questions.* This and the ability to preload responses can make the interview smoother and shorter. The ability to 'fill in' a piece of data from the device's memory by the data capture software and the insertion of that data, such as a name or a date, in the response to a subsequent question can improve the accuracy of collected data.

(v) *Reduced data entry errors*. Such errors that inevitably occur when capturing, coding and transferring data collected paper questionnaires during data processing can be eliminated.

(vi) *Time and cost reduction*. This can be achieved by reducing the amount of post-enumeration data checking. The elimination of paper questionnaires reduces printing, transportation and storage costs. With CAPI the data are immediately available for editing, imputation and validation once the fieldwork is completed. This means that the subsequent analysis can begin sooner and results will be available earlier. However, the increased equipment costs may outweigh the savings (see section on "Challenges of using handheld electronic devices for data collection" below).

(vii) *Reduced number of unlinked forms*. These are commonly encountered in PAPI operations. CAPI also reduces the risk of one section of the form getting separated from the others where they are printed in different pages of a paper questionnaire.

(viii) *Improved field management.* The ability to monitor the performance and progress of enumeration activities in real time can be used to better supervise field operations. Daily data transfer offers a stronger feedback loop between interviewers and the field management team than is the case with paper questionnaires. The ability of managers to provide relevant and rapid feedback to the interviewers, improves both data quality and coverage. Prompt feedback also motivates interviewers to track their own progress toward targets more effectively.

(ix) *Added features*. Electronic data capture allows users to take advantage of value-added features that can be programmed into handheld devices, such as integrated Global Positioning System (GPS) and digital mapping capabilities, computerized case management, and built-in instructional and help materials for enumerators. A range of operational information (GPS

coordinates, data and time stamp for start and end time of interview) captured through these added features can be used to monitor operations, control quality and provide logistical metadata.

(x) Ease of handling. Handling and use of handheld devices is straightforward and more convenient to carry compared to bulk quantities of cumbersome paper questionnaires, particularly in remote areas, difficult terrain or poor weather conditions. Such devices can also be used in low-light situations enabling interviewers to be able to work during evening hours, that could be a challenge with paper questionnaires in areas with limited electricity coverage. Moreover, use of these devices can also facilitate questionnaires in multiple languages not practicable with paper questionnaires.

(xi) Positive perception of respondents. Respondents might show a more positive and cooperative attitude towards the census through use of up-to-date technology in the data collection process. Some respondents might also have a greater trust in the electronic process in protecting confidentiality than in paper-based forms since the electronic versions cannot be readily seen by others.

1.2. Challenges of using handheld electronic devices for data collection[3]

C.6. Although the use of handheld electronic devices has many benefits, the innovation is not without its challenges. There are also costs and risks associated with using CAPI instead of a paper questionnaire. Among the major challenges of implementing handheld devices for large-scale data collection operations are:

(i) High equipment costs with limited long-term use. A census generally employs a large number of enumerators and purchasing a mobile device for each is costly. In addition, the equipment is likely to become obsolete quickly so that it cannot be utilised in subsequent censuses. As has been noted earlier, such additional costs need to be carefully assessed against the benefits listed above. The risk of devices getting lost, stolen, or broken during the census enumeration also presents a challenge.

(ii) More time may be needed during the preparation stage. Preparing for a census using handheld electronic devices requires more time for the procurement of the hardware, programming the application, setting up systems for data transfer and storage, and the extensive testing necessary for a successful implementation, especially if the technology is being used for the first time. But even prior to this preparatory stage, the decision to move to a CAPI technology is not a quick process and can often require years of research and evaluation.

(iii) The need for sufficient technical expertise and support. The adoption of a CAPI methodology requires not only skilled technical staff who are able to do sophisticated programming specific to the handheld electronic device (such as, Android) and all the necessary components of an electronic questionnaire application, but also technologically skilled enumerators with appropriate training. Enumerators need to be familiar with, and competent in, the use of the handheld devices. Field supervisors and headquarters staff will also need more costly training on the use of these devices, as well as on the means of monitoring and managing a more technically-oriented data collection operation. There is also a need to provide technical support in the field to replace or repair devices and to resolve hardware or software application problems that could interfere with enumeration or cause loss of data.

(iv) Physical safety and security. The safe storage and transport of the devices during fieldwork and their protection from theft or damage due to handling and from the particular environmental challenges present. Back-up systems are therefore required to mitigate against any such loss or damage.

(v) Privacy and confidentiality. Although the utilization of CAPI may in fact afford greater levels of privacy to the respondent than is offered by paper questionnaire, this may not necessarily be the public's general perception, which may be more influenced by previous examples of data disclosure resulting from other computerised processes. It is important therefore for respondents to be thoroughly assured of the confidentiality of data once collected.

[3] Adapted from material by the US Census Bureau: New Technologies in Census Data Collection. Part 1: Planning for Mobile Data Capture.

(vi) *Infrastructure constraints*. A reliable national supply of electricity needs to be available to charge the devices, while limited Internet availability may cause difficulties in data transmission and other functions of the mobile data capture software applications. A realistic assessment of Internet connectivity in all areas should be conducted during the planning stage. A system to transfer the data from the handheld devices in a timely and secure manner also needs to be provided; this could be the Internet, local area network, or through manual data transfer.

2. Planning considerations for implementing data collection with handheld electronic devices

C.7. Adopting the innovative tools of electronic data collection requires careful planning. The success of any electronic data collection depends on sound strategic, operational and managerial planning as well as a well-designed institutional environment. Plans should be made based on a realistic assessment of the effort and costs required, including accurate estimates for training, maintenance and associated costs, and should be made early enough to provide sufficient time for preparation and testing, taking into account any existing in-house experience in digitization of enumeration areas and ongoing surveys to determine what will and will not work in the country. It is recommended to build capacity and skills with handheld data collection in smaller surveys or smaller field tests before deploying them in large-scale operations such as a census. The design, programming, testing and deployment in the field of these collection systems need to be adapted to the exigencies required in conducting large-scale data collection operations. Prior to the deployment of the technologies in the field, several pilot exercises using the selected or developed devices and systems should be conducted to test the reliability in the different circumstances presented in the field. Such testing must be built into the project schedule, and adequate time allocated to make any necessary improvements prior to implementation.

2.1. Critical factors in planning

C.8. In order to ensure the success of the census, it is critical to identify all requirements for introducing electronic data collection technology, and to develop plans for doing so early in the census life cycle. The planning should take into consideration a number of critical factors.

(i) Census timetable

C.9. The census timetable should be adjusted to fit the needs of implementing data collection with handheld devices particularly when the technology is being used for the first time. Planning for the software development for the questionnaire, the collection management system and other related systems and tools should begin early, even before the questionnaire specifications have been finalised. With CAPI data collection, previously separate processes may be integrated, or may need to be carried out earlier in the census life cycle. For example, data collection, capture, and editing can be done simultaneously when adopting a CAPI solution. However, generally, more time is needed to develop and test the application, set up the data transfer and processing systems, and procure, program, and test the handheld devices. Given the pressure to release data soon after collection, if edit checks are to be added to the application, the edit programming must be completed before the enumeration begins, rather than programming those separately in the post-enumeration stage. Adequate preparation and sufficient time must be allocated to designing and testing the electronic questionnaire and to the overall testing and debugging the software, particularly for questionnaires in multiple languages or those in a non-Latin script. It is crucial to ensure that the question flow and skip patterns function correctly before using them in the field. Furthermore, sufficient time should be allotted for training the field staff (both interviewers and supervisors) to include the proficient use of the handheld devices.

(ii) Budget considerations

C.10. The adoption of any new technology presents challenges and should be considered only after costs and benefits have been carefully evaluated. Cost components of electronic data collection include systems design, software development, hardware acquisition, communications, system maintenance, technical support, human resource planning, and training. Using an electronic questionnaire may save costs both in the printing of paper questionnaires and data capture, but, as noted above, the costs of the electronic equipment may be higher than the savings. It is important to carefully consider all the costs involved in introducing handheld technology and to account for them in the budget.

(iii) Differences in questionnaire development process

C.11. As with a paper questionnaire, developing an electronic questionnaire is an iterative process. Both the technical and content elements must be developed, tested, revised, and then tested again, repeating the cycle until the questionnaire works as intended. After the subject matter specialists have finalized the questionnaire content, specifications are needed to serve as a blueprint for programmers to design the application. Adequate documentation of the questionnaire design and specifications is also required. Not only does the lack of such documentation make it difficult to discuss the questionnaire with users and other various stakeholders, it also makes testing more time-consuming and error prone since skip patterns are less obvious. In addition, an electronic questionnaire has the capacity to contain additional features that are not possible in a paper questionnaire, such as data validation and error messages. These features also must be specified so that programmers can design the application as intended.

C.12. When designing an electronic questionnaire, the subject matter specialists may lose control over the wording, layout, and design of the questions, thus impacting on the statistical outcomes. Therefore, it is critical that the subject matter specialists work closely with the programmers throughout the process to ensure that there is clear communication and understanding regarding the purpose of the questionnaire content, layout and design, data validation, and other specifications. It is also important to have a good understanding about the timeline, ongoing changes to the content, data security, and quality assurance. These issues are discussed in more detail below in the section on electronic questionnaire design.

(iv) Infrastructure considerations

C.13. Infrastructure issues such as availability of electricity and Internet access can affect the success of electronic data collection. Early in the planning stage, places that lack electricity and/or Internet coverage should be identified. If there is to be a reliance on a mobile/cellular (GPRS, 3G, 4G) or Wi-Fi data connection to transmit data, it is important to research the speed of the data transmission and plan accordingly. Mapping those areas that lack such connectivity is helpful in planning. Contingency plans should be developed, for example, for charging and backing up the devices when and where electricity and/ or Internet access is not available, or even for adopting a more traditional data collection methodology in such areas.

(v) Systems design, software development, hardware acquisition

C.14. Hardware and software needs should be considered carefully taking into account the minimum requirements for both installing and operating the electronic questionnaire, in addition to any restrictions on the operating system on which it works. (Sections 1.6 and 2.3 below provide more information on hardware and software evaluation and acquisition.)

(vi) Data transfer from the field

C.15. A major part of the consideration to adopt handheld technology in data collection includes the data network infrastructure to use, whether it be cellular networks, the Internet, other types of connectivity between devices, or a combination of these. If the census operation plan calls for transmitting data and monitoring fieldwork directly from the handheld devices in the field, then a widely available (and reliable) cellular and/or Internet coverage is essential. Where the infrastructure for cellular networks coverage is poor or non-existent, mechanisms need to be developed for the transfer of data from the field by establishing multiple data collection stations with better means of connectivity to central servers at headquarters.

(vii) Monitoring

C.16. Regular, often immediate, feedback can help to resolve technological and field-related problems in a timely fashion, resulting in improved coverage and data quality. A rigorous monitoring system is crucial for achieving the collection of complete and accurate census information. Given the complexity and the hierarchical structure of census enumeration and the associated delineation of responsibilities in the field, electronic data collection programs must provide comparable sets of tools for enumerators, supervisors and managers to employ in the management of their work. (Section 7 below provides more information on monitoring.)

(viii) Data security

C.17. Data security is a prime issue (for any form of data collection); daily backup of the data should be done securely. After completing each interview, the data should be saved and secured until transmission to the central database server. Data collection via handheld devices requires investments in data security and staff training to prevent unauthorized access and the loss of sensitive personal data. Security concerns include failures in hardware and software, human error and accidents. Data transfer protocols from the field should be designed with specific security features, including encryption. (Section 4 below provides more information on data security.)

(ix) Technical skills and capacity development

C.18. Given the highly technical nature of digital data collection, careful consideration should be given to the type of expertise needed to build, integrate and implement a handheld collection system. This requires evaluating the technical skills held by, and the distribution of responsibilities among, the staff of the statistical agency, and developing training and capacity-building programmes or hiring external contractors, where appropriate.

2.2. Major items for scheduling a CAPI-based data collection[4]

C.19. As has already been noted, a typical CAPI-conducted census requires a longer time for fieldwork preparation than for the traditional paper questionnaire census due to the need for developing and testing the data collection application and the data transfer and processing systems, and for the procurement, programming, and testing the handheld devices. While the schedule of a CAPI census might vary substantially based on factors pertinent to the national context, the items (e.g. tasks and events) in a typical CAPI schedule might constitute the following:

(i) Coverage maps for Internet access and electricity

C.20. If the plans call for transmission of data and monitoring of fieldwork directly from the handheld devices, then, as noted above, the widespread availability of reliable cellular and/or Internet coverage nationally is essential. On the other hand, if frequent data transmission is not critical, or if fieldwork monitoring is conducted in the field, the need for such widespread connectivity might not

[4] Adapted from the World Bank's "Implementing a CAPI Survey with *Survey Solutions*".

be as important. Internet coverage maps will help to determine the best network provider and routing of interviewer teams to optimize their opportunities to transfer data effectively. If necessary, a combination of providers might be used to increase coverage or to develop field work routines to cope with specific locations. Similarly, information on coverage of electricity supply can assist in making provision for charging of batteries during field work.

(ii) Decision to use CAPI

C.21. As has been discussed in some detail in Chapter B any decision to adopt a CAPI (or any other electronic data collection technology) approach should be done in consultation with all stakeholders, and with a clear understanding of the new technology. A major part of this decision includes the data network to use, and whether it uses the Internet or cell phone infrastructure, or a combination of both.

(iii) Procurement of devices

C.22. The process of the procurement of the handheld devices should be started at an early stage. Prior to procurement it is important to conduct market research and engage early with suppliers in to order to better understand the technical requirements, costs and timescales. It is also important to check whether the equipment could be sourced from within the country and is compatibility with the chosen data entry software and systems. If necessary, some agencies may wish to seek external advisors for help and guidance. Other important steps could include implementing a proof of concept investigation and developing decision criteria for evaluating and selecting the technology. More guidance on device acquisition is set out in section 3.4 below.

(iv) Electronic questionnaire software development/acquisition

C.23. In terms of developing or acquiring a CAPI system, census planners have several alternative approaches from which to choose, such as:

- complete in-house development;
- outsourcing of development to external suppliers;
- customization of an existing software package;
- utilizing an existing of-the-shelf solution, whether commercial or freeware.

C.24. This decision is complex and needs to be made after taking into consideration information about the budget and availability of time, human resources (software developers, testers), and clear vision of the final product and operating system, and full understanding of the features and limitations of existing alternative or corporate systems, together with that of the handheld device to be used. Sufficient time should be allocated.

(v) Questionnaire implementation on devices

C.25. The process of loading the electronic questionnaire and associated software (e.g. collection management application) onto the devices require substantial training of technical staff or the extensive reliance on outsourced assistance. Some data entry software requires the use of programming languages, and provides extensive flexibility and power for large, complex questionnaires that are generally typical for census. Other software packages may require little or no programming but are usually appropriate only for use with simple questionnaires and sample designs.

(vi) In-house questionnaire testing

C.26. An initial test of the data entry system and associated applications (e.g. collection management application) should be conducted within the census agency, ideally by staff members who are familiar with the questionnaire and subject matter. This will help to resolve the most obvious errors and design faults prior to any field pre-test.

(vii) Training of interviewers and supervisors

C.27. Supervisors should receive the same training as interviewers to provide them with a clear understanding of the questionnaire and associated applications and the use of the devices. Training should cover not only the content and routing of the questionnaires and use of the devices, but also on data export, import, and analysis. The training specific to supervisors should clearly define their role and enable them to be familiar with the data and case management tools they will be using in the field. This will enable the supervisors to take advantage of CAPI by checking the quality and completeness of the data as they are collected. In most data collection software, this is done by either visually checking the data on the devices or using separate management software.

(vii) Field tests

C.28. It is essential that there should be the opportunity to test the handheld-based data entry system under realistic, field conditions prior to any formal pilot census. Locations for the test should identified that contain a varied profile of households and housing types and different geographic conditions, and should avoid those areas that are likely to be included in any subsequent census test. Interviewers should be conducted with real households, as this will provide an opportunity to assess both the data collection process itself and the training experience for the field staff. Based on observations from this early pre-test, problems with field procedures and the electronic questionnaire must be resolved. If necessary, changes should be made to the data entry system on the handheld device. The result of this task should (hopefully) be the final version of the data entry system However, once the questionnaire is finalized the pilot census can be used to test the final questionnaire as it is to be implemented on the devices, and which can also focus on connectivity and communication issues to test the network infrastructure and ensure that interviewers and supervisors are familiar with data transfer procedures. This will ensure that all of those changes based on the first pre-test have been properly implemented and that the data can be transferred when needed. It will also ensure that all supervisors are able to provide the necessary support to their teams in the event of a technical failure in the field.

(ix) Fieldwork

C.29. As is the case for any data collection activity, when scheduling the fieldwork for handheld data collection it is important to consider the trade-off in costs between the size of the field force (and its associated hardware costs) and the time taken to complete the enumeration.

(x) Data cleaning

C.30. In this, the final step in the data collection, use of a properly designed CAPI system should minimise the data cleaning elements of data processing, since the data entry and the built-in case management systems can check for, and correct, many of the inconsistencies and errors encountered during the interviews.

3. Considerations for selecting handheld devices

3.1. Overview of handheld electronic devices for data collection

C.31. The term 'handheld electronic device' typically refers to a small device which has computing power, a display screen with keyboard and information storage along with retrieval capabilities.[5] Handheld devices today come in many shapes and sizes, but a typical device has a touch-screen interface for input and output along with a miniature or virtual keyboard. Most handheld electronic devices have an operating system and can run various types of application software. Most are equipped with capabilities for connection to cellular networks and for establishing connectivity to the Internet and other devices, such as a personal computer (PC) and other mobile devices, through such mechanisms as WiFi, Bluetooth, IrDA and near field communication (NFC). The synchronizing function of these devices allows the exchange of data with a PC or other devices such as servers. Recent developments have seen handheld electronic devices that can send communication via voice, text or email, capture and send high quality photographs and video, allow one to measure or calculate, capture and communicate location, navigate, act as an alarm clock or flashlight, turn on/off remote systems and much more. Such devices may also provide biometric user authentication, such as using the built-in camera for facial recognition or using a fingerprint sensor for fingerprint recognition.

C.32. As census agencies assess their needs, it is important to consider many of the different features of such devices for usability, durability and security. It is also necessary to understand what accessories might need to be considered such as: SIM cards and dongles for Internet connection to synchronize data and update data collection tools; power banks, solar chargers and car chargers to avoid running out of power during data collection; and, screen protector and pocket/case for tablet or other handheld devices.

C.33. The variety of devices on the market is as varied as the applications and tasks that they can perform. Among the many types of handheld devices, the most common that can practicably used in collecting census data are:

- ***Laptop (Notebook) computers*** – portable computers intended to provide the same functionality as desktop computers but with greater mobility and possibility to be used in the field. Laptops are usually equipped with the same operating system as their desktop counterparts, and execute the same software applications.
- ***Tablet computers*** – personal computing devices that trade off some peripheral functionality (such as a keyboard) for a greater portability. Tablets utilize their screens as both an input and output device, displaying an on-screen keyboard when an input is expected from the user. Only some tablets are designed to execute standard desktop software, while most are based on mobile operating systems[6] (primarily Android or iOS), and have different software compatibility requirements. Tablets may or may not have a cellular communication module, but most contain WiFi and Bluetooth modules to permit wireless communications and transfer of data over short distances. Modern tablet devices represent a fresh view on the design of a portable device addressing the limitations of PDAs and providing many more capabilities.
- ***Smartphones*** – are practically smaller tablets with a cellular communication module always included. With similar screen sizes as PDAs and UMPCs, however, many smartphones have limited utility for data collection over extended periods of time. However, they are great devices for various communication functions including Internet surfing on the go.

[5] Handbook on the Management of Population and Housing Censuses, Revision 2.

[6] A mobile operating system is an operating system that is specifically designed to run on mobile devices such as mobile phones, smartphones, PDAs, tablet computers and other handheld electronic devices. The mobile operating system is the software platform on top of which other programs, called application programs, can run on mobile devices. The global mobile operating system market is dominated by two major players: the Android OS developed by Google and the iOS (previously iPhone OS) developed by Apple Inc. and distributed exclusively for Apple hardware. Other less deployed mobile operating systems include the Windows Phone by Microsoft.

- ***Personal Digital Assistants (PDAs)*** – sized similarly to that of the smartphone, PDAs are going out of favor, since smartphones can do what PDAs do plus add telephony and data capabilities. The PDAs included most of the functionality attributed now to smartphones, but implemented it with the aid of technology such as PalmOS and WindowsCE which by now are mostly obsolete or no longer supported. PDAs have been tested by many developing countries to improve the efficiency and accuracy with which data is collected, but they did not become widely adopted as the technology at the time was deemed expensive.

C.34. Other devices include *phablets* as an intermediate category between smartphones and tablets but which are hardly distinguishable from them in terms of relevant functionality. *Mobile phones* (limited in capabilities in contrast to smartphones) also have some utility in data collection. There is a growing community of development agencies and practitioners using mobile phone-assisted personal interviewing, referred to as MAPI and running on Java applications, for data collection purposes, especially for monitoring and evaluation. Such tools could hold promise for smaller statistical surveys collecting a limited amount of information for which high frequency collection could be useful. *Ultra-mobile PCs* (UMPCs) are another category of mobile devices with some utility for data collection. They are mini computers with touchscreen/stylus/keyboard input options. With 7 inch or smaller display screens and weighing less than 2 pounds, UMPCs are true pocketable devices and offer traditional or full-fledged operating systems like Windows XP, Vista, and Linux (although some UMPCs run Windows CE and other specialized operating systems). UMPCs offer broader traditional or general-purpose application support than smartphones, and a much smaller form factor than laptops or netbooks. They also have less battery life and smaller screen, however, and demand premium prices due to their small size and lower market demand. However, like PDAs, UMPCs are also becoming obsolete.

C.35. The requirements of the particular device that would best suit the business needs of the census agency would need to take into account: device specifications (such as processing speed, display size, ruggedness, memory, connectivity options, battery life, alphanumeric keyboard, etc.); potential application for various aspects of census operations (for example, for integrating census maps and collecting real-time data for field management and supervision of field enumeration); budget availability; and the required accuracy for the fieldwork application, especially if GPS functionality is important.

3.2. Features of handheld electronic devices

C.36. As census agencies assess their needs, it is important to consider many of the different features of these devices for usability, durability and security. When selecting a mobile device for the purposes of the census, important features that should be understood and sized appropriately to need include:

(i) Processor/performance

C.37. The central processor units (CPUs) deliver computational power to the device, the speed and capabilities of which determine the responsiveness of the device and ultimately the interviewer's performance. New models of CPUs are developed annually, but since they are not user-interchangeable, the CPU that is included with the device will stay with it for its operational life. This should not impact on the census data collection operation. The nominal speed measured in terms of the number of elementary operations per second be only an approximation of the actual device performance, since a particular application may utilize some, but not all, capabilities, and also interacts with memory and storage. However, better CPU performance generally translates into better application responsiveness, and permits the conduct of more complex checks on-the-fly. Multiple computational cores contained in contemporary CPUs generally improve responsiveness of the tablet by handling background computations and parallel applications.

(ii) Operating system

C.38. A mobile operating system (OS) is software that allows handheld devices to run applications and programs. A mobile OS typically starts up when a device powers on, presenting a screen with icons or tiles that present information and provide application access. Mobile operating systems also manage cellular and wireless network connectivity, as well as phone access. In considering the handheld device dynamics, the operating system makes one of the biggest differences in the performance of the device. It should therefore be assessed at carefully when making the choice of device. The applications and features that a particular device is able to run depend highly on the capacity of the operating system. The selection of the OS should take in to consideration the technology planned to be used to develop the data collection application as not all development languages are cross-platform but platform specific (OS specific).

(iii) Storage capacity

C.39. Most of the modern tablet devices will have no problem storing the responses to hundreds of interviews at a time, which should be more than sufficient to capture the enumerator's normal workload. However, if any multimedia features are employed (recording images, audio or video material for example), this may expand the footprint of the database significantly, and the size of the database should then be taken into account. The actual size can be determined experimentally, by completing mock interviews and observing how the size of the database changes. If the software permits the storing of interview data on an external media, such as a removable memory card, this removes most concerns regarding any overflow of the storage, but, in turn, creates data security and integrity risks. It is recommended to save this data encrypted. To ensure continuous availability of storage, the system should erase the locally stored content when it has been transmitted to the server and free up the memory space used for it on the device.

(iv) Keyboard

C.40. Tablets and smartphones do not usually contain a physical keyboard, though most permit an external wired or wireless keyboard to be connected, for example, using a Bluetooth connection. Commonly, however, the on-screen keyboard is utilized for data entry. The bigger the screen the more convenient it usually is for the interviewers to type using an on-screen keyboard thus completing interviews faster and with fewer typing errors. Modern data entry algorithms predict the words being typed based on the previously entered content, perform spell-checking and utilize other techniques to speed up and make the input more accurate even on smaller devices. The length of the questionnaire and the question types (e.g. many questions requiring text responses) could influence the type of device and keyboard that should be chosen.

(v) Screen

C.41. The larger is the screen of a tablet, the more information it can display, or make it more readable, but at the same time larger screens consume more power. Large screen size also increases the weight of the tablet, especially if it comes with bigger battery, and the chances for damage during transportation and use. The quality of the screen for a given size is usually summarized by the resolution, color reproduction, and screen glare. If the interviewers primarily work with textual information, the latter characteristic may be more critical, as high screen glare may result in tablets not being usable in bright sunlight, or the screen brightness to be maxed out resulting in higher battery drain and shorter life. However, if the devices are used to their full potential and maps are used by the interviewers, all three characteristics may be important.

(vi) Battery

C.42. All portable devices contain a battery (or sometimes multiple batteries), either fixed or removable. Besides the main and obvious characteristics of capacity, agencies should pay attention to

the number of recharging cycles, speed of recharging, and, in some cases, working temperature limits. Typically, older batteries may experience a lower performance after a prolonged storage time, even if the devices have not been used. The battery capacity may be indicated with mAh or in number of hours that the device can operate on a full charge until shut down. Note that the manufacturer's measurements are commonly under some 'ideal' conditions, which may not hold in the field due to such factors as screen brightness, attached external sensors, wireless networking mode, etc. A calibration test of one or several devices may help determine the actual duration of the battery life.

C.43. External batteries (also known as power banks, USB-chargers) with USB charging jacks may be used to supplement the main device battery and extend its battery life. They are available from various manufacturers and vary greatly in their capacity, quality, and technology used. While the smaller power banks may provide emergency power for a few minutes – sufficient perhaps to finish an interview and close all applications - larger ones can sustain a tablet for days, with their capacity reaching multiples of the device's own power storage.

(vii) Connectivity and communications

C.44. Embedded connectivity modules facilitate the exchange of data between a handheld device and a server directly or through a network. Most tablets, for example, will have a Wi-Fi and Bluetooth modules integrated, with other connectivity options available as add-ons. Both Wi-Fi and Bluetooth are short-range technologies, providing connectivity within a limited range (10-30 meters typically). A cellular module (GPRS, 3G, 4G, or other applicable standard) may facilitate transfer to larger distances utilizing cellular towers and networks, but availability of cellular signal in any particular location within an enumeration area depends on the coverage. A cellular module may add significantly to the price of the device, but its presence is often desirable due to added flexibility for transmitting data from the field. Wi-Fi is the most common way of accessing the Internet from a tablet device, while Bluetooth connectivity is crucial for connecting external sensors, such as GPS.

(viii) Portability

C.45. The larger the screen or battery that the device carries the heavier it becomes and more cumbersome to carry around. Similarly, the more metal parts that are used in their bodies so they become more robust, but even heavier. The balance between weight and utility therefore needs to be assessed. A smaller physical size of the device is an advantage when fieldwork is to be conducted in particular areas either where the terrain or environment is challenging, or where there are particular security risks and where hi-tech devices may attract unnecessary attention or put the enumerator's life in danger.

(ix) Ruggedness

C.46. As consumer devices, typical tablets (if these are being considered) are fragile and hardly protected, but specialized models are available from manufacturers to address common vulnerabilities: screen protection with specialized film, plastic, or reinforced glass cover; rubberized buffers for corners and edges to defend against cracks, plugs for power, audio and other sockets to protect against sand, dust, and moisture, etc. This protection is usually available in the form of a specially manufactured device, or a do-it-yourself (DIY) kit to protect a device made by a third party. When a handheld device is lacking adequate protection and no specialized protection kits are available, generic cases/bags/pouches may be acquired to protect and/or conceal the device. In some cases, they can double as a sun shade to reduce screen glare.

(x) Location sensor

C.47. Many modern handheld devices, particularly tablets, include a location sensor, typically based on the US GPS system, or its Russian GLONASS equivalent. Some tablets can query both to improve

the estimation of its position, which is typically within 5-15 meters range in clear sky conditions. External location sensors are available that can be connected to a tablet or laptop via Bluetooth or Wi-Fi to achieve greater positional accuracy, with some manufacturers promising sub-meter precision. However, tablets that are GPS enabled are preferable to those that add on a separate GPS tool as it could be difficult to merge data collected with standalone GPS with data collected with the mobile device.

(xi) External sensors and peripherals

C.48. Most handheld devices are largely self-sufficient, having all the functionality to collect data for a census or a survey, but occasionally there may be a need to connect external sensors, such as location sensors, external cameras, etc. Typically, these devices are either replacing the similar sensors built into the device delivering better performance, or provide some new functionality. For example, an external camera may produce better quality images than the camera built into the device, or a keyboard or a mouse may also be connected. New functionality may be provided by, for example, a fingerprint sensor, infrared heat-sensitive camera, temperature sensor, etc. These specialized sensors are unlikely to have an application in census data collection, but the possibility of connecting and using them may be an important consideration for any subsequent use of the devices for other data collection activities.

C.49. Other important considerations include: the device's support for multiple local languages (non-Latin) needed for displaying questions as well as for data entry; and, the period of warranty covered by the vendor for the devices; it is desirable for the warranty to cover the time period needed to carry out the census.

3.3. Evaluating requirements for selection of handheld electronic devices

C.50. The UN Census Management Handbook elaborates on some of the general factors to take into consideration while evaluating hardware (and software) for census operation needs (see UN, 2016, pp 89-94) including:

- Fundamental to the adoption of any technology is understanding the purpose to which it will be put and how the purpose fits into the overall census plan. Fully understanding the system requirements will make the acquisition decision and the trade-off between functionality and cost easier to establish.
- The budget available to the project is also a vital factor in making decisions about hardware and software.
- Before agencies commence the formal processes of evaluating and acquiring software and hardware, they should take the opportunity to research and investigate other organizations' experiences with similar systems. During this period, it may also be possible to acquire versions of software and/ or hardware that can be used for testing purposes. This will allow agencies to become familiar with, and better understand, the potential and/or limitations of particular systems. This experience can be valuable when developing evaluation criteria.
- Evaluation criteria need to be drawn up before the hardware is acquired for evaluation. Before the evaluation takes place, specifications must have been drawn up to describe clearly the requirements for the hardware, and suitable hardware acquired on the basis of a tender or direct purchase, if there is only one possible supplier. The requirements for evaluating hardware for census operation will depend on the nature of the hardware, its complexity and any links with existing hardware or software, and on whether it will be reused in other statistical data collection programs.
- An evaluation team should be set up to carry out the evaluation. The number of people involved in this team will depend on the complexity of the hardware, the number of different hardware configurations to be evaluated and the resources available. The members of the evaluation team must have the necessary knowledge to be able to make a valid, consistent and unbiased assessment of the equipment—from both a technical skills perspective and the ability to manage an objective evaluation process over time. It is

important to remember that, despite what performance promises may be made by vendors, any decision to implement this new hardware must be based on full evaluation.

C.51. The evaluation of the requirements for hardware should be part of the decision-making process on the software platform to be used. The chosen devices must be compatible with the software being used and provide adequate performance. This is easier to achieve with an off-the-shelf option, where minimal hardware requirements usually accompany the software, but more difficult for in-house developed software, where development typically starts years before the devices are procured, and, consequently, where it is hard to predict how the technology market will develop.

C.52. Typically, the minimal requirements for the hardware are different from the optimal requirements, and this should be recognised in the procurement process. It is not sufficient to simply copy the minimal requirements from the software documentation into the tender specifications, but rather a working group or review body should be formed which would conduct a critical examination to determine where more capacity should be reserved for the particular case.

C.53. One of the errors in formation of the teams for evaluating the requirements for the handheld devices is to delegate this decision only to the IT department of the statistical office on the grounds that this is a hardware IT issue. Instead, those responsible for determining the topic content of the census should also take active part in the discussions, since they will probably have a good vision of the intended application and user requirements for the use of this equipment. The IT department can play a useful role by raising important questions on the device quality, hardware specifications and compatibility with the expected features as well as the operating system.

C.54. Another error that statistical offices may be prone to is blindly copying the practice of another country. The technological developments in this arena have become so rapid in recent years, and an optimal solution adopted by one country may be inappropriate, or even completely inefficient, in only a few years or months later. While the country's own, and international, experience may remain valid inputs in the decision-making process, they should not constitute all of it. Instead, a search for new alternatives and independent examination should be performed to strengthen the decision-making process. The working group should examine both the needs for particular features and their availability in the contemporary devices, and their associated costs.

C.55. Through a careful evaluation of requirements in the selection of any one device, the census agency can better ensure a good outcome in the data collection process. While hardware features are important, it is equally important to consider the full handheld device network environment as the evaluation requirements are established. This includes the need to take account of the security systems that will be used for data in transit (for example, VPN, VoIP, Web Browser).

C.56. Some of these components are bundled as part of the handheld device by the manufacturer, while others are developed by third parties, and must be separately validated. Additional applications that may come pre-installed on the device, and which are not validated, could potentially cause issues, and should be assessed as well.

C.57. To best meet the agency's needs, it is important to understand the use case as well as the users. Some typical use case scenarios include:

- Agency-owned device for general-purpose corporate use and limited personal use
- Agency-owned device for specialized high-security use only
- Personally-owned device for personal and agency use (often referred to as 'Bring your own device' - BOYD)

C.58. Most census agencies that adopt electronic data collection, use their own high security-protected devices since the data being collected contains personally identifiable information and is

often of a sensitive nature. The risk of inadvertent disclosure must therefore be kept to the absolute minimum.

C.59. While it may seem that BYOD is an attractive option (on costs grounds), it brings with it many challenges. Handheld devices are prone to the same sort of threats as traditional computer systems, as well as some that are unique to their mobile nature. With a BYOD approach, the agency's IT staff must manage many different types of device with varying specifications and requirements. Organizations who wish to adopt a BYOD policy must therefore consider how they will ensure that the census information transmitted to, or accessed from, the organization's network infrastructure by such devices will be protected from malware. With BYOD, there is a risk that confidential information will stay on the device after the collection is completed. Another concern with BYOD is that there is more chance that respondents will think this is fraud since device may not look "official". Also the device may be old and it may be required to charge the battery more often. No matter which type of use an agency is thinking of implementing, it is important to lay out clear security guidelines and objectives. Risks to data on a handheld device can result from insider intrusion, direct attacks, malicious software, physical loss or theft. To manage this risk, certain safeguards must be put in place including authentication, encryption, remote device wipe, device firewall, and management and application controls.

C.60. Following are the suggested criteria to be considered in any evaluation of the device(s) being considered. They fall into four major categories:

Security criteria

- Power-on password – a password is requested when unit is powered on
- Content encryption – the device has ability to encrypt information
- VPN to agency – the device can securely access a virtual private network (VPN) infrastructure either natively or with software applications to connect the user to the agency.
- APN (Access Point Name) – capability to configure mobile device with APN to make a data connection
- Credential store – the device stores certificates securely using industry standards and prevents the removal of credentials through any mechanism.
- Device intrusion protection – small device operating systems typically implement a 'deny by default' approach; the level to which the device can leverage malware protections should be considered

Manageability criteria

- Agency management – the device supports the agency's device management solutions
- Discovery – the device's properties can be identified at the provisioning stage and, based on that device's information, different levels of services can automatically be provided.
- Over-the-air (OTA) provisioning – the device can be provisioned and applications can be installed or activated OTA.
- Configuration enforcement – the device has the ability to identify the preferred agency configuration profile centrally, to determine how this configuration is implemented at the OS level, and to implement the deployment.
- Software delivery – new applications, updates, and line-of-business applications can be delivered and made available for downloading to employees or contractors; applications developed in-house can be offered without the need to post to external application stores, speeding up delivery times and adoption.
- Proactive monitoring support – the device supports health and status reporting and allows IT staff to provide auto-configuration options and profiles, which eliminate manual input errors for configuring services and reduce service desk calls. Information can also be used to measure configuration health; the more information the device reports, the more accurately the profiles can be made to improve services such as battery performance.

- Backup and restore – the device configuration can be identified, and the data or configuration can be backed up for restoration in case of loss.

Productivity criteria

- Intuitive user interface – the device's user interface should be intuitive and easy to use; the user should not need to read a manual to be productive.
- Tools and applications – the application ecosystem for the device's operating system is mature, providing business productivity gains.
- Intelligent updates – when a new OS update is available, the user is advised, and the update can be easily completed.
- Offline consumption – the device can access data and services that allow for review even when offline; this feature is especially important when evaluating larger screen devices.
- Fluidity of use – the device must allow users to easily switch between tasks, move data between applications, and navigate the device's capabilities without adding complexity

Performance criteria

- Battery life – the battery enables a minimum of one full day of active use before requiring charging; the 'best in class' provides greater than two days, but here is where there is often a trade-off between screen size, battery capacity, and usage.
- Responsiveness – the device powers on immediately or is always on and has little or no lag between uses.
- Application multitasking – users can move between tasks with ease and without loss of data, application state, or progress
- Camera and video – those devices with cameras should provide sufficient image quality for their purpose and provide a simple interface to access content sharing, storage, user preferences, and privacy controls.
- Screen size – the screen size is appropriate and sufficient to provide a good user experience without significantly impacting battery life
- Radio frequency – the device can operate on multiple frequencies or bands, such as four-band Global System for Management communications (GSM), Wi-Fi*, WiMAX*, 2G/3G/4G, and GPS.
- Storage capacity and RAM – the device has sufficient on-device storage and RAM, based on needs.

C.61. As with all elements when adopting a new technology, the testing of devices is always recommended. Both in the office and in field, testing of the physical hardware under real world conditions should be conducted, as well as tests that include the configuration of software and applications expected to be used. Software testing goals should ensure the software does not crash in conditions of insufficient computational resource, such as memory or space.

3.4. Device acquisition

C.62. Once a thorough evaluation of the hardware options has been undertaken to ensure that the chosen device is the most appropriate for the job, careful planning is still required to gain the most benefit from a bulk hardware acquisition. The four main options for the acquisition of handheld electronic devices are:

(i) Outright purchase

C.63. When the devices can be procured outright, the statistical office has the most control over their specifications and can thus ensure that the devices best fit the requirements for the census enumeration. However, after the end of the fieldwork it becomes the agency's responsibility either to find a way to re-use the devices in some other application or dispose of them, as they would more

than likely become obsolete within a few years, and certainly before the next census. Disposal is typically the most expensive option.

(ii) Sharing (pooling) devices among agencies

C.64. Pooling the devices between different government departments or ministries may be a viable alternative in cases where there is no central statistical office and where data collection is routinely performed by different agencies (such as agricultural censuses, health surveys, business surveys, etc.) In that event, the scheduling of all the data collection operations should be reviewed to ensure there are no conflicts that would prevent the use of the devices for the census at the critical time. Pooling the devices may reduce the cost of the acquisition to about the level of rental costs, and resolves the issue of the immediate disposal of the devices after the census, as the devices would then be re-used by other agencies. But there may be several inhibiting factors to this alternative.

C.65. Firstly, different agencies may prefer to have devices based on different platforms, or with significantly varying performance specifications, which may obstruct finding a suitable common software platform. Secondly, the devices may already have a significant legacy of stored information and configuration, which it may not be possible to preserve, and which must be cleared in preparation for the census data collection. This may incur the cost of restoring the devices to their original state and re-integrating them back to the original operating system. Thirdly, shifts in the survey schedules of different agencies are always possible and when that happens, the unscheduled unavailability of devices may increase the risks for the census data collection. Similarly, the particularly extended nature of the census timetable, requiring a long preparatory period, might risk the non-availability of the devices required for pre-enumeration testing and field force training. A final, and perhaps overwhelming, barrier is likely to be the sheer volume of devices required for the census, being so much greater than the quantity used by other agencies for their far smaller survey applications.

(iii) Renting

C.66. Renting devices for a census may be an attractive alternative when the market offers a large number of potential sources, and the simultaneous demand for the devices may be fulfilled by the available vendors. Even in such a case, it would be critical to conduct early negotiations to secure the devices prior to the census enumeration period as well as obtaining an early sample number of the devices for testing purposes. In cases where the suppliers have a range of different brands and models, it should be clarified at the outset whether a particular model or a mix of devices will be supplied, and each model should be separately tested for compatibility.

(iv) Bring your own device (BYOD)

C.67. As the proliferation of handheld devices increases there can be financial benefits as well as a reduction in training needs, if field officers can utilize their own current devices rather than being issued with a new device with which they may not be familiar. The BYOD approach can be utilized when there is an expectation that sufficient numbers of enumerators will have a compatible device already available, or when the level of remuneration is high enough to cover the cost of acquiring a new device. These two situations are not identical, since if the enumerators only get the funds to obtain devices shortly before the start of the field work, they may run into a problem of temporary shortage of the devices and have to resort to older, less capable, or more expensive devices. Furthermore, such enumerators will be less familiar with their devices. An alternative and more strict approach would be to make it a condition of employment that enumerators should have their own compatible devices.

C.68. However, finding enumerators with a compatible device may be a technically challenging task, as the field management team may have to test many different types of device for compatibility with the selected software. Another challenge could be that the enumerators are reluctant to install the

limiting software on their personal devices as this may prevent their normal use. This, however, can be resolved, again, by making such installation of condition of employment.

C.69. While the benefit of reduced acquisition costs and greater familiarity with the handheld devices among the enumerators - since these will be their own devices - may increase the appeal of the BYOD approach, a significant consideration should be given to the fact that some devices, such as mobile phones, for example, operate on different platforms, and that developing applications that would enhance communication and monitoring would necessitate developing platform agnostic applications, possibly increasing both costs and development time. Furthermore, where field staff temporarily appointed for the purpose of the census own handheld devices by virtue of their more permanent positions with other employers, the use of such devices for the collection and transmission of confidential statistical data may raise technical, security, and legal concerns. Similar concerns may exist where, conversely, where the devices are acquired centrally by the statistical agency (under the outright purchase option described above) but are given to the enumerators at the end of the fieldwork either as part payment, or for free, or with a significant discount. In this case, it would be in the enumerator's best interest to maintain the equipment in working order.

C.70. Whichever is the strategy adopted by the statistical office, it must ensure that the devices become available early enough to conduct compatibility testing and training of enumerators, which may precede the actual field work by weeks or even month. It is important that the additional time to be allocated to field preparation activities should not be underestimated. When insufficient time is allocated to the development and testing of the CAPI questionnaire, data quality may be severely compromised.

C.71. Where the hardware represents technology that is new to the agency, there will normally be a tender process to ensure that the hardware is the best solution, both technology-wise and financially. The request for tender must be compiled carefully, with due regard to the legal requirements of the agency itself and to more general government policies and rules, including ethical and probity considerations. A detailed specification of requirements must be prepared before the tender document is released or panel suppliers are contacted. The UN Census Management Handbook (UN, 2016) details some basic rules that should be followed for acquisition of hardware in (see Chapter II, Section K).

4. Data collection application

4.1. Introduction

C.72. Computer-Assisted Personal Interviewing (CAPI), coupled with the use of handheld electronic devices and connectivity technologies, is becoming popular, internationally, as a data collection methodology, replacing entirely, or at least in part, the need to use paper questionnaires. The use of this technology has a proven potential for improving data quality and reducing the data collection time, even in countries with a limited infrastructure, such as inconsistent electricity supply and wireless connection, and where an extremely difficult environment and terrain is encountered. As mobile and wireless technologies continually improve and become more affordable, reliable, powerful and user-friendly, the adoption of CAPI is expected to expand even in those less-developed countries where access to infrastructure for information and communication technologies is limited. For statistical agencies planning large scale data collection operations such as the census, CAPI has become an alternative with sizeable benefits to the traditional paper and pencil interview (PAPI) techniques. The various factors which make CAPI more advantageous than PAPI, as well as those that pose challenges in large-scale data collection have been discussed in the first part of this chapter. This second part of the chapter deals with the application of CAPI in the census.

C.73. In CAPI, the interviewer typically reads questions to the respondent from the screen of a handheld device, preloaded with the questionnaire. The respondent's answers are immediately entered into the device, which eliminates the need for the manual re-keying or scanning of the responses during the data processing of a paper questionnaire. The handheld device also automates the routing through the questionnaire, and enables the interviewer to run a set of consistency checks during the interview so that any anomalies or inconsistencies can be resolved with the respondent. Automatic sequencing of questions and programmed skip patterns result in smoother and faster interviews by eliminating pauses and hesitations as enumerators turn pages and look for the next appropriate question on a paper questionnaire. As noted earlier in the chapter, it also results in more consistent interviews as only the relevant questions asked of each respondent, determined by the responses given to previous questions, and regardless of the enumerator, the sequence of questions will be the same, given the same set of responses. Validation checks, automated routing, customising of questions, pre-coding of certain responses, collection of operational information, provision of built-in instructional and help materials for enumerators and other features help to improve the quality of the data and the speed of its delivery.

C.74. The use of CAPI significantly reduces the time lag between data collection and data analysis. It provides for the instantaneous or rapid transmission of data to central servers, and the equally quick production of performance metrics associated with the field operation that can be used for monitoring and supervision of the enumeration. Since the data is captured during the interview and some basic consistency checks are carried out at the same time, the main data processing phase of the census can be completed more quickly as less editing and validation of the collected data is required. It is important that decisions on the edits built into the CAPI application are made within the context of balancing the time required to complete a questionnaire (that is, the system performance and respondent burden), and ensuring high quality data required for the subsequent processing phase.

C.75. As has been noted in the first part of this chapter, there are also challenges, risks and costs associated with using CAPI. In particular, when considering the CAPI method, the cost of providing all enumerators with the handheld device used to administer the questionnaire must be incorporated into the project budget. The cost of implications of the various options open to the statistical agency for acquiring such devices are set out in the previous section.

4.2. Essential functional features of CAPI[7]

C.76. The ideal CAPI software must be effective at every stage of survey implementation including during questionnaire development, field deployment, and data management. It should be equally effective for all those with a need to use the devices at different stages of the census operation including census designers and planners, as well as all levels of the field force – enumerators, supervisors and managers. For developers, the program should provide powerful tools and a facile environment for creating a questionnaire and for accomplishing all other associated tasks of questionnaire development. The CAPI software platform should enhance and extend the PAPI data collection system.

C.77. To do this the platform would first need to support complex skip patterns and simple questionnaire navigation capabilities. Beyond this, the platform should automate mundane but error-prone aspects of data collection such as the filling in of ID codes and facilitate the seamless capture and effortless integration of peripheral or reference data such as geographical coordinates and enumeration district areas codes. Software is only as useful as it is adaptable to the circumstances and skills of those who use it. Hence, the ideal CAPI program should be flexible enough for most users. Through support and documentation, it should be approachable for a broad class of users, or at least best suited for users with specific skills.

[7] Section adapted based on material from The Iris Centre (2011). Comparative Assessment of Software Programs for the Development of Computer-Assisted Personal Interview (CAPI) Applications. The Iris Centre, University of Maryland at College Park. July 2011.

C.78. Based on assessment of a number of CAPI software packages, the following functional features are deemed desirable in CAPI programs to be suited for such complex and large-scale data collection operations as the census:

(i) Interface for field users

C.79. The CAPI software solution should offer a simple but powerful interface for enumerators. The software platform should create an easy-to-use interface for recording and correcting responses as well as a straightforward method of navigating the instrument. Additionally, the platform should provide a powerful in-built suite of interview aids, including access to census support materials, multiple language versions of the questionnaire, and interactive prompts to check the consistency and accuracy of answers. The interface should also cover the facility for enumerators and field managers to interact with the application to assign/receive assignments; navigate, complete and review questionnaires; track progress; and share outputs for management review. The interface should be user-friendly for the average field staff, and the tools for accomplishing the interviews and other field tasks must be straightforward and intuitive.

(ii) Questionnaire navigation

C.80. CAPI programs should allow enumerators to move relatively freely through the questionnaire in order to capture the responses in the most effective way. For example, the software should allow the enumerator to complete the questionnaire in a non-linear way, or to pause the interview and resume it at the last answered question with a "save and continue later" functionality. On the other hand, the design should impose some restrictions on navigation, for example, by preventing enumerators from entering certain questions without having first obtained responses from other, earlier, questions. The tools for questionnaire navigation should provide powerful and easy-to-use navigation abilities.

(iii) Skipping/branching (automated routing)

C.81. Basic skips allow the response to a particular question to determine whether or not the next question is relevant, while complex skips are those that either use responses from several previous questions to determine whether the next question is relevant.

C.82. Automated routing is one of the most important error reducing features of CAPI. It obviates the enumerator from asking questions that should have been skipped, and which may reduce the length of the interview, minimise confusion and/or irritation among respondents, and decrease the time spent in cleaning and editing data during the main processing operation. Automated routing also avoids the converse - skipping questions that should have been asked - and may therefore minimise the need to impute for missing responses.

C.83. The way CAPI navigates the questionnaire through programmed jumps is one of its most important features. For instance, if a respondent reports being employed, the subsequent model of questions inquiring about the occupation, status of employment, working hours or income can be displayed. This is particularly important when the questionnaire includes complex routeing or skip patterns. Similarly, if a set of questions has to be asked a number of times (for example, for each household member), the software will automatically repeat the questions the correct number of times and then move on. CAPI's routeing capabilities have two main advantages over paper questionnaires. Firstly, the possibility of error from interviewers failing to follow routeing instructions is eliminated; they cannot follow an incorrect route and ask inappropriate questions, nor can they inadvertently skip over questions. Secondly, the interview flows much more smoothly and intuitively since the interviewer does not have to keep referring to earlier answers to establish the correct route through the questions.

(iv) Pre-coding

C.84. In a well-designed CAPI program, answers to relevant questions could be selected from pre-coded drop-down menus. In some cases, drop-down menus could be altered dynamically, depending on previous responses, so that the interviewer is never presented with an impossible response code.

(v) Customising of questions

C.85. Interviewing is also made easier and better data quality achieved from the 'customising' of questions. The data capture software can fill-in a piece of data from its memory, such as a name or a date and insert it in the appropriate place in a question. Using CAPI, interviewers would not have to keep a check on which member of the household they are collecting information on. In this way, the continuity of the interview and the consistency of the responses are both improved.

(vi) Data quality control (Validation)

C.86. Censuses require complex data quality controls. When data is collected on paper questionnaires there have to be systems to scan, code, clean and edit the responses in the post-enumeration main data processing period. CAPI programs must at least offer the same scope of quality controls during as well as after the interview. CAPI packages must, in particular, provide at minimum two types of data consistency checks: those within modules and those across modules. The logic and graduated level of increasingly greater requirements between intra-module and inter-module consistency checks is the same as with basic and complex skips.

C.87. One of the main advantages of CAPI over PAPI is in its ability to reduce human error during data collection. At the core of a well-designed CAPI application is its internal validation checks to ensure for example that all compulsory fields are captured and verified, and, by using consistency controls, that the proper skipping patterns are followed, thus improving the integrity, accuracy and completeness of data collection.

C.88. Because the checks are run during the interview in real-time, errors and inconsistencies can be resolved with the respondent. The check procedures are run automatically at various stages during the interview, typically: after completing all the questions on one screen; a final, global check at the end of the interview; through checking procedures by the supervisor as each questionnaire is submitted (often at the end of each day); and, finally, by the data processing team at headquarters after data transfer (typically the day after data collection).

C.89. Real-time data validation checks can correct inadmissible or inconsistent responses that could be the result of either interviewer or respondent error. For example, 'range checks' can be carried out to ensure that an answer falls within an acceptable range, while 'logic checks' can identify inconsistent or contradictory responses – highlighting, for example, a situation where the age that someone started school at exceeds his current age or where a ten-year old reports an occupation as brain surgeon. The program can either generate a report the end of an interview summarizing the data entries to enable the interviewer to verify the plausibility of collected data, or it can raise an error message allowing the interviewer to investigate a particular inconsistency, before submission to the field supervisor.

(vii) Case management

C.90. The CAPI software should have the capability to gather and update information on the status of cases for monitoring purposes, and to support the work of all levels of field staff (interviewers, supervisor, and managers) by providing comparable sets of tools for each in the management of their work. Case management should encompass the methods by which

- interviewers receive interview assignments and manage the completeness and quality of their questionnaires
- field supervisors assign interviews, oversee the completeness and quality of interviewer outputs, and upload outputs for management review, and
- higher level field managers allocate workload across field teams and track the progress of survey operations.

C.91. For the latter category, the CAPI software system should provide tools for the prompt export of data into a desired format. Much as with the traditional paper questionnaire approach, field managers should have the means to track the progress of a census, with regards to overall coverage, completeness of responses, and the identification of systematic errors so that the necessary action can be taken.

(viii) Data management

C.92. Censuses generate large volumes of data that are systematically stored in the data file format of one of the major statistical analysis software packages (such as SAS, Stata, and/or SPSS). CAPI programs must make transfer to these file types no less onerous than for PAPI. CAPI programs must be able to generate data sets, ideally with value and variable labels, in or at least in CSV format, that can then be integrated into one of these packages. This tool provides the way that data is transferred from the handheld devices in the field to the data processing computers at headquarters. Such a tool is often a specialized FTP (file transfer protocol) or server application that encrypts and protects the data. Data transfer features should be powerful in tracking the performance and progress of data transfers, and function when their complexity is hidden to users but their power not diminished.

(ix) Support and documentation

C.93. Support and other documentation should cover training manuals and training course materials, and any other instructional materials, as well as software support services. These provide support and documentation for field staff on how to use and exploit the software's functionality. The clarity, usefulness, and comprehensive nature of the support and documentation is an important consideration in the selection of a CAPI program.

(x) Tools for design

C.94. The CAPI package should offer a user-friendly developmental environment for the census agency to design and (if necessary) modify or update the census questionnaire. The CAPI development environment should be simple and straightforward enough that CAPI applications can be modified after questionnaire pre-testing, and be re-designed if flaws are identified during the questionnaire design phase. The ideal CAPI program should be robust and easy to use during questionnaire development and should have a set of instructions—a programming language—that provides complete control over the design of the questionnaire. The software should also have the capacity for programming questionnaire instructions and accomplishing all other associated tasks of questionnaire development. The types of questions available to the designer and the ways in which the questions are supported should include options such as radio buttons, checkboxes, and text fields, among others. Question support may include definitions as well as text in multiple languages.

(xi) Extensibility

C.95. Extensibility concerns how, and to what extent, the CAPI software package provides users with the means of building on old, or creating new, software functionality—whether through open source code, integration to external programming languages, or facilities for creating user-defined functions.

(xii) Other features

C.96. Other important features of CAPI include the collection of operational information. As noted earlier in this chapter, CAPI can capture a range of operational information (or logistical metadata), such as data and time stamps for the start and end times of the interview and GPS coordinates, that can be used for monitoring operations, coverage and quality control purposes, and the analysis of responses.

4.3. Considerations for acquisition/development of a CAPI system

C.97. The selection of a CAPI software package has important consequences for other choices that census planners have to make. Therefore, sufficient time should be allocated during the preparatory stages for the proper consideration and evaluation of the software. The kind of software package selected for the census data collection will:

- determine the kind of devices to be used, such as laptops, tablets, smartphones or PDAs;
- determine the minimum requirements for hardware parameters (and hence have implications for equipment costs);
- provide a certain range of features that determine what can and cannot be done;
- introduce certain skills requirements for the users and have implications for the type of training required;
- carry a price tag of its own if the selected CAPI software is not a freeware.

C.98. The selection of a CAPI software package is full of trade-offs: the more potent the software package is, the higher the cost (typically) and the more complex the configuration. Nevertheless, whatever CAPI solution is selected, it is expected that it should have at least the following basic subsystems to provide the essential functionality described in section 2.2 above:

- questionnaire management;
- user accounts and roles control;
- interviewing/data capture module;
- error detection and resolution subsystems;
- data aggregation and exchange subsystems;
- data export module;
- progress reporting and problem reporting for administrators.

C.99. When it comes to CAPI systems, census planners face the age-old question of whether to build or buy (or use freeware). This decision is complex since it is often taken without complete information about the exact budget and availability of time, human resources (software developers, testers), and a clear vision of the final product, or a full understanding of the features and limitations of existing alternatives. The following paragraphs discuss the pros and cons of each of a number of alternative options.

(i) In-house development of a CAPI system

C.100. This approach often seems attractive and dominates other alternatives during the planning meetings and discussions. One of the positive sides of in-house development is the perceived control over the product. The planner can be tempted to believe that if the product is developed in-house it is totally secure, robust, error free, and fully modifiable on a short notice. The reality, however, is often far from this.

C.101. Software development is generally not within the main competences of statistical offices in conducting its main business - that of collecting and processing data - and although some agencies may employ a number of personnel nominally producing software, they are predominantly occupied with the production of various data transformation utilities and computational routines exclusively for internal use. These products are usually heavily dependent on existing infrastructure to solve isolated

tasks, and lack the robustness and interface elements necessary for the software to be used by temporarily employed field staff with little training.

C.102. Development of software capable of handling Census operations with thousands of enumerators submitting their data is a non-trivial task, which stands out of from the more routine tasks, and the complexity of which may be underestimated by programmers, who more often than not have no say in the decision-making process. One of the first risks that is encountered in this process is laying out the specification for the software. While different interested parties may agree on internal software development, their vision of the product may differ, or even be opposing each other in some aspects. The developers may thus receive contradicting instructions on some elements, and be forced to take unguided decisions on others. At the same time, there are objective reasons for the difficulty in writing exact specifications for the intended product, since some of the details can only be determined after fully establishing data users' needs, and testing the prototype versions and assessing their practical applicability.

C.103. As the designers are being diverted from their day-to-day software development activities, they are put under pressure to come up with a working product in a short period of time, and to deliver this they may often select only partly-adequate libraries and components that promise to deliver a certain functionality. The reality of software development is such that promised functionality often comes with restrictions on compatibility, performance, or portability, presenting the challenge of combining third-party libraries and components into a coherent and reliable product. The use of the third-party libraries and components gradually reduces internal control over the product being developed and increases dependency on outside vendors. While developing software in-house, statistical offices will face the challenge of the trade-off between the development and testing efforts, often skewed towards the former. A systematic approach to testing is often hampered by the lack of exact specifications of the product, differing perceptions between developers and testers, and other factors.

C.104. For software of such complexity and importance, numerous tests and trials are required that can cover various modules and subsystems, making sure they are working properly under different conditions. Even large statistical offices may conduct only about 10-20 surveys a year, providing limited opportunity to test the system under realistic census conditions. In contrast, universal off-the-shelf solutions (discussed below) benefit from multiple applications (often hundreds of deployments for popular packages) by various clients and end-users in different environments, modes, and workloads. While no system is perfect, the sheer scale of application of the standardized application results in problems being detected and fixed sooner, ultimately resulting in a more robust product with a smoother user experience.

C.105. Finally, while statistical offices may have sufficient resources to develop a CAPI system for their census data collection, they may face a different challenge in providing support for this system, starting from development of help files, documentation, training materials to troubleshooting and problem resolution in the field during deployment and application.

C.106. When discussing the decision-making process in CAPI system implementation, the difficulty of reaching an agreement between various groups within the statistical office cannot be underestimated. Indeed, even in the smallest of agencies there is commonly a division of employees into subject matter and IT departments, which may have very different views on the functionality, capabilities, and other dimensions of the CAPI system. The subject matter specialists commonly distance themselves from any and all IT-related tasks, delegating these responsibilities to the IT department, while the IT department does not encroach on the subject matter domains. Thus, when it comes to developing a CAPI system, the objectives of these two parties may not be entirely aligned. While both are concerned that the census data be of good quality, the subject matter specialists are usually interested in reaching this goal in the most simple, transparent, and straightforward manner. On the other hand, the IT department may have the incentive of creating a fully functioning product, which, due to its complexity, requires constant updates, maintenance, provision of training sessions,

and other services, often in an attempt to justify the role and importance of the IT department within the statistical office. When given a choice, the position of the IT department is universally tilted towards the development of its own application or system and identification of particular details and attributes not facilitated by standard systems to justify customization.

C.107. Commonly, such a position of an IT department is a result of misunderstanding of the importance of IT support required even by a standard system. While the development task is largely substituted by a standard package, the peripheral tasks of data preparation, transformation of exported data, connection to existing systems, storage, maintenance and other tasks are plentiful and can fully occupy, if not overwhelm, an IT department of the statistical office.

C.108. Another common justification for the development of the agency's own system is lack of trust in any external system supplier, whether in terms of capacity to deliver the product or sufficient support for it. Here a track record of previous involvement with suppliers is an important factor that can demonstrate their reliability, integrity and capabilities.

C.109. While the perceived independence of the statistical office from outside suppliers may be a declared objective of the in-house CAPI system development, in practice this approach often leads to locking onto a particular team or individual maintaining tight control over all the functionality and development, and constantly under the risk of separating from the organisation, thus jeopardizing the continuity of such system development and support.

(ii) Outsourcing

C.110. Outsourcing the development of the CAPI system to an external software developer may appear to be an attractive solution for statistical offices that have only a small IT department or lack prior experience. Outsourcing may seem to offer the prospect of a perfect solution to any problem as long as the price is right. In reality, however, outsourcing brings its own challenges and problems.

C.111. One of the first challenges is finding the right partner for outsourcing. While government regulations may require any such service provider to operate within the country, software may need to be developed abroad and subsequently sent to the statistical office as a final product. The global market is competitive and may offer better solutions than those available locally. It thus requires some knowledge of the global vendors, their possibilities, and even their business culture and practices.

C.112. Most importantly, outsourcing requires a clear and comprehensive specification for the product more than any other CAPI development alternative. The software producer will have every incentive to do just that which is clearly specified and only that, hence all the possible situations and complications, and the ways to resolve them, have to be anticipated and fully described in any such specification. This is no easy task.

C.113. Communication with an internationally-based outsourcing partner may be further hampered by differences in language, time zones, inability to travel and other factors. At the same time, the statistical office risks having less control over the lower-level implementation decisions, and may get a surprise when the final product is delivered for inspection, by which time it may be too late to introduce changes to the software specification and the CAPI system without incurring heavy costs.

C.114. In-house produced software is less vulnerable to specification imprecision, since the developers are usually much more approachable and it is easier (and less costly) to add features that may have been overlooked in the original specification, or to address any unanticipated performance issues.

C.115. Considering budgeting, outsourcing is not necessarily a cost-saving option, particularly for data collection and data processing systems. Even when the software developer is local, the cost of

development may be dictated by global prices for software development, given the global nature of the software industry.

C.116. Another problem with outsourcing is that the statistical office may become dependent on a particular external contractor for its future surveys. In such a case, the sustainability of a CAPI platform depends on the supplier's business success and pricing policy. CAPI systems are constantly evolving and the costs of maintaining and developing such systems will increase with system complexity. If the contracted supplier decides to change its business model, the whole data collection effort of the statistical office may be put at risk.

C.117. From the perspective of international organizations providing technical and financial support, outsourcing creates a duplication of effort and multiplication of costs, which could otherwise be diverted to development of a standard software package, exploiting significant economies of scale in the software industry.

(iii) Configuring an existing software package

C.118. Selecting this alternative imposes a significant responsibility on the statistical office making a choice of the software package. This choice will have a snowball effect on all other decisions and requirements throughout the planned system.

C.119. One of the challenges with this approach is researching the market for available alternatives. While some software packages may directly advertise their applicability for census data collection, others that do not may nevertheless still be applicable. Omitting an option from consideration may cause delays and higher than optimal costs for the software procurement.

C.120. As a next step, several alternatives must be reviewed for their available features and possible extensibility. While not all of the necessary features or elements may be readily available in such a package, it must at least provide the possibility for any such missing elements to be added. Researchers will wish to review the software package documentation and any feedback from users, make direct contact with the manufacturer, or use their own professional experience in deducing which essential features are available and what level of customizations will be required. While some packages provide an open and documented API for introducing extensions, others do not, and this may require close collaboration with the original manufacturer to introduce any necessary changes or extensions to the basic product.

C.121. It is important to strike the right balance between the agency's own experience and the professional/industry assessments of packages being promoted as the best fit for the purpose. Many users tend to be heavily biased towards selection of the packages previously used for other purposes or suggested by partners/donors. In-house experience and prior knowledge of what is already being available is important to the extent that it reduces the costs of customization.

C.122. Another resource that can often be tapped is the user base of the standard packages. These users are often available in the country (experts and consultants working in the central and regional statistical offices, other government ministries and departments, NGOs, universities, think-tanks and other places), or, where necessary, may be brought in as advisors from abroad, sharing their expertise on a particular subject.

C.123. In cases where an existing package is being utilized, it is crucial to understand that any customization of the package effectively results in a new derived product, which must be re-tested for performance, stability, and security. Even small adjustments may result in significant deviations, and the testing should be comprehensive even in those cases.

C.124. Standard software packages are sometimes available for free and may be distributed with the source code, but it is important to remember that customizing even a free product with full source

code is not free, as these efforts require a solid understanding of the existing software, its inner structure and dependencies, as well as possibilities of introducing extensions or modifications to the basic functionality, which, in turn, may come at a cost.

(iv) Utilizing an off-the-shelf solution

C.125. In many cases, the off-the-shelf solutions (whether commercial or freeware) may represent a better alternative to the options described above. In most of their other activities, statistical offices rely on off-the-shelf solutions: they may use off-the-shelf statistical packages for data analysis, standard packages for data imputations and cleaning and online data dissemination. It is reasonable, therefore, to expect statistical offices to utilize similar approach for CAPI systems. The advantages of off-the-shelf systems are their wide familiarity and acceptance by a large number of users. Moreover, many such systems are free and have been developed and supported by large international or country institutions (for example, CSPro is developed by US Census Bureau and SurveySolutions by the World Bank).

C.126. The selection of an off-the-shelf software package is one of the most important decisions by statistical offices, as there will be little recourse for modifying and correcting missing functionalities once implementation begins. Not only the whole scope of available features of such packages must be studied, but similar attention must be drawn to any known limitations and defects of the software (such as bugs and other issues), which are inevitably present in any software product. The decision makers must feel comfortable that the plan to conduct handheld data collection with the selected package is feasible within its own national context, and does not create any gaps or omissions that need to be rectified later on in the process.

C.127. The decision to utilize an off-the-shelf product is sometimes based on a specific positive example (such as a census or large survey successfully done in a different country) but caution must be taken to identify which version of the product was used and whether any customizations were made to the base product to make such an application possible. Even if it worked successfully elsewhere, differences in networks, servers and other infrastructure elements may prevent the cost-effective use of the same solution.

C.128. The selection of an off-the-shelf solution should take into consideration important aspects of the data collection needs, including: the complexity of the questionnaire; the statistical agency's capacity and know-how to develop in-house this kind of solution; the level of integration needed with external systems; and, the level of customization required to take control of each aspect of the user interface in order to fulfill the agency's requirements, including the look-and-feel.

C.129. With the off-the-shelf solution, the statistical office is investing not only in a software solution, but also in increasing the capacity of its own personnel that will be using the standardized tool. These skills and knowledge will be then applicable in other survey operations long after the census has been conducted.

4.4. Evaluation requirements for CAPI data collection application

C.130. In the context of evaluating CAPI software packages, the strengths and weaknesses of each software package should be taken into account. As with the hardware options described in section 1, CAPI software packages should be evaluated to assess whether they are robust enough in performance and broad enough in functionality to support a census data collection. The evaluation criteria for performance assessment of each CAPI software package should include at least those essential characteristics and functionalities described above.

C.131. As the suitable CAPI software must be effective at every stage of survey implementation, each package should be evaluated through the three complementary lenses of census designers,

enumerators and field managers. As the suitable CAPI software should be flexible in the broadest possible circumstances, each package should be evaluated with respect to the human, computing, and budget resource requirement. Also, the CAPI software must be open to redesign and improvement, when appropriate, so each package should be evaluated for the potential for expanding and extending its basic functionalities.

(a) Evaluation areas[8]

C.132. The following paragraphs cover the most important aspects for evaluation:

(i) Performance in the field

C.133. For evaluating each package's performance in the field, two key features – the interface for field staff and questionnaire navigation – are particularly important.

C.134. The evaluation of the interface for field staff should examine how enumerators, supervisors and/or field managers interact with the application to assign and receive assignments; navigate, complete and review questionnaires; validate data; track progress; and share outputs for management review. The interface should be user-friendly, and the tools for accomplishing all census tasks must be straightforward and intuitive, and require minimal training.

C.135. The means and ability for the enumerator to navigate the questionnaire during an interview should also be thoroughly evaluated. Simply put, the tools to provide for such navigation should powerful yet easy-to-use.

(ii) Tools for managing survey cases and survey data

C.136. Three tools are particularly important for managing census data collected in the field.

C.137. *Case management*: This tool provides the methods by which (i) enumerators receive interview assignments and manage the completeness and quality of their questionnaires, (ii) field supervisors assign interviews, oversee the completeness and quality of interviewer outputs, and upload outputs for management review, and (iii) field managers allocate workload across field teams and track the overall progress of enumeration. Power and simplicity are the dual foci of this evaluation area. The power of the case management tools must be commensurate with the challenge of field operations, but should be simple enough for users at all levels of the field force hierarchy. Operational management tools should be configurable and provide real-time view of staff in the field and support reporting on the results.

C.138. *Data transfer*: This tool provides the way that data is transferred from the handheld devices in the field to the computers in headquarters. As has been noted earlier, such a tool is often a specialized FTP or server application, including transfer protocols that encrypt and protect sensitive personal information. Data transfer features should be powerful in performing and tracking the success of data transfers, and function best when their complexity is hidden to users but their power not diminished.

(iii) Needs in human, computing, and financial resources

C.139. For meeting the needs of human, computing, and financial resources for census activities, the evaluation of the software should address three key areas.

[8] Section adapted based on material from The Iris Centre, University of Maryland at College Park. Comparative Assessment of Software Programs for the Development of Computer-Assisted Personal Interview (CAPI) Applications. July 2011.

C.140. *Support and documentation*: This area is assessed on the breadth and quality of the documentation and tools covering training manuals, training courses, and any other instructional materials, including, software support services.

C.141. *Hardware and software needs*: This area relates to the minimum hardware requirements for installing and operating the CAPI software, taking account of any restrictions on the operating system on which it works. Hardware and software needs should be assessed on the level of appropriateness for each the type of device(s) to be used. Features to be assessed include: support for questionnaire design, integration with GIS systems and other applications (e.g., work force management applications), languages (including support for right to left languages), browsers, and common security methods; first public release and versioning (how long the product has been in use, how stable, and how frequently are updates provided); and, ability to capture para-data off device.

C.142. *Pricing and upgrades*: The cost-effectiveness of the software, software training, and technical support to be provided, as well as any fees associated with subsequent upgrades should they be necessary, should also be assessed with regards to their appropriateness. It is also important to consider the licensing method (open Source, commercial COTS) and delivery method (software as a service, on premise) of the CAPI system.

(iv) Tools for design

C.143. The evaluation in this area should assess three factors:

C.144. *Programming language*: The programming language is the set of computer instructions, or language for creating instructions, that determines the functioning of a questionnaire. In the simplest case, these are the computer equivalent to the skip instructions (for example "if Q23=2 then skip to Q2") that paper questionnaires provide. In more sophisticated cases, these instructions cover the response options to be displayed under different sets of conditions. A programming language should provide extensive control over how a questionnaire works and appears. It should also simultaneously be able to provide complex instructions to the device in commands that are simple to understand by potential users.

C.145. *Development environment*: The development environment constitutes the assembled toolkit for programming instructions, modifying the graphical layout, and defining the content of CAPI questionnaires. The tools of a development environment should provide control over all aspects of a CAPI questionnaire, and should be integrated into a unified system which is intuitive and easy to use.

C.146. *Questionnaire implementation*: The questionnaire implementation is a combination of the types of question structure available to the designer and the ways in which those questions are supported. Question implementation options may include radio buttons, checkboxes, and text fields, among others. Question support may include definitions or pictures to support the terminology used as well as text in multiple languages. The questionnaire implementation should provide a large array of options, for both the question themselves and the support.

(v) Tools for expanding and extending current capabilities

C.147. This dimension is assessed through the investigation of the extent of any extensibility necessary to build on to existing software or to create new software functionality - whether through open source code, integration to external programming languages, or facilities for creating user-defined functions. This is rated by the extent to which the software—through in-built tools or the way it is built—is flexible enough to be changed by its users.

(b) Steps for the evaluation of CAPI software packages

C.148. The CAPI software evaluation is comprised of four distinct tasks:

(i) Complete feature checklists

C.149. The first phase simply involves investigating whether or not a software package has each item on a pre-determined list of functionality within each area of evaluation. The checklist moves area by area carefully through all of the dimensions.

C.150. There should be a short version and a long version of this feature checklist. The short version captures, in one simple listing, whether or not a software package has the features deemed most important for CAPI software. The more detailed, longer version delves more deeply into additional features in each area of evaluation, thereby providing a richer picture of software-specific performance.

(ii) Test features through developing a questionnaire

C.151. The second phase entails putting those features identified at (i) to the test. Having established whether or not features exist, the evaluation tests how well they perform. To preserve uniformity, the evaluation should attempt to build a CAPI questionnaire that emulates the most complex features of the census questionnaire, including: rosters of household members; complex skip patterns and consistency checks (such as whether or not a household member is age-eligible for a particular module of questions); and calling up the contents of complex internal and external databases (such as a list of household members that meet certain criteria or a list of Districts that fall within a given State).

(iii) Evaluate the performance of individual software packages

C.152. The third phase, built from notes taken during the first two phases, consists of evaluating the performance, area by area, of each software package in isolation as well as in relation to the ideal CAPI package outlined earlier in this section.

(iv) Compare the performance across software packages

C.153. The fourth and final phase compares each software package and highlights the strengths and weaknesses of each package relative to one another.

4.5. Questionnaire design and performance considerations[9]

(a) Developing the electronic questionnaire

C.154. Converting a paper questionnaire into an electronic format involves more than simply replicating it on the screen of a handheld device. The particular device used fundamentally affects the way that enumerators interact with the questionnaire. The wording and structure of some questions may need to be changed to make it easier for the enumerators to work quickly and accurately on the device. Furthermore, added features like data validation, edits, and preloaded answers can be included in an electronic questionnaire. As noted above, the specifications for these features must be written when developing the questionnaire, in order to program them into the software application.

[9] This section is based on material from the US Census Bureau: New Technologies in Census Data Collection. Part 2: Developing an Electronic Questionnaire.

C.155. When converting a questionnaire originally designed for the printed page to an electronic one, it should be adjusted for the different ways in which the interviewer interacts with the handheld device. In particular, a typical tablet or smartphone screen will be much smaller than the paper size used to print a questionnaire, and will not be able to show the same number of questions on a single screen shot as would be printed on a page of a paper questionnaire without compromising usability.

C.156. In addition, questionnaire designers should consider how to take advantage of the added features of an electronic questionnaire, particularly the ability to: preload existing data: implement consistency checks, range checks, and edits; take GPS coordinates; and offer on-screen help features.

C.157. Below are some particular considerations to keep in mind when adapting a paper questionnaire to an electronic version.

(i) Roster (Grid/Matrix) compared to verbatim questions

C.158. A 'roster' is a grid where the census questions are indicated only by brief terms in the column headings. A roster is often used in paper questionnaires to record tabular data and to save space on the paper. Verbatim questions are those that enumerators are instructed read exactly as written on the questionnaire. In an electronic questionnaire, rosters may need to be converted to verbatim questions since the screen on a mobile device is often too small for enumerators to view the roster comfortably. Using verbatim questions with customized prefills may improve both usability and accuracy of the responses. For instance, in a roster, enumerators must navigate a grid, making sure that the responses are recorded in the correct row and column. The verbatim questions allow for specific questions about each person in the household. For example, for a question like "How old is [name]?" the name of the relevant person can be prefilled.

(ii) Open-ended compared to closed questions

C.159. Open-ended questions are those with no predefined answer categories. Closed questions have a set of specific response categories that are predefined. In a paper questionnaire, open-ended questions are often used when the response categories are too numerous or when the expected responses are unknown, for example, occupation. They require the response to be written in by the enumerator. As a result, open-ended responses are more time-consuming and costly to process and analyze.

C.160. An electronic questionnaire can more easily accommodate multi-option response categories by using drop-down menus or look-up tables. Therefore, some open-ended questions can be converted to closed questions when using an electronic questionnaire. However, using too many response options can make it difficult for enumerators to find the appropriate response item or to code consistently. In addition, if there are numerous response codes, the codes may not fit on the screen, requiring enumerators to scroll down the page. This may result in enumerators selecting response items that appear at the top of the list more frequently than those that appear at the bottom of the list, creating bias in the data. This problem may be mitigated by including a search function to allow enumerators to search for specific words or by using browse hierarchy. For example, in the case of occupation codes, enumerator may use a browse hierarchy to first search by major occupation groups; then browse by occupation within the major occupation group; then select the appropriate code from the subset of occupations. Also, the order of the of response items can be randomized to avoid bias from some responses appearing at the top or the bottom of the list.

(iii) Response format options in an electronic questionnaire

C.161. The response format in an electronic questionnaire can accommodate various types of response options.

(iv) Filtering questions and skip patterns

C.162. Electronic questionnaires can facilitate filtering questions and skip patterns by automatically displaying only the relevant questions and skipping those that are irrelevant or not applicable to particular respondents. The automatic skips both improve accuracy of the response and reduce enumerator burden by eliminate the need for complex instructions.

C.163. When designing the questions, all branching paths of the questionnaire should be considered. The questionnaire should be developed for use under all possible circumstances, even for some rare situations such that all questions should be asked of at least some subset of the population; no question should be included on a questionnaire that ends up being skipped by all segments of the population.

C.164. Once programmed correctly, skip patterns are less obvious in an electronic questionnaire. There are no conventional design cues like arrows and skip instructions that are visible on the screen. Skip patterns and branching paths should be clearly specified by the subject matter specialists so that the programmers can program the application correctly. A flow chart may be useful to make sure that all branching paths are considered and no question is left unasked. Also, a progress bar could be used to further assist the navigation by showing the enumerator how far the interview has progressed and which questions are yet to be asked. See section on specifications development below for more information.

C.165. One disadvantage of having hidden skip patterns programmed into the questionnaire is that if the enumerator makes a mistake on a filter question, then a set of questions will be skipped erroneously. Since the set of questions will not appear on screen, the enumerator may not detect the mistake until later in the interview – if then. One way to mitigate this problem is to consider using consistency checks instead of skip patterns or re-asking the filtering question before a long skip.

(v) Preloading the questionnaire with administrative data and geocodes

C.166. One advantage of using an electronic questionnaire is that some administrative data and geocodes can be used to prefill the census forms. This can save interview time and improve accuracy. However, there should be a facility for the enumerator to edit any such prefilled items so that if there is an error or there has been a change to the prefilled data, the correct information can be recorded in the field. Enumerators may be able to take and record GPS measurements, which can not only be used to validate the geocodes but can assist field monitoring and management.

(vi) Centralized post-coding compared to field coding

C.167. Centralized post-coding is necessary when the respondent answers an open-ended question, the interviewer then records the response on the questionnaire as given by the respondent, and the coding is done at census headquarters during data processing after the transmission of the completed questionnaire. Field coding refers to where the enumerator him/herself codes such responses to a numeric category at the time of the interview. Post-coding with a small number of specially trained staff can produce more consistent results, but it is more time consuming and costly. On the other hand, field coding paper questionnaires is fraught with difficulty, as such coding generally requires skills and training not usually provided during enumerator training. However, in an electronic questionnaire, drop-down menus and table look-ups can be used to facilitate much easier field coding. This reduces the need for the time-consuming exercise of post-coding while improving consistency in coding in the field.

(vii) Multiple language capabilities

C.168. As with a paper questionnaire, an electronic questionnaire can be prepared in multiple languages but at a much lower cost. An option to select the language can be programmed at the beginning of the questionnaire. The questionnaire should, however, be tested in all languages before implementing it in the field, ensuring that back-translations of the different language versions have been carried out to ensure consistency across all versions.

(vii) On-screen help

C.169. Electronic questionnaires can include a help feature available to the enumerators from the screen of their mobile device. A help feature can eliminate the need of the enumerators to carry around a separate manual and makes it easier for the enumerators to access definitions or other items needing clarification during the interview. Unlike a paper manual - which is usually a separate bulky document - the help feature in an electronic questionnaire can be linked to each question or a particular term that often needs defining or clarifying. Subject matter specialists should prepare the text for the on-screen help items and work closely with the programmers to implement them.

(ix) Change log

C.170. Unlike in a paper questionnaire, changes made to an electronic questionnaire may not be immediately visible to a reviewer. For example, changes to skip patterns in the program may not be detected unless the appropriate options are selected. It is useful to keep a change log for any changes to the questionnaire. The log can serve as a communication tool between the subject matter specialists and programmers and should be regularly maintained. A number of version control and software configuration management tools are available, such as Git. These tools can be hosted locally on an organization's own server or on a remote hosting service like GitHub.

(b) Data validation

C.171. One advantage of using an electronic questionnaire is that it can validate the data as the enumerator enters the responses on the handheld device. To do this, data validation rules should be written by subject matter specialists in the questionnaire development stage so that they can be programmed into the application. Subject matter specialists are best suited for writing the validation rules because they have deep knowledge of the questions and possible responses.

C.172. When writing the data validation rules, the following questions should be considered:

- Which errors should be flagged?
- What should happen when there is an error? Can the enumerator continue with the interview or does the error have to be corrected before proceeding?
- What message should be displayed to the enumerators to notify them of the error?

C.173. Some of the checks that can be included in the validation rules are:

- Range checks: Does a value fall within a given range? (For example, age range of 0–110.)
- Inconsistency checks: Is a response consistent with a response given for an earlier question? (For example, if a respondent says she has given birth to one child, the respondent must be female.)
- Data completeness checks: Is a response missing where there should be a response? (For example, sex information is missing.)

C.174. Once the errors are identified, there are two ways to manage them: hard and soft edits. With hard edits, the enumerator is not able to continue the interview until the error has been rectified. With soft edits, the enumerator is notified of the possible error and should attempt to correct it, but the interview can continue without doing so.

C.175. Hard edits are useful when there are clear known errors that must be corrected (such as a missing response to the question on sex or an age of 150 is reported). Hard edits enforce stricter quality control. However, they are not recommended if it is difficult to predict all possible answers. For example, a woman who has given birth to 15 children may be unusual, but not impossible. Similarly, having seven members of the household die in the past 12 months would be unlikely, but may have happened. But it may also be in this latter case that the respondent is reporting deaths that have ever occurred in the household, rather than in the past 12 months. For these cases, soft edits should be used accompanied with a displayed message to alert the enumerator that the response entered may be erroneous (and should therefore be checked), but allows the enumerator to continue with the survey after acknowledging the message.

C.176. While error checks are useful for controlling the quality of the data, too many checks can slow down the enumeration, or may frustrate the enumerator, who then may ignore them. Particularly with hard checks, the enumerator can get stuck on an error and be unable to complete the interview. Also, if the checks are mis-specified, then implementing checks could lead to data quality problems. For example, in the case in which the maximum number of children born is set at 5 and there is a woman who has given birth to 8 children, if the software does not allow the enumerator to enter 8 for the number of children, then the enumerator may enter 5 instead just so that the interview can be completed. This would result in a known incorrect number of children to be recorded.

C.177. Error messages should inform the enumerators about which questions have errors, what the errors are, and how to correct them. They should be short but instructive. For missing responses, it may be more practicable to indicate these with an arrow and highlight instead of displaying an error message. The questionnaire application should allow enumerators to go back to the problematic questions easily in order to correct the errors. As with the data validation rules, subject matter specialists are best suited to write such error messages because of their in-depth understanding of the questionnaire content.

(c) Questionnaire layout and design

C.178. Easy-to-use graphical layout and design on an electronic questionnaire are critical to reducing data entry errors and saving time during the interview. Electronic questionnaires should be designed in such a way that the enumerators can navigate through the questions easily, quickly, and accurately. Setting design standards and working closely with the programmers are critical to a well-designed electronic questionnaire.

C.179. There are many layout and design considerations when preparing an electronic questionnaire. These are summarised in the following paragraphs. Compared to paper, an electronic questionnaire has more elements to design because it has more features (such as the data validation and error messages noted above).

C.180. Although programmers write the code that determines how an electronic questionnaire looks, it is important that they work closely with subject matter experts who write the content so that the design is consistent with the way the questionnaire is intended to work. This is particularly important if corresponding paper questionnaires are also being used in a multi-mode census approach in order to avoid modal bias.

(i) Setting design standards

C.181. Establishing standards for layout and design creates a consistent look to the questionnaire. Inconsistent designs can confuse enumerators and lead to less efficient data collection. Standards are especially helpful when there are many people involved in designing the questionnaire. Design standards should include both overall screen layout and detailed standards including font, color, placement, and other specifications. They should be developed for all elements of the questionnaire.

Many questionnaire applications (like CSPro for Android) already have built-in design standards. In such a case, the built-in design standards can be used instead of creating new ones. It is a good idea for the designers to discuss the built-in design standards with the programmers.

(ii) Design tips

C.182. Below are some recommendations for creating design standards.

(i) Make sure the enumerator instructions are clear and are placed where they are needed
If the instruction is required before question text, it should be placed before the question text. If the instruction is required after the question text, it should be placed after the question text. Give careful consideration where any particular instruction to a question is placed. Some instructions are more helpful if they are given *before* the question text, others *after* it. In the following example, note that the instruction is placed *between* the responses "Female" and "Other".

Q3. What is [Name]'s sex?
1. Male Θ
2. Female Θ
In case the respondent wishes to return other than code 1 or 2 then give code "3"
3. Other Θ

(ii) Use different parts of the screen for different purposes
For example, use the top left portion for module heading, left half of the screen for navigation tools, and bottom right corner for the link to the next page. Make sure that this format is consistent across all modules.

(iii) Use different colors for different purposes
For example, use colors to identify modules or use different color to distinguish enumerator instructions from a question to read aloud.

(iv) Use different formatting fonts for different purposes
For example, use bold font for emphasis and italics for module headings.

(v) Use progress headings or tabs
This will enable the enumerators to see the bigger picture of where they are in the questionnaire.

(vi) Make use of icons to navigate through the screens
For example, an arrow can be used to indicate go to the next page. Make sure that the enumerators can easily understand the meaning of the icons.

(vii) Make sure that the screen is not too dense
The questions should be clearly separated from each other. Too much text makes it more difficult for the enumerators to see the questions.

(viii) Think about the number of questions to be shown on each screen
Some designers prefer to show just one question per screen so that the enumerator can focus on one question at a time. Others think it is helpful to include related questions on the same screen wherever this is possible without conflicting with (vii) above.

(ix) Consider whether to use paging or scrolling design
Where all of the required content does not fit on one screen, the overflow content can either be placed on the next page (paging) or the page can be made longer than the screen and the enumerator can scroll down the page (scrolling). If using a scrolling design, avoid nested scrolling (having a scrolling screen within another scrolling screen) or using both horizontal and vertical scrolling on the same page.

(x) Consider whether to use radio buttons or dropdown lists
Radio buttons allow the enumerator to see all the responses, while drop-down lists can save space if the responses are numerous.

(xi) Make sure that there is enough space for answers
For example, make sure all household members can be listed on the roster.

(d) Questionnaire specifications

C.183. Specifications are a set of instructions for writing the program for an electronic questionnaire. They should contain all instructions for the programmers to write the code for the questionnaire, including wording for the questions, response options, skip patterns, instructions to the interviewer, data validations, error messages and output data format (e.g., flat vs. hierarchical, long vs. wide, comma separated vs. fixed width)

C.184. Although developing questionnaire specifications may seem time-consuming, it will save time in the long term by avoiding potential questionnaire programming errors. Without questionnaire specifications, the programmers, who may have limited knowledge of the questions, are left on their own to interpret the questions and make programming decisions. Furthermore, when many persons are involved in writing and programming the questions, the specifications help to maintain consistency. Such specifications are also useful when testing the questionnaire, because they indicate exactly how the questionnaire should work. Finally, without an associated paper questionnaire, the serve as the documentation of the questionnaire.

C.185. Annex 1 contains suggested topics to include in electronic questionnaire specifications.

(e) Questionnaire testing

C.186. The purposes of testing are to make sure that the questionnaire is:
- *Functional*, that is all aspects of the questionnaire design (including the question texts, response options, missing values, branching, routing instructions, error messages, and data transfer) work as intended under all possible situations; and
- *Usable:* in that the enumerators can effectively and efficiently collect and record the requisite data.

(i) Testing approaches

C.187. Conventionally, pre-testing is carried by simulating the census experience by having interviewers ask the questions among a selected sample of respondents in the same way that the actual interview will take place, then tallying the response distribution and debriefing with the interviewers. However, other more rigorous methods for pre-testing include:
- *Cognitive interviewing*: This focuses on particular questions and understanding the thinking processes involved in answering them through 'think alouds' and probing. This approach is often used for deciding whether or not to include a potentially sensitive or difficult question.
- *Behavior coding:* Interviews are monitored, and interviewer and respondent behavior (such as whether or not the interviewer asked the question exactly as worded, or if the respondent asked for any clarifying information) are coded.
- *Experiments***:** These determine whether or not any revisions are improvements by comparing original and revised questions.
- *Statistical methods***:** Applying statistical methods for questionnaire evaluation, including modeling measurement error and item response patterns and predicting reliability and validity.

C.188. The six main approaches to testing a questionnaire are as follows:

- *Question-by-question testing*: Go through each question thoroughly and check for question wording, response options, missing values, fills, branching questions, overall appearance, validation specifications, error messages, and other aspects of the question. This is probably necessary in all testing situations.
- *Testing by task*: Divide up different testing tasks among the testers. For example, one tester checks for skip patterns and another checks for wording and response choices.
- *Scenario testing*: Construct various scenarios of responses and enter them into the questionnaire. This is essential in making sure that all possible branching paths are covered.
- *Data testing:* Examine the preliminary data output from the software program to make sure that the output fits expectations and the census specifications.
- *Pre-testing with a sample of respondents*: Select a wide range of respondents and expose them to a simulated census experiences as noted above.
- *Simulating census data*: Produce random responses with the questionnaire software, then examine them for branching and other types of logical errors.

(ii) What to test

C.189. As with a paper questionnaire, each new question should be carefully tested and questions from previous censuses should be reviewed and re-evaluated. Electronic questionnaires require more rigorous testing than paper questionnaires because they have more features all of which must be assessed, and because the skip instructions are not visible.

C.190. Annex 2 shows a partial list of questionnaire features that should be tested, possible errors associated with them, and the testing approaches that can help detect them. In addition to testing to ensure that the questionnaire works according to the specifications, the importance of testing the logistics for implementing handheld data capture cannot be over emphasized. Many agencies fail to adequately test the logistics, such as lack of a reliable electricity supply to charge the mobile device in the field or the lack of Internet connectivity in some remote areas of the country, and lack of safe storage for the mobile devices.

(f) Planning for questionnaire testing

C.191. Sufficient time and budget should be allocated for testing an electronic questionnaire. Testing should be conducted early in the preparation stage of the census life cycle so that there is sufficient time any necessary corrections can be made and the questionnaire re-evaluated. It is often useful to prepare a written test plan with quality standards for each element to be tested so that all features of the questionnaire can be assessed in a consistent manner. The consequences of not testing an electronic questionnaire adequately may mean data loss of, or errors in, the data, which could be costly if, in the census itself, households have to be revisited.

C.192. Steps for questionnaire testing process may include the following elements:

- Make sure that specifications for the questionnaire (and for the subsequent census output) dataset have been written. The questionnaire should also be configured successfully and installed on selected handheld devices.
- Identify a person or a team of people responsible for managing the testing process.
- Form a testing team of people with different expertise (programmers, subject matter specialists, researchers, field staff, etc.). Endeavour to include some enumerators, who will be the end-users of the questionnaire, for usability testing.
- Determine the goals of testing and develop written testing plans including timeline, quality standards, and specific testing procedures.
- Establish a process for logging and reporting errors. This could be a database or on paper.
- Implement the testing approaches.

- Review identified errors, decide what changes need to be made, make the changes, then test again. When revising the questionnaire, be careful to maintain version control.
- Continue the test-retest process until no more errors are found and critical errors have been corrected.

5. Data transfer

5.1. Introduction

C.193. When using mobile devices for a survey or census it is important to be able to transfer data collected in the field back to the head office quickly and securely. This not only allows for faster data processing and analysis but also better monitoring of the progress of the field operation. Regular transmission of data from the field to the central data center is vital for the management of data collected with mobile devices. This allows early detection and resolution of potential problems. The plan to build a data transfer system should consider all available means of data transmission. Where the communications infrastructure permits, cellular data connectivity provides the best and most powerful tool for transferring data directly from remote handheld electronic devices in the field to central servers. The ability to transfer data remotely without the need to work within specific Wi-Fi 'hot spots' is a powerful mechanism for efficiency and reliability. The cost and performance impact of using cellular networks will depend on the frequency and amount of data transmitted. Use of cellular data for data transfer can also aide in realizing cost savings as the enumerators/supervisors may not need transportation to regional centers or locations to find WiFi hot spots.

C.194. Where the infrastructure for cellular networks coverage is poor or non-existent, alternative mechanisms need to be developed for the transfer of data from the field. This will require establishing multiple data collection/reception stations with means of connectivity to central servers at headquarters. The data collection stations could be computer-equipped (with microcomputer, WiFi, broadband access and modems) or not (with only modem and phone line available). Where necessary, partnership agreements could be struck with public entities such as regional or local authorities, the military or the telecommunications service in order to access their phone lines, computers and Intranet connections to complement the census agency's own field network. Radio antennas for Internet connection could be deployed to provide broadband service in remote areas where the existing telephone system is inadequate for data transmission. Enumerators at data collection stations could use means of connectivity such as WiFi, Bluetooth, USB cables and removable media to download data from their handheld electronic devices. In such manner data can be periodically transmitted without the need to wait until an enumeration area is completed – enabling centralized monitoring of the data collection, and allowing review and analysis to begin sooner. Saving data on to an SD memory card available on the handheld electronic device can help avoid data loss in case of device crash or freeze-up or until the collected data is downloaded at the data collection stations.

C.195. There should be a well-documented data transmission plan in place to support enumeration efforts. Infrastructure issues such as the availability of electricity and Internet access can affect the success of mobile data capture. As has already been noted, early in the planning stage, it is important to identify and map areas of the country that lack electricity and/or Internet access. If relying on a cellular connection to transmit data, it is important to conduct a realistic assessment of Internet connectivity, including the speed of the data transmission, in all areas during the planning stage. It is important to consider what is feasible in all areas throughout the country, whether urban, rural or remote, when setting up the data transfer system. It may be necessary to establish more than one system according to infrastructure constraints.

C.196. To mitigate the risk of poor cellular network connectivity in areas with multiple service providers, each enumerator should be provided with SIM cards from each of the suppliers. If one

provider does not have good coverage in some areas, the enumerator will have a back-up option. It is critical to have contingency plans for when electricity and/ or Internet access are not available. Plans should be developed for charging and backing up the devices as well as for transmitting collected data. Where the handheld devices are unable to work or are lost or broken, there should be a provision of back-up paper questionnaires. It is important to allocate time and resources to test the data transfer and storage system. Planning for the data transfer system should include a thorough testing of the system during the preparations and the pilot test. The data transfer system should be ready and thoroughly tested before training of field staff begins. Time should be allocated for training supervisors in cell phone network configuration on mobile devices.

5.2. Means of data transmission

C.197. A mobile data collection system allows the collection and transmission of data from remote geographical locations to centrally located data storage repositories through wireless or cellular networks. Transferring data between devices in the field and to central servers at head office, or in a cloud service, is referred to as synchronization. Synchronization can occur either as a one-way or two-way data transfer. This means that, depending on the capabilities of the CAPI application, it is possible to send data from the enumerator's device to the server as well as to download data from the server to the enumerator's device. The system for synchronization can be configured to only send data to the server, to only receive data from the server, or to do both. It is possible to synchronize both data files and other non-data files such as application files, images, and text files.

C.198. Synchronization commonly performs two tasks. Firstly, it automatically pushes any completed assignment to the supervisor for review. Secondly, it automatically pulls all new assignments and data collection instruments on to the enumerator’s device. After synchronization is complete, the number of new assignments received and number of completed interviews sent, can be displayed. It is common to use synchronization to update data entry applications in the field by downloading the latest from the server. This way, modifications to the application at the head office can easily be distributed to interviewers in the field.

(a) Networking for synchronization

C.199. Data collected in the field on a mobile device will eventually need to be uploaded to the data processing center using its networking components. Different mobile devices have different networking components present and it is important to plan ahead and get devices that have the necessary components required. The choice of networking components will have a real impact on the price paid for the devices. Either only one or two, or all of following components can be present:

C.200. **WiFi**: This is the most basic networking component. Different standards exist and thus different WiFi types and components, but for CAPI work it does not really make a difference which WiFi network is supported. Almost all handheld devices have WiFi capability. Since WiFi will only work near a WiFi network, it will not allow the uploading and syncing of data from the field.

C.201. **Cellular 2G/3G/4G**: These are not usually present in low-end/mid-range devices. This component comes at cost when included in mobile devices and when used for cellular data transfer. Usually a data plan is needed to use a cellular network and the usage fees could be costly for large data collection operations. Where cellular networks are available, data upload can be executed as soon as an interview is completed. When deciding to select a device with cellular capabilities, it is important to make sure that the device supports the available network carrier technology.

C.202. In remote areas where there is no cellular coverage, satellite communication systems pertaining to Very Small Aperture Terminal (VSAT) and Broadband Global Area Network (BGAN) could be used. However, in some countries satellite communication systems could be a prohibitively expensive solution.

C.203. **Bluetooth**: Not always present in lower-end devices but will usually be included in the mid-range and up. Bluetooth allows the connection of one device to another similar device or central server for the transfer of files and data. Bluetooth transfer requires proximity between the devices to transfer data.

(b) Synchronization options

C.204. There are three data transmission scenarios:

(i) Online

C.205. This transmission mode involves a fully network-based data transfer from the mobile devices in the field directly to the servers. Online transmission is recommended for face-to-face data collection when data collectors are equipped with mobile devices, when large volumes of data are submitted at any one time, and when there is an access to the Internet by all levels of field staff. Interviewers use their CAPI data collection application to collect data on their devices and then use the Internet to synchronize the data on their devices with a server at the head office or in the cloud. In case of 2G/3G/4G coverage in the field work areas, each device should be equipped with a compatible SIM card connected to a cellular network, preferably via a virtual private network (VPN) or multiprotocol label switching (MPLS), for data transmission.

(ii) Partially online

C.206. In this scenario, the collected data is not immediately transferred as there is no Internet connection. The collected data is stored in the mobile devices until an interviewer is able to move to an area with cellular coverage when they may connect to the Internet and synchronize with the server and transfer any data collected since the last synchronization. Synchronization may be done using Wi-Fi or cellular network connection (2G/3G/4G). This data transmission mode is appropriate for face-to-face interview using mobile devices when an enumeration area is not covered by cellular networks.

(iii) Off-line

C.207. In situations where an interviewer rarely or never has access to the Internet, data transfer can occur through WiFi at a data collection station or through peer-to-peer synchronization between devices using Bluetooth. Bluetooth synchronization does not require an Internet connection; it is a direct connection between two devices that are in close proximity. Using Bluetooth, an enumerator may synchronize their device with a supervisor's device, transferring their data to the supervisor. Data could also be transferred to a supervisor's device manually with the use of USB cable or removable media such as flash drives and SD cards. Later, the supervisor travels to an established data collection/reception station or a location where he/she is able to connect their device to the Internet in order to synchronize with the central server. In this scenario, a supervisor might visit multiple enumerators in order to synchronize with them and later upload their data to the server at the head office. In this mode, case assignments and questionnaire application updates are transmitted to the enumerators' devices in a similar fashion.

(c) Synchronization servers

C.208. For synchronization over the Internet, a central server is required. Depending on the capabilities of the CAPI application, three types of servers could be supported:

Web server: In order to use Internet synchornization, a server running a web application software is required. The server can be set up on a system on-site at the head office that is connected to the Internet or it may be set up on a hosted website or virtual server in the cloud.

Cloud based service: Cloud based synchronization services such as Amazon Web Services Cloud (AWS) could be employed, obviating the need to configure a server at the head office for synchronization. This would require setting up an account with the cloud service.

FTP server: Some CAPI applications can synchronize with a FTP (file transfer protocol) server for the purpose of data transfer. This option requires an account configured on an FTP server.

C.209. The choice of synchronization option should take into account the extent to which security and encryption is supported by each option for data transfer.

C.210. For CAPI packages there is a two-fold typology of data transfer systems: end-to-end solutions and partial solutions (IRIS, 2011). Those that are end-to-end provide services from data encryption to data transfer to data transfer management (and other services such as the synchronization of paradata). Those that are partial only handle one segment of the data transfer system, typically getting files from the field to headquarters. The data transfer is provided in most packages as synchronization from field interviewers directly to the statistical agency's headquarters. In other packages, the synchronization must first be approved by supervisors, or by headquarters but requiring supervisory sign-off, before a case is considered ready for integration with the database. The way data is transferred and handled at headquarters depends entirely on the case management system.

C.211. Some CAPI applications are able to synchronize data files at the case (questionnaire) level and keep track of which cases have been added or updated and only send cases that are new or have been modified since the last synchronization. This significantly reduces the amount of data transferred and therefore reduces bandwidth and the cost of air time. Once enumerators have used data synchronization to upload data to the server, data management tools associated with the CAPI application can be used to view, export and download the aggregated data on the server. All the data on the server can be downloaded into a single data file that can be used by other statistical applications and tools for data cleaning and analysis. It is important to ensure the security of the server and data.

5.3. Technical considerations for data transfer via cellular networks[10]

C.212. Cellular data transmission is an increasingly exploited mechanism for communication with remote mobile devices. Being able to collect and distribute data virtually anywhere without requiring the limitation of working within specific WiFi 'hot spots' is a powerful force for efficiency and reliability. However, the fact that cellular data is metered means that the frequency of transmission and amount of data sent in each exchange can have significant cost and performance impact.

(a) Estimating volume of data flow

C.213. One of the most important technical considerations for data transfer via cellular communication networks is the estimation of volume of data flow. It is important to understand the type of services that are available across all enumeration areas and throughout field and regional offices. The types of access will likely vary based on conditions such as urban, sub-urban and rural/remote areas, elevation and topography.

C.214. To understand **data flow**, we need to consider a number of factors including:

- geographic area to be covered (square kilometers or miles and terrain/elevation)
- urbanicity (percentage of urban, sub-urban or rural land)
- number of days/weeks estimated to complete fieldwork

[10] DIGI: Efficient Data Transfer over Cellular Networks. White Paper. https://www.digi.com/pdf/wp_gatewaysecurity.pdf

- total population to be enumerated
- number of estimated enumeration areas (EAs)
- number of questionnaires per enumerator (size of workload)
- size of field workforce (enumerators and all supervisory staff)
- percentage of questionnaires that will be collected offline

C.215. We also need to understand typical upload/download scenarios. For example, if the area being enumerated is a remote area with no access to connectivity, how often will the enumerator be able to check in? What volume of data will be uploaded at check-in time? Will the enumerator download new assignments at the same time as well? How many will face this same constraint? Where will they go to upload data? How many will check in and use the same facilities for up/download? Will there be regional centers? Will schools or other public institutions also be used as upload centers? Will enumerators leverage available Wi-Fi networks?

C.216. The instructions to enumerators and their training should treat data-collection protocols and typical upload/download scenarios, including on how often to check in, where to go to upload, how much to data accumulate before uploading, etc. In situations where there is a two-way synchronization and supervisors can "reject" questionnaires, it is important that all errors are rejected in one go rather than sending a few, re-syncing, getting the changes and then sending the others. Each sync takes bandwidth/data.

C.217. If APNs (Access Point Name) are used on mobile networks (setup and managed by carrier), they can allow data to be "pooled". This can be useful in managing data requirements. APNs also permit filtering, allowing the whitelisting/blacklisting of various applications to minimise unauthorized use of data by enumerators. In this regard the use of APNs can aid in simplifying the process of estimating enumerator data requirements.

C.218. Understanding these various factors will allow the statistical agency to more accurately estimate the type of data plans and systems required to support data transmission needs.

C.219. No matter what type of backend system and applications will be used, it is important to conduct a system-sizing exercise to ensure that systems will be able to scale to handle peak loads. Network communications provide the required connectivity for distributed operations. Network capacity however, can often limit the software technology solutions that perform well within the statistical agency. System architecture design must identify and address network communication constraints and provide the right technical solution for a successful implementation. Technology solutions can work well if the required network connectivity is available but will not work well if the required network connectivity is not available. GIS and data collection applications are typically heavy users of network traffic (particularly if photos are taken of buildings, etc.). Data must be transported to/from where the program is executed to display or capture information, generating lots of traffic across the network.

(b) Challenges of managing mobile devices over cellular networks

C.220. Before implementing a data transfer system using cellular technology, census agencies will need to carefully consider three technical requirements in order to achieve maximum benefit and meet cost targets.

(i) **Network performance**

C.221. Network performance constraints include:

Network coverage: Cellular network carriers are subscriber-focused and concentrate their efforts on updating their infrastructure first in areas where the number of subscribers is greatest. Remote devices

that need cellular coverage are not always deployed in these zones, so it is important to work closely with the carrier(s) and cellular hardware vendor to coordinate rollout of cellular devices based on available and planned infrastructure.

Network reliability: No single technology solution can offer 100 per cent reliability. Cellular technologies are resilient against rain-fade and cloud cover than most satellite networks. Cellular data networks are also usually segregated from voice/circuit based connections, so that even when "all circuits are busy" for voice, cellular data can still get through. Nonetheless, cellular connections can still experience momentary cellular network dropouts and data loss, so while cellular data may be "highly available" it is not "100 per cent guaranteed delivery."

Network imposed latency: Performance of data transfer across cellular networks can vary significantly based on carrier coverage, type of network, and activity on the network at the time of transmission. Voice calls have lower latency than data calls because voice calls can lose significant quantities of data before comprehension is degraded. Data calls are routed through a separate network to improve data fidelity, at the expense of a significant increase in latency imposed by the cellular carrier's network architecture.

Available network bandwidth: Most cellular networks, particularly the first releases of 3G technology, are designed to maximize download (meaning data flow into the mobile device) rather than upload performance. Remote device connectivity would typically have better performance if this was reversed. A central site sending a query to a remote device will almost always send less data (downstream across the cellular connection) than it expects to receive in reply. Likewise, in cases where the data is sent from the field locations unsolicited to the central site, the primary data flow is upstream. Therefore, when connecting remote devices to the network, it is important to remember this upload/download imbalance.

(ii) Network overhead

C.222. The network overhead is measured by how the application operates across the transport mechanism, and how often communications are re-attempted when the end device is non-responsive. Additionally, various security measures may also increase network overhead.

C.223. **Data transmission overhead:** There are two primary methods of communication within an Internet Protocol (IP)-based network such as a cellular data network: Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). Each has its benefits and limitations. Selecting the correct approach for a given application is the single greatest contributor to implementing a cost-effective and satisfactory solution. It is often deemed that TCP is reliable – it guarantees delivery of data – while UDP is unreliable. While this is technically (mostly) true, it is more accurate to think of the difference between the two, as TCP provides a mechanism within the network layer to identify and attempt to retransmit dropped packets, while UDP leaves that up to the application layer. Many applications, especially in the device monitoring space, already have mechanisms in place to validate data integrity and request retransmission of missing information. Reliable data communications are quite commonly implemented over UDP using these applications. Letting the application handle the data integrity/retransmission often results in considerable cost savings and can sometimes even lower latency end-to-end. However, in other cases, TCP is a requirement because there is no satisfactory mechanism in the device or in the application to store data, or every transmission must definitively succeed or fail.

C.224. **Network disconnections and duplicated requests:** A dropped packet[11] will generate multiple TCP retransmissions by default before the data is discarded. If the polling (periodic sending out of queries and getting responses to those queries) rate is less than the TCP timeout, the application might send multiple requests for the same information across the network, and occasionally receive

[11] Packets of data travelling across a computer network that fails to reach their destination.

double responses from the device. Each time a TCP connection is re-established or torn down, additional traffic is generated. Keep-alive packets[12] to ensure connections remain active also generate traffic. All these contribute to the cost of using the network.

C.225. **Security concerns:** Cellular data is transmitted in an encrypted form while traveling over the air, but once the data reaches the wireline network of the cellular carrier it is normally transmitted in the clear. Some applications (and particularly in the case of the transmission of census information) require that data be encrypted while traveling on the network (sometimes just on public networks, sometimes end-to-end between sending and receiving equipment). There are several methods of providing such encryption, most of which increase the cost of sending the data.

(iii) Application performance

C.226. In general, satellite and cellular networks require software to be patient. Prematurely timing out and retrying when the network is busy makes matters worse and can actually prevent successful communication. Factors that impact on performance include:

C.227. **Connection delay:** Most applications use the operating system defaults for data timing (on Microsoft Windows this is generally five seconds). Applications may not provide a mechanism to modify this default, so users may not have any option to change this default behaviour. In the best-case scenario, not waiting long enough to open a socket just makes reconnection difficult at times. As long as the application waits at least 30 seconds before it retries the connection, it will eventually recover. However, the worst-case occurs if the application not only times-out too fast, but retries too fast. The TCP peers alternate between thinking they are connected but having to 'reset' the connection due to timeouts and thinking they need to retry the connection.

C.228. **Response delay:** Many applications by default assume Ethernet/LAN responses occur in 250 milliseconds or less. Fortunately, most applications allow users to change this value. Unfortunately, some applications limit the maximum response delay to five or 10 seconds. A WAN-aware application should allow this setting to be at least 30 seconds – preferably at least 60 seconds. Besides the obvious performance problem of too many timeouts repeatedly putting the remote device 'off-line', a more risky problem is how the application will handle unexpected responses (technically, 'no-longer expected' responses).

C.229. **Cost to communicate:** For applications across a WAN, a disproportionate of the data that is being paying for is either protocol overheads or data updates without any change in data. The obvious solution to reduce cost is to slow down data polls (periodic sending out of queries and getting responses to those queries). However, if idle time between transmissions on TCP sockets becomes too long, the ability of an application or the network stack to keep track of valid sockets can become compromised because it may run into a transient network outage, or the device on the other end may have become non-responsive in a way that prevents replying to a packet. It will send a packet, wait, and see no ACK or other indication the socket is closed; then it will follow the normal TCP rules of back-off and retry. This issue likely varies based on WAN technology, but a good rule of thumb at present is that it is necessary to either send data or a TCP keep-alive every four to five minutes to keep the TCP socket healthy.

5.4. Risk mitigation in data transmission

C.230. Managing mobile devices over cellular networks poses some unique challenges due to the bandwidth limitations of typical cellular data networks as well as the coverage and connectivity available for cellular networks. It is important for an effective management solution to make the

[12] When two hosts are connected over a network via TCP/IP, TCP Keepalive Packets can be used to determine if the connection is still valid, and terminate it if needed.

enhancements and adjustments needed to compensate for the extra challenges. Some of the risks in communication over cellular data networks that need to be mitigated along with their solutions are:

(i) **Availability/Disconnected state**: Mobile devices that are geographically dispersed may not be connected all the time unlike devices connecting to LAN / Wireless LAN networks. The devices could be in a 'disconnected' state due to roaming out of the cellular coverage area, or it might not be feasible to have the devices stay connected for extended time periods due to the high cost of cellular data usage in some regions. A successful management solution needs to adapt to the minimal connected durations by offline/batch processing, queuing and opportunistic communication.

(ii) **Intermittent connectivity:** Even when the devices are connected, the connectivity may not always be optimal, resulting in frequent interruptions during a session or transfer. Mobile devices in the field are seldom stationary and are often used in moving vehicles, which may lead to the data connection being interrupted as the device moves from one place to another. A management solution needs to utilize check-points and session persistence to successfully communicate in these conditions.

(iii) **Latency/Bandwidth limitations:** While the speeds of the cellular networks are improving, the majority of devices worldwide still connect to networks where the throughput is often limited to bandwidths typically less than 40-50kbps. A solution for communicating over the cellular network needs to be bandwidth-efficient and should utilize optimization techniques including caching and compression.

(iv) **Efficient network selection:** Frequently, the cellular data network is not the only option as devices may return to a central location after normal work hours and might have access to a high-speed connection like Wi-Fi, Ethernet cradles, etc. A management solution needs to be able to optimize network selection, limiting heavy data transfer to the faster networks for better user experience and savings.

(v) **Alternate connectivity:** In the event that a remote device cannot connect to the cellular data network, physically accessing the device for troubleshooting or securing data on it may not be an option for a device roaming several hundred miles away from the centralized helpdesk. A solution needs to provide alternate transport to the device through other modes of communication.

6. Security of data collected with handheld electronic devices

6.1 Introduction

C.231. Electronic data collection with a handheld device and the transmission of data in the field as required in the census carries with it numerous potential risks and challenges related to data security and privacy, as has already been noted. Census data contains information that can be misused to uniquely identify, or locate a single person or household (personal information) which can also be particularly sensitive and which should be kept secure and confidential. If stored on devices, data can potentially be stolen or improperly accessed, and the same holds true during data transmission. Multiple layers of security are therefore required to protect data both in storage on the handheld device and in transit between the device and servers.

C.232. It is not a trivial task to maintain data security in this day age, in an environment where IT systems are subject to failure and also vulnerable to cyber-attacks, hacking, and many other threats offered to digitalized information, regardless of their location or connectivity. The use of encryption at both the device level and during transmission can greatly mitigate such security risks. Assuring the protection of census information will require the use of digital data security tools, protocols, and good practices, as well as the application of related regulatory frameworks, laws and guidelines governing the use of such tools.

C.233. Handheld electronic data collection systems typically need to support multiple security objectives, the core principles of which can be represented by the so-called 'CIA triad' consisting of:

- Confidentiality: ensuring that data is properly protected from unauthorized disclosure both when stored on the mobile device and when transferred to the server through restricting access to information based on a 'need to know' principle;
- Integrity: ensuring that data will not be modified (intentionally or unintentionally) or corrupted during storage and in the transmission process from the field to the server; and
- Availability: ensuring the information system is functional and that authorized users can access data and services whenever needed.

C.234. To achieve these objectives, the entire data collection system should be secured against a variety of threats. This can be accomplished through the application of information security industry standards and mechanisms for protection of hardware, software and communications. The IT infrastructure for data collection should be implemented through a combination of security features and controls built into the mobile devices and other components of the IT infrastructure. Where third party vendors or tools are utilized during the mobile data collection process, care needs to be taken to ensure that ownership, possession and utilization of data collected and transmitted are clearly articulated. Sufficient mechanisms need to be in place to audit related arrangements and agreements, and to ensure that penalties for non-compliance are clear and enforceable.

6.2 Overview of security threats and vulnerabilities

C.235. A security threat is defined as "*any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, or individuals through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service*".[13] Because of their nature, mobile devices are exposed to many security threats and vulnerabilities (including loss or theft) that need to be addressed. Mobile devices are typically used in a variety of locations and are often transported from place to place. When planning mobile device security policies and controls, organizations should be aware of the potential for third parties to attempt to obtain sensitive data either directly from the devices themselves or indirectly by using the devices to access the organization's remote resources.

C.236. Because mobile devices primarily use external networks for Internet access, organizations normally have no control over the security of the external networks the devices use. Communications systems may include wireless mechanisms such as Wi-Fi and cellular networks as described in the previous section. This opens up the possibility for these communications systems to be susceptible to eavesdropping and 'man-in-the-middle attacks' (see below) which places the personal and sensitive census data at risk of compromise. Agencies need to enact strict security policies whereby all issued mobile devices are provided with sufficient encryption to prevent 'leakage' of information on external networks. If properly implemented, this will mitigate the risk of any third party acquiring and misusing the information.

C.237. Mitigating information security threats is a continuous process. Before designing and deploying security solutions for data collected with mobile devices, agencies should develop system threat models for the mobile devices and the IT and network resources that are accessed through such devices. Threat modelling is a process commonly used in the computer security community by which potential threats and vulnerabilities as well as potential adversaries and their motivations are identified. Threat modelling also involves quantifying the likelihood of successful attacks and their impacts, and finally analysing this information to determine where security controls need to be improved or added.

[13] National Institute of Standards and Technology (NIST). Information Security: Guide for Conducting Risk Assessments. Special Publication 800-30. September 2012.

C.238. The major security concerns (threats and vulnerabilities) in the mobile data collection process that should be taken into consideration are:

(i) Threats to data stored on mobile devices

C.239. These threats relate to the challenges of securing the data after being collected by the enumerators and stored on mobile devices. They include:

Physical threats: Possibility of mobile devices being lost or stolen because the devices are valuable primarily because the hardware itself can be re-sold, but also because of the sensitive personal and organization information it may contain.

Sensitive information disclosure: unauthorized parties/individuals accessing data and sensitive information such as login credentials, shared secret keys and access token being disclosed to an attacker by reverse engineering.

Application based threats*:* Downloadable applications may introduce many security threats on mobile devices (such as malware and spyware), including both software specifically designed to be malicious as well as software that can be exploited for malicious purposes. These threats have a high probability of occurrence if field staff are provided with the capability of installing third party applications on the devices.

Web based threats: Since mobile devices are often connected to the Internet and used to access web-based services, web-based applications containing untrusted content could introduce risks and threats such as phishing scams, malicious code in downloads, browser exploits, parties posing as a legitimate service provider, drive-by downloads[14]. Use of untrusted content such as Quick Response (QR) codes could also direct mobile devices to malicious websites.

Poor authorization and authentication*:* Poor authorization and authentication schemes relying on device identifiers such as IMEI (International Mobile Equipment Identity), IMSI (International Mobile Subscriber Identity), UUID (universally unique identifier) values for security are the perfect recipe for a failure and can lead to broken authentication and privilege access issues.

Insecure data storage*:* This applies to scenarios when sensitive data stored on device or cloud synced data is left unprotected. It is generally a result of non-encryption of sensitive data, caching of information not intended for long-term storage, global file permissions and not leveraging platform best practices, leading to exposure of sensitive information, privacy violations and non-compliance.

Use of location services: Mobile devices with GPS capabilities typically run what are known as location services. Mobile devices with location services enabled are at increased risk of targeted attacks because it is easier for potential attackers to determine where the user and the mobile device are, and to correlate that information with other sources about who the user associates with and the kinds of activities they perform in particular locations.

Bluetooth attacks: Bluetooth attacks are a method used for device-to-device malware spreading. As soon as the two devices are within range, the compromised device pairs with its target by using default Bluetooth passwords. When the connection is established, the compromised device sends malicious content.

Interaction with other systems: Mobile devices may interact with other systems in terms of data exchange (including synchronization) and storage. When remote system interaction involves

[14] A drive-by download refers to the unintentional download of a virus or malicious software (malware) onto a computer or mobile device.

automatic back-ups of data to third-party backup or cloud-based storage solutions, the risks could be significant.

(ii) Threats to data in transit between device and server

C.240. These threats relate to the challenges of securing the data while being transmitted to servers. Mobile devices typically support cellular networks as well as local wireless networks. There are a number of threats that can affect these networks:

***Insufficient transport layer protection*:** Complete lack of encryption for transmitted data is often observed in mobile applications. Even if strong encryption is in place, ignoring certificate validation errors or falling back to plain text communication after failures can put security in jeopardy.

Network exploits: This results from software flaws in the mobile operating system or other software that operates on local networks (such as Bluetooth, Wi-Fi) or cellular networks (such as SMS, MMS).

Wi-Fi sniffing: This refers to the compromising of data being sent to or from a device as a result of the fact that many applications and web pages do not use proper security measures, sending their data in the clear (not encrypted) so that it may be easily intercepted by anyone listening across an unsecured local wireless network.

Phishing attacks: Phishing is an attack strategy in which the attacker gains sensitive information from the user by presenting itself as a trustworthy entity.

***Man-in-the-middle* attacks**: This is an attack where the attacker secretly relays, and possibly alters, the communication between two parties who believe they are directly communicating with each other. Unless it is absolutely certain that the mobile device will only be used on trusted networks, census agencies should plan their device security on the assumption that the networks between the mobile device and their servers cannot be trusted.

(iii) Threats to data at aggregation and storage on a server

C.241. These threats relate to the risks to the security of the data at the point of reception by central servers and storage in the data centre. The threats include:

***Insecure data storage**:* This refers to where sensitive data stored on servers, or cloud synced data, is left unprotected. As noted in the context of threats to data stored on handheld devices at (i) above, it is generally a result of non–encryption of sensitive data or caching of information not intended for long-term storage.

***Server side controls**:* Failure to implement proper security controls such as patches and updates, secure configurations, changing default accounts or disabling unnecessary running services, in the backend services can result in compromise and confidentiality and data integrity risks.

C.242. Other threats can arise from:

- Connection failure during data transmission between the field and data center.
- Denial-of-service attacks preventing data from being uploaded to the server
- Unauthorized access to data on remote servers, leading to accidental or malicious modification or deletion of data once it is stored centrally
- Natural disasters such as fire, flood, storms, etc.

(iv) Other potential security related challenges

C.243. These include:

- Enumerators entering fabricated or falsified data in an attempt to simplify or modify their own job performance, committing human errors, or violating the confidentiality of data by disclosing private information to unauthorized parties through mal-intent or coercion.
- Challenges faced when trying to secure mobile data collection system projects running on very low or inadequate budgets. This has repercussions on the type of hardware and software used as well as the security system that can be put in place to support data collection.
- Where the infrastructure for mobile communication and Internet access is not yet fully developed, the deployment of security control measures may be challenging. Furthermore, where much of the data collection might take place in remote or isolated locations, and the possibility of transmitting data through mobile networks is very limited or even non-existent, and where data collection is done off-line, there may be limited opportunity for enumerators to be able to authenticate themselves on the mobile devices.

C.244. Clearly, not all threats are equally likely nor have the same impact. Some threats may never manifest themselves because they are either too costly for an adversary or the rewards too little. The degree of the measures necessary to combat security threats need to take this into account.

6.3 Measures to overcome security threats and vulnerabilities

C.245. Data security is important for the sanctity of mobile data collection operations. Unsecured wireless devices and networks have become significant points of vulnerability and open up statistical agencies to possible hacker access. Therefore, it is becoming increasingly important to prevent access to networks holding personal information, given in confidence, by unauthorized persons. The encryption of all data transmitted between wireless devices is also important to prevent inappropriate disclosure of confidential information. The main security concerns in mobile data collection systems are the confidentiality and integrity of the data and their availability, while keeping costs for instigating and maintaining security measures and hardware requirements as low as possible without compromising usability. This section summarises some measures and mitigation strategies, based on standard best practices, that can help to overcome security threats and vulnerabilities.

(i) Measures for securing data on devices

C.246. Important measures include:

User and device authentication

- Provide a device password/passcode and/or other authentication (such as token-based authentication, network-based device authentication, domain authentication) before accessing the agency's network. This includes basic parameters for password strength and a limit on the number of retries permitted without negative consequences (such as, locking out the account, wiping the device).
- If device account lockout is enabled or the device password/passcode is forgotten, an administrator can reset this remotely to restore access to the device.
- Have the device automatically lock itself after it is idle for a period (for example, 5 minutes).
- Under the direction of an administrator, remotely lock the device if it is suspected that the device has been left in an unlocked state in an unsecured location.

Data storage

- Strongly encrypt stored data on both built-in storage and removable media storage. Removable media can also be 'bound' to particular devices such that encrypted information can only be decrypted when the removable media is attached to the device, thereby mitigating the risk of offline attacks.
- Wipe the device (to scrub its stored data) before reissuing it to another user or retiring the device. The device can also be wiped remotely if it is suspected that the device has been lost,

stolen, or otherwise fallen into untrusted hands and is at risk of having its data recovered by an unauthorised party.
- A device can also often be configured to wipe itself after a certain number of incorrect authentication attempts.

General device-use policy. General device-use policy restrictions of particular application to mobile device security include:
- Restrict, where appropriate, user and application access to hardware, such as the digital camera, GPS, Bluetooth interface, USB interface, and removable storage.
- Restrict, where appropriate, user and application access to native operating system (OS) services, such as the built-in web browser, email client, calendaring, contacts, application installation services, etc.
- Restrict which applications may be installed through whitelisting[15] (preferable) or blacklisting[16].
- Install, update, and remove applications. Safeguard the mechanisms used to perform these actions. Keep a current inventory of all applications installed on each device.
- Control the use of application synchronization services (such as, local device synchronization, remote synchronization services and websites).
- Prohibit devices from connecting to unauthorized third-party back-up services or home computers.
- Verify digital signatures on applications to ensure that only applications from trusted entities are installed on the device and that code has not been modified.
- Distribute the agency's applications from a dedicated mobile application store.
- Manage wireless network interfaces (Wi-Fi, Bluetooth, etc).
- Automatically monitor, detect, and report when policy violations occur, such as changes from the approved security configuration baseline, and automatically take action when possible and appropriate.
- Preferably use an operating system that allows a sandbox environment[17]/secure container that isolates the organization's data and applications from all other data and applications on the mobile device.
- Preferably secure device with a mobile device management (MDM) system, avoiding the installation of unauthorized apps.
  - Create a policy for a frequent synchronization of the data by the enumerator, avoiding the risk of non-transmitted data loss.
  - Train users and raise awareness of the risks of untrusted content and other insecure physical security practices such as connecting mobile devices to unknown charging devices.
  - Perform a risk assessment on each third-party application before permitting its use on the organization's mobile devices.
  - Impose geographic restrictions (geo-fencing); this refers to the notion of limiting certain functionality, such as data collection or access, to specific geographic regions where the enumerator is assigned.

(ii) Measures for securing data during transmission (security for client-server communication)

[15] An application whitelist is a list of applications and application components (libraries, configuration files, etc.) that are authorized to be present or active on a host.

[16] Application blacklisting, sometimes just referred to as blacklisting, is a network administration practice used to prevent the execution of undesirable programs. Such programs include not only those known to contain security threats or vulnerabilities but also those that are deemed inappropriate within a given organization.

[17] Application sandboxing, also called application containerization, is an approach to improving security by isolating an application to prevent outside malware, intruders, system resources or other applications from interacting with the protected app.

- Strongly encrypt data communications between the mobile device and the servers. This is most often in the form of a virtual private network (VPN) or other established secure protocols such as multi-protocol label switching (MPLS) to make sure data will not be modified or corrupted during the transmission process from the field.
- Prohibit the use of insecure Wi-Fi networks, such as those running known vulnerable protocols. Also, all network interfaces not needed by the device can be disabled, thus reducing the attack surface.
- Use Hypertext Transfer Protocol Secure (HTTPS) through Transport Layer Security (TLS)/Secure Sockets Layer (SSL) for network communication in order to protect the transmission of data between field staff and the server.
- Use HTTPS with certificates signed by a trusted Certificate Authority (pre-installed on the mobile device by the manufacturer).
- Compress transmission package and use a long password with special characters, to avoid brute-force break[18].
- Transmit and store separately. Use link or reference IDs or both to match data sets with personal information. Designate a limited number of specific individuals who will have access to such information.

***(iii)* Measures for securing data at aggregation and in the data center**

- Request authentication and user certificate before providing access to servers in data center.
- Implement identity and access management tools as an integral part of maintaining data security.
- Use access list to protect the data center from unauthorized access. Applying the minimum privileges on database users, so that database users only have the privileges they need. No root privileges for any user.
- Track user-access to data and actions performed, such as data downloaded, etc.
- Host servers on DMZ[19] (demilitarized zone, sometimes referred to as a perimeter network) to add an additional layer of security by firewalling an organization's local area network (LAN)
- Back-up data and implement a disaster recovery site.
- Use the latest technologies in firewall, intrusion detection system (IDS), and web application firewall (WAF) to ensure data security.
- Build redundancy into the data center in terms of hardware, software and power source to make sure all services are available to users continuously during the entire census operation.
- Control storage of personally identifiable information (including geo referencing) by storing them separately and using links or reference IDs to match data sets. Designate a limited number of specific individuals who will have access to personal information.

6.4 Technologies for mobile device management[20]

C.247. Centralized mobile device management technologies (MDMs) are increasingly being used as a solution for controlling the use of mobile devices deployed by any organisation. In addition to managing the configuration and security of mobile devices in the field, these technologies offer other features, such as providing secure access to data transfer networks and other organizational resources. MDM solutions represent a critical platform to support the secure management of mobile devices and

[18] Brute-force break (also known as brute-force cracking) is a trial and error method used by application programs to decode encrypted data such as passwords or Data Encryption Standard (DES) keys, through exhaustive effort (using brute force) rather than employing intelligent strategies.

[19] In computer security, a DMZ or demilitarized zone (sometimes referred to as a perimeter network) is a physical or logical subnetwork that contains and exposes an organization's external-facing services to an untrusted network, usually a larger network such as the Internet.

[20] Adapted from National Institute of Standards and Technology (NIST) Guidelines for Managing the Security of Mobile Devices in the Enterprise. NIST Special Publication 800-124, Revision 1. June 2013.

associated applications. Particularly in a BYOD scenario, MDM can be helpful in ensuring that confidential data is not leaked. Ensuring that confidential data is wiped completely is a key feature of MDM solutions.

C.248. With the use of MDM technology, a "kiosk" approach can be used which creates a customer home screen (for example, which can have logo of census office) and then only provides access to the applications required by the enumerator (i.e. data collection app, user manual, camera, GPS). This simplified screen can prevent the enumerator from getting "lost" on their tablet. MDM software is also very useful if devices are stolen or lost as they can be tracked or remotely locked/erased.

C.249. There are two basic approaches to centralized mobile device management: use a messaging server's management capabilities (often from the same vendor that makes the brand of mobile device operating system used for the census), or use a product from a third party, which is designed to manage one or more brands of mobile device operating systems. It may be possible, with the latter approach, to have a single product that can manage multiple brands of mobile device operating systems. However, a product provided by a mobile device manufacturer may have more robust support for their own mobile devices than have third-party products.

C.250. Architecturally, both approaches to centralized mobile device management are quite similar. The typical solution has a straightforward user/server architecture. The statistical agency may have one or more servers that provide the centralized management capabilities, and one or more field/user applications may be installed on each mobile device and configured to run in the background at all times. If the device is issued by the agency, the user application typically manages the configuration and security of the entire device. If the device is BYOD, the user application typically manages only the configuration and security of itself and its data, not the entire device. The user application and data should be sandboxed from the rest of the device's applications and data in a secure container in order to help protect the data from a compromised device.

C.251. Services commonly needed for the security management of mobile devices may be provided by the mobile device operating system, enterprise mobile device management (MDM) software, or other security controls. These services apply to the entire mobile device (if it is fully managed) or to the mobile device's secure sandbox/secure container, unless explicitly noted otherwise. These services are equally relevant for centrally managed or individually managed mobile devices.

C.252. Most statistical agencies will not need to implement all of the security measures listed in section 4.3. Those deploying mobile devices should, however, consider the merits of each measure, determine which are needed for their particular environment, and then design and acquire one or more solutions that collectively provide the necessary management.

6.5 Development of security policies[21]

C.253. Security management is a continuous process of reviewing and updating security rules and supporting technology to maintain a proper level of defense against evolving security threats. Statistical agencies should have a security policy for their mobile data collection system. Such a policy should define which of the agency's systems may be a securely accessed via mobile devices, which types of mobile devices can be permitted to safely access such systems, the degree of access that various types of mobile devices may have—comparing, for example, agency-issued devices with personally-owned hardware (when adopting a bring your own device approach)—and how provisioning should be handled. It should also cover how the agency's centralized mobile device management servers are administered, how policies in those servers are updated, and all other requirements for mobile device management technologies. The mobile device security policy should

[21] Adapted from NIST – Guidelines for managing the security of mobile devices in the Enterprise.

be documented in the system security plan. To the extent feasible and appropriate, the mobile device security policy should be consistent with and complement security policy for non-mobile systems.

C.254. Mobile devices deployed in the field often need additional protection because their nature generally places them at higher exposure to threats than other similar devices used within the agency's facilities and on the agency's networks. Before designing and deploying mobile device solutions, agencies should develop system-threat models both for mobile devices themselves and the systems that are accessed by them. Threat modelling helps agencies to identify security requirements and to design the mobile device solution in order to incorporate the controls needed to meet those security requirements. It involves identifying systems of interest and the feasible threats, vulnerabilities, and security controls related to these systems, then quantifying the likelihood of successful attacks and their impacts, and finally, as has previously been noted, analysing this information to determine where security controls need to be improved or added.

C.255. ***Agencies deploying mobile devices should consider the merits of each provided security service, determine which services are needed for their environment, and then design and acquire one or more solutions that collectively provide the necessary services***. Most organizations do not need all of the possible security services provided by mobile device solutions. Categories of services to be considered include:

- General policy: enforcing security policies on the mobile device, such as restricting access to hardware and software, managing wireless network interfaces, and automatically monitoring, detecting, and reporting when policy violations occur.
- Data communication and storage: supporting strongly encrypted data communications and data storage, wiping the device before reissuing it, and remotely wiping the device if it is lost or stolen and is at risk of having its data recovered by an untrusted party.
- User and device authentication: requiring device authentication and/or other authentication before accessing agency systems, resetting forgotten passwords remotely, automatically locking idle devices, and remotely locking devices suspected of being left unlocked in an unsecured location.
- Applications: restricting which app stores may be used and which applications may be installed, restricting the permissions assigned to each application, installing and updating applications, restricting the use of synchronization services, verifying digital signatures on applications, and distributing the agency's applications from a dedicated mobile application store.

C.256. ***Agencies should implement and test a pilot of their mobile device solution before putting the solution into production.*** Aspects of the solution that should be evaluated for each type of mobile device include connectivity, protection, authentication, application functionality, solution management, logging, and performance. Another important consideration is the security of the mobile device implementation itself; at a minimum, all components should be updated with the latest patches and configured following sound security practices. Also, use of jailbroken[22] or rooted[23] mobile devices should be automatically detected when feasible. Finally, agencies should ensure that the mobile device solution does not unexpectedly 'fall back' to default settings for interoperability or other reasons.

C.257. ***Agencies should fully secure each of their own mobile device before allowing a user to access it.*** This ensures a basic level of trust in the device before it is exposed to threats. For any already-deployed agency-issued mobile device with an unknown security profile (unmanaged device), agencies should fully secure them to a known good state (for example, through deployment and use of centralized mobile device management technologies). Supplemental security controls should be deployed as risk merits, such as antivirus software and data loss prevention (DLP) technologies.

[22] Jailbreaking is the process of removing software restrictions put into place by manufacturers and carriers on devices.

[23] Rooting is the process of allowing users of mobile devices to attain privileged control (known as root access) over subsystems running on the mobile operating system.

C.258. ***Organizations should regularly maintain mobile device security.*** Helpful operational processes for maintenance include: checking for upgrades and patches, and acquiring, testing, and deploying them; ensuring that each mobile device infrastructure component has its clock synced to a common time source; reconfiguring access control features as needed; and detecting and documenting anomalies within the mobile device infrastructure, including unauthorized configuration changes to mobile devices. Other helpful maintenance processes are: keeping an active inventory of each mobile device, its user, and its applications; revoking access to or deleting an application that has already been installed but has subsequently been assessed as too risky to use; and scrubbing sensitive data from mobile devices before reissuing them to other users.

C.259. Also, agencies should periodically perform assessments to confirm that their mobile device policies, processes, and procedures are being followed properly. Assessment activities may be passive, such as reviewing logs, or active, such as performing vulnerability scans and penetration testing.

7. Use of geospatial technology during enumeration

C.260. The use of geographic information systems (GIS) technology is becoming essential for achieving a more accurate, timely and more cost-effective outcome in almost all the phases of a population and housing census. The emergence of digital mapping, GIS technology, allied with the availability of more accessible satellite images and GPS has made great advances on the logistics, planning, monitoring and operation of the census.

C.261. Use of GIS is, in particular, changing the way that a census enumeration is conducted. Typical use of GIS in the fieldwork for previous censuses was primarily in the production of enumeration area (EA) maps. However, with the move to digital technology, paper maps are being replaced with digital versions on mobile devices. Provision of map services allow field staff to access base maps with EA boundary information overlaid directly through an application (app) on the device.

C.262. The main contributions of a GIS system during enumeration is to support the logistical planning, workforce management, data collection, and monitoring of the census operations and progress. GIS can be used to improve data collection, help navigate or route workers to the location, manage work assignments, track workers and project progress and store data to the geodatabase. In essence then GIS mobile apps offer the ability to perform form-centric[24], accurate data collection in the field, then return the data directly to a secure environment for analysis and reporting. These features are discussed in this section.

7.1. Workforce management

C.263. One of the most important tasks in a field enumeration is workforce management. Workforce management has evolved from a traditional approach of simple staff scheduling to improved time and resource management to creating efficiencies and providing transparency across the workforce. There are many different considerations in workforce management; the forecasting of workload and required staff, management of working times, technical or specialized skills and equipment as well as needs of the respondent. Workforce management should be a complete approach designed to make a workforce

[24] In form-centric data collection, the focus is a list of questions, with geographic information (points) being just another question in the questionnaire (form).

as productive as possible, reduce labour costs, reduce respondent burden, and improve the overall quality of the census.

C.264. The GIS technology can be used to assign work to individual enumerators, as well as to monitor their activities and provide the necessary assistance. The tasks are assigned on the basis of the statistical division of the country – for example, into statistical regions and census areas. The GIS system can be used to entrust enumerators with the tasks specific to their assigned enumeration areas.

C.265. GIS solutions allow for complex scheduling analysis and assignments. The characteristics of enumerator (such as their address and languages spoken) and other logistical variables can be used, along with the underlying street transportation network, to suggest best possible scenarios for completion of work.

C.266. Additional factors can be used in optimization such as travel time, estimated travel costs, and estimated length of interview.

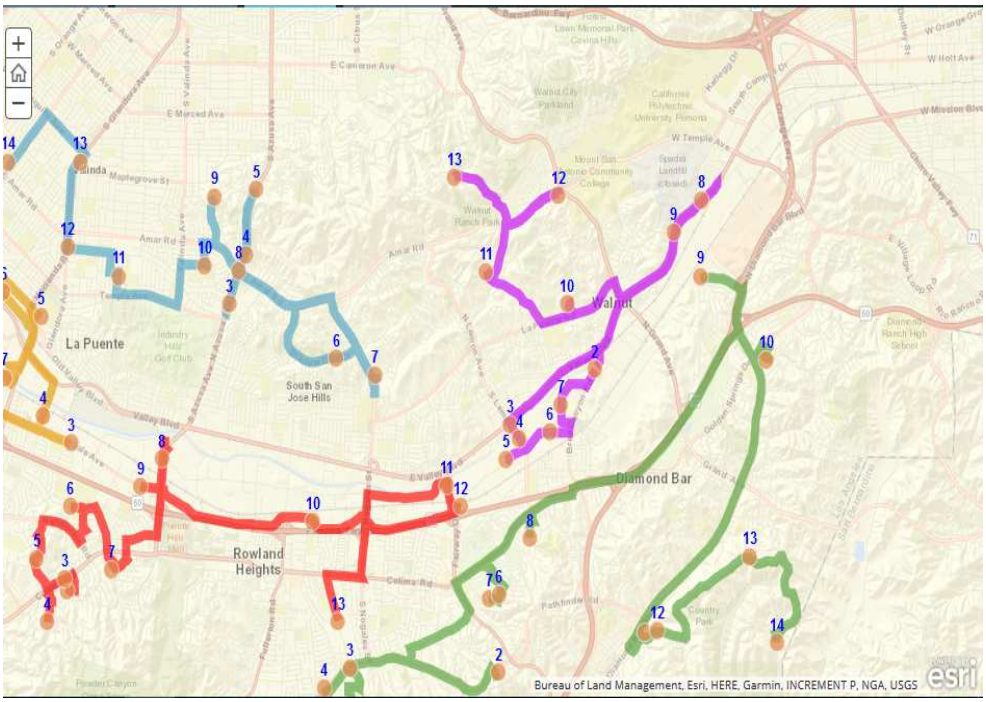
C.267. Specific functions can be performed such as:

- Optimized routes by determining the quickest, or shortest, or most cost-effective route through the EA. Routes can accumulate any number of cost values such as distance, time, or other attributes.
- Finding closest facilities in order to estimate the cost of traveling between locations and facilities to determine which are nearest to one other.

C.268. Pre-planning routes saves time and produces more reliable schedules for household visits. This is particularly important if households need to be re-visited in the follow-up phase. It can also help with fuel and labour optimization.

C.269. Figure 7.1 shows a typical territory with optimized routes for each day for one enumerator. The routes for each day are depicted in different colours and include the optimal stop sequence number for each site visit.

Figure 7.1. Example of daily optimized routes for one enumerator



C.270. Using handheld devices to carry maps and assignments makes it easy for enumerators to organize their daily workloads by determining the optimum route to each household, report progress, and call for any necessary assistance.

7.2. Use of enumerator map application during data collection

C.271. By integrating GIS in the data collection process, statistical agencies can collect and update information in the field and capture locational information. Putting GIS mapping in the hands of the field staff improves the accuracy and currency of census data.

C.272. The enumerator map on the handheld device can be used not only as a simple guiding tool, but as an essential instrument for improving the accuracy of the data collection process. By following a pre-determined path, and knowing their exact location in real time, the risk of enumerators getting lost is reduced, and there is less effort in identifying particular dwellings on the ground. This process can be assisted with the application of a zoom functionality to provide more geographical detail, and is particular helpful if the EA is extensive, which is very often the case in remote rural areas as shown in the example on Figure 7.2.

Figure 7.2. A view of a remote EA in Brazil

C.273. With the aim of ensuring enumerators' safety, the mobile application should be equipped with an alert function to notify the supervisor of any emergency situations and to provide support (emergency service, police) through an embedded GPS module.

7.3. Monitoring and operation management

C.274. While the enumerator operates in the field, producing geo-data of his/her route and household locations, the supervisor has the ability to monitor the progress of the census enumeration locally. All such data should be sent to the supervisor regularly whether or not there is a real-time transmission process embedded or a delayed transmission process. The use of these coordinates is very important to facilitate better management of the enumerator's workload by checking the effective progress, comparing the actual completions rates compared with those expected. Also, by knowing they are being monitored in this way, the enumerators are discouraged from making any fraudulent returns, knowing that their outputs can be easily verified by the supervisor. Figure 7.3 shows an example of an attempt to complete a questionnaire at a location beyond the boundary of an enumerator's EA, that can be verified by the supervisor on an management information system (MIS).

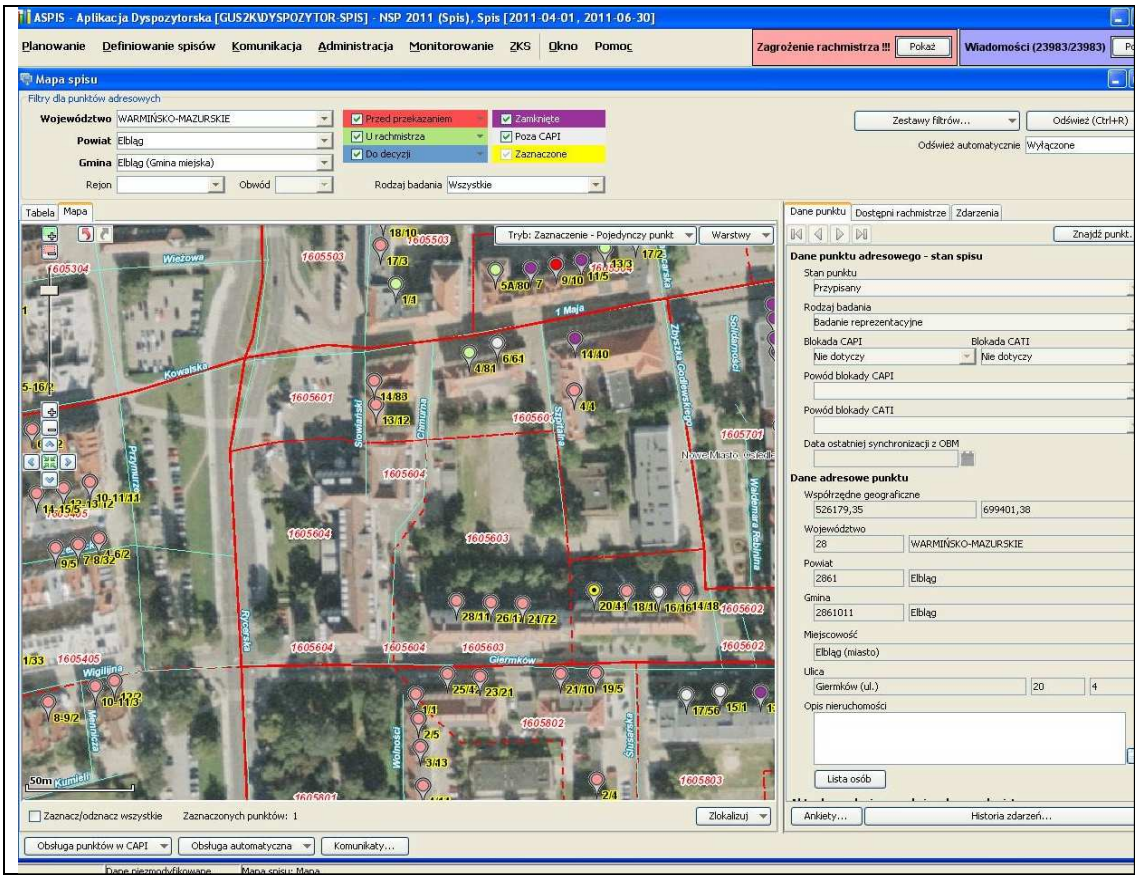
Figure 7.3. A view of filling the questionnaire out of the EA

C.275. GIS operational dashboards bring together a common view of the progress of the enumeration. These dashboards can be configured to allow for the monitoring of real-time data feeds for day-to-day operations on the handheld devices. Typical features to look for in an operational dashboard include:

- Use maps with dynamic data sources
- Provide real-time views
- Configure charts, gauges, histograms, and more, to provide statistical context
- Create and share operation views that are focused on a specific need
- Design views for use on multiple monitors or single-display devices
- Use the operation view in a browser

C.276. The progress and completeness of the enumeration can be monitored by means of a 'dispatching' application that contains a background map with reference data (an orthophoto map, the statistical division, a network of roads and streets) as shown in Figure 7.4. By visualising the EAs on such a map, the application enables monitoring progress at any level of geographic aggregation (census area, statistical region, local Districts or Regional level).

Figure 7.4. A view of the dispatching application in the enumeration mode, Poland



C.277. By monitoring each enumerator's progress in real time, supervisor can verify whether or not completed questionnaires have been dispatched for checking, while, at the same time, monitoring progress at the workload level, supervisors can make decisions on any need to reallocate tasks between individual enumerators, with the aim of ensuring a smooth and timely completion of the enumeration.

C.278. When utilizing GIS for field management purposes, it is necessary to consider some key features of mobile GIS, such as the following, to ensure that mobile GIS will integrate seamlessly with other systems.

- What data formats can be imported/exported
- Data projections supported
- Data display, data query
- Map navigation
- Map query
- Map display
- Support for GPS receivers
- Mobile data collection

7.4. Updating and correction of EA maps during enumeration

C.279. Census maps are usually prepared several months, or even years, ahead of the actual enumeration. Therefore, new constructions and infrastructure developments may not be shown in the EA maps. Moreover, census maps may contain errors - sometimes significant errors - that may lead to either under- or over-coverage.

C.280. It is usual practice to verify EAs and units to be covered just prior to the actual enumeration. The enumerators themselves will usually be entrusted with the task of inspecting their census areas, as this provides a good opportunity to get to know the geography and characteristics of an area with which that they may not be familiar and to determine enumerator workloads. This round of validation of EAs is aimed primarily however at verifying the existence of buildings and supplementing the address list with missing address points. This data will allow the statistical agency to correct and update the digital maps in good time for the enumeration itself.

8. Field operation management and monitoring

C.281. In recent years, increasing access to modern technology has led to significant progress in management and monitoring of field operations. With the use of handheld devices and systems that integrate these devices with the Internet, it is not very difficult to establish a centralized system for an effective management, monitoring and controlling operational activities. This kind of system may have many of the capabilities of on-site monitoring and tracking the risks and making right decisions. For building such a system, it is important to have a good understanding of its benefits to improve the quality of enumeration as well as how to integrate it with field operations in order to get maximum benefits through making it available to field managers and staff.

C.282. Before starting the actual census enumeration, a number of preparatory activities have to be implemented, including (among others) the organisation of the field structure, and the recruitment and training of the field staff. During this period, for any type of census, the information about the field staff, collected for administrative and organisational purposes, is crucial for a successful enumeration. Establishing a system for capturing this information and updating it as necessary should be considered by statistical agencies in order that such administrative information can be shared between the different levels management of census operation. Moreover, during the period of the actual enumeration, the speed and efficiency of communication in the field and monitoring the coverage and quality of the enumeration is very important in order to be able to respond quickly to issues that arise in the field. The use of CAPI technology and extensive use of Internet at sub-national level will make it much easier to establish such a system.

C.283. Establishing management and monitoring system with the use of technology CAPI has, basically, two main objectives. These are:

- To improve the efficiency of enumeration through effective communication between census management and field staff;
- To improve accuracy and quality of administrative and operational procedures through recording them in the system and sharing them with all relevant census field staff from the local level through to headquarters.

C.284. This chapter overviews field operations in the view if the use of CAPI and also discusses key features and functions of a Management Information System (MIS).

8.1. Organization of field enumeration[25]

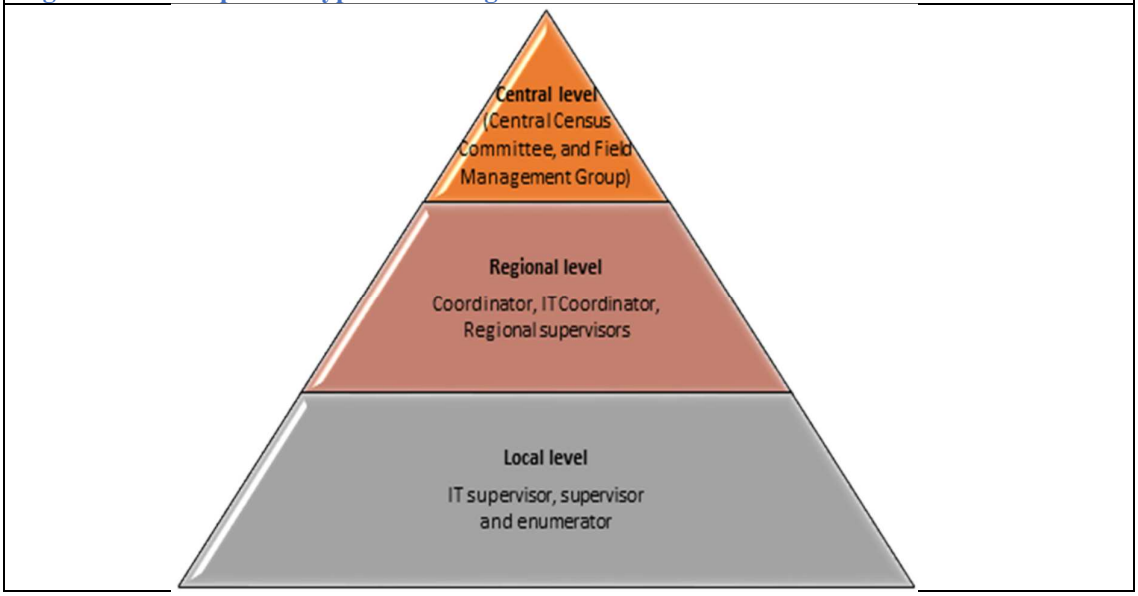
C.285. Regardless of the data collection methodology adopted, the field organization for the census should typically have a hierarchical structure, reflecting both the territorial division of the country and the division of statistical competences (see Figure 8.1). Therefore, at least two levels (central and regional) should be distinguished, whereas a third 'local' level (such as at the municipality or district

[25] The UN Handbook on the Management of Population and Housing Censuses Revision 2 provides detailed information on organisation and management of field operation and duties of census field staff (see paragraphs 2.92-2.176).

level) should also be considered in countries with large populations, with the aim of ensuring a better organization of field enumeration.

C.286. **The central level** has a critical role with the responsibility of monitoring the enumeration of entire country. As noted earlier, with the use of CAPI, the managers at central headquarters will be able to evaluate the progress of the enumeration and make decisions on problematic issues or problematic geographical areas which cannot be resolved at the local or regional level. For this purpose, a special team can be set up and designated as a 'Field Management Center' or 'Field Operational Control', and will be responsible for daily monitoring the field enumeration and informing the central level managers for the purposes of making decisions on critical issues.

Figure 8.1. Example of a typical field organization structure



C.287. **The regional level,** as long as it corresponds to the division of competences within official statistics, is usually focused on preparing and conducting the data collection process, following which it is dissolved. Regardless of the data collection method, for a successful field enumeration, establishing a dedicated management team at the regional level is necessary for the management and monitoring of field operation. With the use of CAPI, setting up regional offices in terms of staff involved and technology needed requires more attention and maybe more time to build capacity at the regional level. In general, the team's duties include: (i) implementation of the activities necessary for the recruitment of the field staff, training, organisation of the work of supervisors and enumerators within their designated areas, and logistical issues; (ii) close monitoring of the field enumeration; and (iii) providing a support to the field staff. As it is the main body responsible for organisation and implementation of the field work at the sub-national level, the role of the regional level management is critical for the success of the field enumeration. The technological infrastructure at the regional level should be secure and fit for their purpose.

C.288. If the data transfer protocol calls for the involvement of regional offices, the regional level field staff should be sufficiently well-trained and skilled in the use of the technological infrastructure.

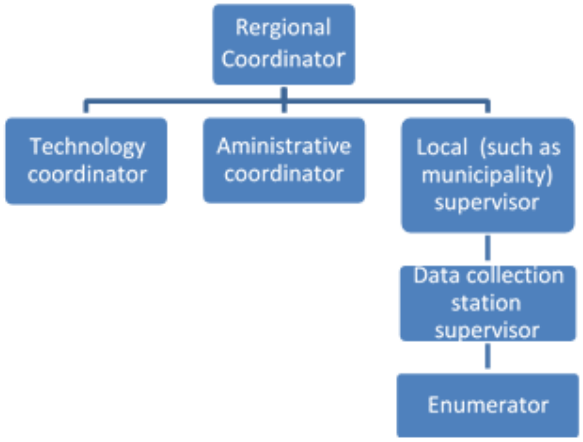
C.289. **The local level** is necessary mainly for the purpose of providing census enumerators and their immediate supervisors with direct and immediate assistance within their operational area during the enumeration. Especially with the use of CAPI, the local level should have a capacity to provide immediate basic support for IT-related issues. Furthermore, in areas where lack of cellular networks

dictates the establishment of data collection stations at the local level, it would be necessary to provide data transfer capabilities, online and/or offline depending on the circumstances.

C.290. Where enumerators collect data using CAPI, it is also important to determine the appropriate technology for other field staff. For example, coordinators and supervisors may also use handheld devices for undertaking their own responsibilities such as assigning the work to the field staff, evaluating the quality of the work of the enumerators, and monitoring progress.

C.291. In practice, the organisational structure of the field operation can differ greatly from one country to another depending on the census methodology adopted and the necessary hierarchal levels of management required. The following two examples present the particular field organisational structures of the most recent census from two countries that have adopted a handheld device data collection methodology - Brazil and Jordan.

Box 8.1 Regional field organization structure – Brazil Census 2010



8.1.1. Roles and responsibilities of the field staff

C.292. As with the structure of the field operation, the roles and responsibilities of field staff at each level will vary from country to country and will depend on the data collection methodology and the technology used. However, they will always involve some form of management, supervision and communication with the level immediately above or below. Usually one supervisor will have responsibility for managing several enumerators, and in turn, several supervisors will be managed by one regional coordinator/manager who may also be responsible for managing specialist IT staff (see below). The enumerator-supervisor ratio will have impact the roles of supervisors. If supervisors will double-check all the questions, then they will not work much faster than an enumerator and should be limited to possibly supervising 2 or 3 enumerators. If they are only required to check questions which have failed validation rules, which are incomplete, and possibly a few key questions then there could be a larger enumerator to supervisor ratio. Likewise with managers of supervisors. If they are required to double check everything then the ratio needs to be very small. During pilot testing and possibly during the first few days of enumeration, it is important to have all supervisors and managers (headquarters) double-checking everything to make sure all field staff including enumerators and supervisors have clearly understood what they are to do.

C.293. The roles and duties of all levels of field staff should be clearly defined in the various field instruction manuals and should be reinforced during training (see section 8.2 below).

C.294. The roles and responsibilities of regional coordinators, supervisors and enumerators are discussed generally within the context of a more traditional paper-based enumeration methodology in the *UN Handbook on the Management of Population and Housing Censuses Revision 2* (see paragraphs 2.141-2.176). Where a CAPI methodology is adopted, the roles of the field staff will be broadly similar with the addition, however, of those tasks specific to electronic data collection and transfer of data from the field during the enumeration. The main duties of the field staff, focusing on their specific roles in the use of CAPI technology are briefly summarised below.

(i) Regional managers/coordinators

C.295. This level of field staff is mainly responsible for guiding and monitoring operational and administrative activities and establishing the link between field staff at the local level and central headquarters. It is important that regional coordinators have good knowledge of the CAPI, security procedures, and the capacity to recruit and train field staff, where this is done regionally rather than centrally. They should have the capacity to communicate clearly with the public, media and other stakeholders, particularly on sensitive issues and the benefits of using technology in censuses.

(ii) IT coordinator and support teams

C.296. A team of IT supervisors should be established at the regional and local levels, as appropriate, to provide technical support to enumerators and supervisors for all IT-related activities. A coordinator of the IT team can be assigned at the regional level, responsible for the coordination and organisation of such activities, working closely with the regional coordinator and headquarters. The statistical agency may wish to adopt a different process for the recruitment of the IT team depending on their existing capacity. In many cases, the recruitment of a sufficient number of temporary staff with IT skill – or the training of such staff - would be a challenge for the agency, as such processes would not usually be within the scope of their core competences. In the planning phase, all possible options, including the outsourcing of such recruitment activities, should be evaluated to determine the most effective and feasible process.

C.297. The duties of the IT teams might differ from one country to another but they should be responsible at least for the following activities:

- Installing the operating system and any access to the Internet onto the devices;
- Checking all the device accessories (chargers and power connections);
- IT training of supervisors and enumerators when needed;
- Following-up and assisting the enumerators in the field in the event of technical and hardware/software problems during the field work;
- Monitoring data transfer and, in case of difficulty, supporting the enumerators/supervisors for the timely transference of data;
- Providing substitute devices in the event of any malfunction.

(iii) Supervisors

C.298. Their main roles are to supervise their immediate staff, assign the work of each enumerator to a specific EA and monitor the quality of their work by ensuring good territory coverage and that the schedule and deadlines are met, and to liaise with the IT team in providing direct support for basic IT-related issues such as data collection applications and data transfer.

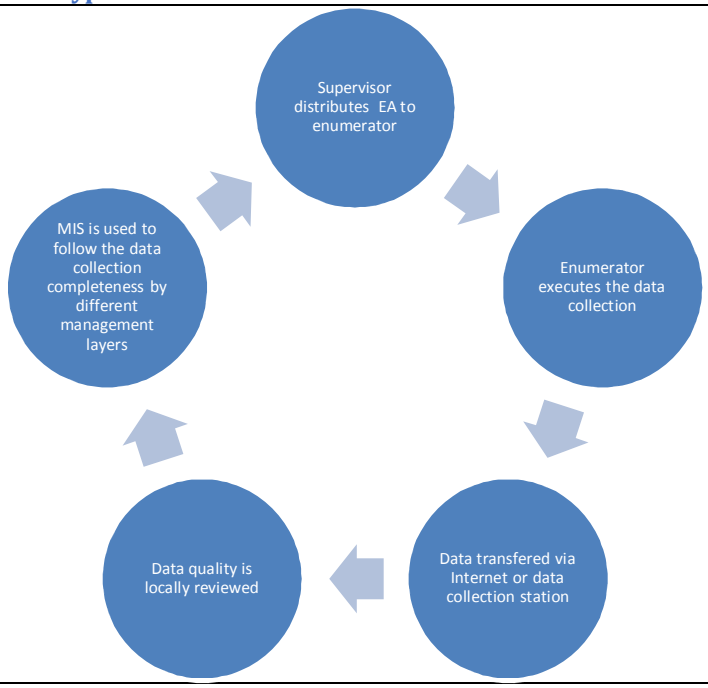
(iv) Enumerators

C.299. These are the field staff mainly responsible for the actual data collection by using CAPI and ensuring (preferably) daily transmission of data during the enumeration.

C.300. The workflow of the data collection in the field will depend largely on organisation of the field operation and also methods of transferring data from the field to headquarters. A typical

workflow for field enumeration at the local level, involving data transfer via Internet and data collection stations, is illustrated in Figure 8.2.

Figure 8.2 Example of a typical local workflow



8.2. Field staff recruitment and training

(a) Recruitment

C.301. For any field operation-based census methodology, very large numbers of field staff, to be deployed over wide and varying geographic areas, are required. The majority of these staff are required only for the relatively short period of the enumeration period. In some countries, these staff may be recruited from the general public. In others, existing staff from other public sectors, such as teachers, may be used. The principal objectives of the recruitment exercise should be to appoint staff who, with appropriate training, are capable of undertaking the duties of the various positions and in sufficient numbers for all geographic areas. The quality of the recruitment campaign will directly affect the quality of the data to be collected, and therefore the success of the census[26]. By the time the recruitment campaign is ready to begin, the structure and ratio of staff at the various levels of the field operations hierarchy should be known.

C.302. The major factors affecting the focus of the recruitment campaign are the mode of data collection and the technology to be used. For the recruitment of the field staff, the job description and duties of each level of field staff should determine the qualifications required. For enumerators and

[26] For more information see UN Handbook on Management of Population and Housing Censuses, paragraph 3.204-3.240.

their supervisors who are going to have to work with handheld devices, it would be preferable to seek for experience, or at least some familiarity, in the use of such devices. Applications form should aim to collect information on the level of knowledge of the use of certain devices and applications. For the recruitment of other field staff such as IT coordinators, regional supervisors, in addition to requiring experience with devices and applications, applicants might be asked to show proof such experience through certificates and/or taking a test after a short training programme.

C.303. It should be noted again that some countries now prefer to outsource the recruitment (and payment) of field staff to external contractors with a particular expertise in field operations. Such services are clearly a non-core activity for statistical agencies who may not be able to provide them internally at the scale necessary for the census without a significant additional investment.

C.304. The field staff recruitment should be done in phases, allowing each role to start working at the correct time. The regional coordinators and supervisors (and IT support teams) should be the first to start working because there is pre-enumeration work to be done before the data collection can begin. Local offices and IT infrastructure must be prepared, enumeration areas must be recognized and mapped, address or dwellings lists prepared, and enumeration area tracking must be planned. All this work must be accomplished before the enumerators can start working.

C.305. Field staff appointments may be best achieved by filtering the better qualified through applying tests and interviews, and perhaps prioritizing people who live near a designated collection area. This can be, in some cases, helpful because a person who lives locally will be more familiar with the characteristics and geography of enumeration areas, and transportation costs will be minimised. However, countries should also be aware of the potential bias and confidentiality concerns of appointing enumerators to areas where they may be known by a large number of respondents.

C.306. Candidates for census enumerator positions must of course fulfil any basic requirements prescribed in national law. Moreover, they should also meet the criteria traditionally imposed on census enumerators (such as sufficient levels of literacy and numeracy). What makes CAPI interviewers different from traditional enumerator is the additional need to have practical skills in using electronic devices. It is also desirable for candidates to be familiar with the functioning of GPS systems and the use of digital maps. However, both terminal operation and the use of digital maps should constitute separate topics of the census-related training courses (see below).

C.307. It is important to develop a dedicated IT sub-system for staff recruitment process, and for the demarcation of enumerators' work. Such a sub-system may facilitate entering candidates' data to the MIS, preparing contracts and other employment documents (as required under national law), calculating enumerators' salaries, developing accounts and generating the adequate bank orders. The following information should be available in the MIS for using standard information for administrative procedures as well as for sharing contact information of the field staff with relevant enumerators/supervisors/managers.

Information about temporary field staff:

- Employee Name
- Employee Number
- Employee Address
- Employee Wage Rate
- Employee languages spoken
- Equipment issued (for example, laptop and standalone GPS)
- Employee special skills

Information be added in the system after recruitment of the field staff

- Enumeration Area Number
- Regional office name
- Regional office number

- Local office name
- Local office number
- Field Supervisor (name, number, address, etc,)
- IT Supervisor (name, number, address, etc,)

(b) Training

C.308. Good and effective training of all the census field staff – recruited only temporarily for the during of the field operation – is vital to ensure a smooth and successful enumeration. Dedicated training should be organised for each of these groups, making them well-prepared to a fulfil their role in the census process. A training plan, together with all the necessary tools and documentation, is usually prepared well in advance of the recruitment process for the staff at all levels.

C.309. Regional managers and IT coordinators should be trained centrally, following which, training courses for census supervisors, and then enumerators, should take place regionally and locally. It is a good practice firstly to train managers and then involve them in organising the training of supervisors, who should then be similarly involved in the training of enumerators in turn. This cascading approach is not only more cost effective but provides an opportunity for managers and supervisors to get to know their teams before the census. Such training should be a mandatory requirement for all levels of field staff.

C.310. A certain part of the training should be devoted to practical activities regarding the use of mobile applications and the enforcement of all relevant use policy provisions (see section 7.6 below). In order to get experience, the training should be implemented on the electronic devices that the enumerators will be expected to use in the field. The devices should contain all the necessary to be used by enumerators at the data collection stage. Good use should be made of the enumerator's and supervisor's field manuals, with which all field staff should be made familiar, and particularly those sections relevant to the CAPI data collection methodology. It is important therefore, that these manuals should be as comprehensive as possible. Use of handheld devices would allow field staff access to the manuals in electronic format thus obviating the need for enumerators, in particular, to carry a bulky document around with them in the field.

C.311. It is important to devote sufficient time for the training of all aspects of the enumeration, but most emphasis should be put on dealing with the known problems of completing the questionnaire – both in its electronic form and (if relevant) its paper equivalent. The training should include a field training exercise. A self-help training video can be used to teach the field staff in the usage of the handheld devices and its applications. The training should end with a test of knowledge and competences acquired by the field staff. Where appropriate and applicable, the contractual agreement with field staff should provide for a 'get-out' should any fail to meet the required standard of performance after training.

C.312. For any MIS training, it is essential to have a separated training environment, particularly if the management system is web based. Having a detached server, with detached data source enables the training to be made in a very dynamic manner, allowing the preparation of practical exercises and analyses of data specially build for the training sessions.

8.3. Provision of technical support to enumerators and supervisors during field operations

C.313. Although the training of the field staff should be as comprehensive as possible in order to cover the correct procedures, in all the situations that can be anticipated, it will be necessary for field staff to be supported by the field management chain. Where issues are not resolved with discussion with supervisors and other field-based staff, remote assistance could be provided via a call center. In addition, more specialist support can also be given at the statistics agency's headquarters. In order to

provide prompt support to the field staff at the regional and local level, and particularly for enumerators, it is advisable to develop a Technical Support Plan, covering both methodological and organizational support, and IT support.

C.314. Methodology *and organization support* can be provided both through the field management structure and via a call center. This kind of support aims mainly to:

(i) help enumerators and supervisors in the field for organizing the field work; and
(ii) provide clarification on those methodological issues (such as definitions and response categories) and the duties of field staff, that may not be sufficiently well covered in the field manual.

C.315. IT *support* is essential when using handheld devices for data collection and can usually be best provided through specialist IT staff in the field but also through a call center where IT technicians may be able to resolve problems by connecting to the devices remotely while speaking to the enumerators.

C.316. An added advantage of using 3G networks for data synchronization is that voice can be used for communication. A single SIM-card is all that is needed to achieve voice communication via the enumerator's tablet. The only problem with using tablets for voice is the speaker quality is generally not good so enumerators should be distributed an earpiece to hear clearly. A Closed User Group (CUG) can be created by the telecom carrier so that all SIM-cards in the group can freely communicate via voice and SMS while in the field. In addition, bulk SMS can be used by supervisors and managers to get important messages to the field staff (for example, to provide a clarification about a question, a weather warning, etc.). This would also be useful in those countries that require enumerators to send a summary SMS at the end of each day indicating numbers of households visited and people enumerated as a double check.

(a) IT Support Team

C.317. Considering the complex structure of the field enumeration and the involvement of a necessarily large number of field staff, the success of the data collection operation will largely depend on the effective use of CAPI. Therefore, potential IT-related risks should be identified early in the planning in order to recruit sufficient numbers of technical staff and train them appropriately for working either in the field or remotely at the call centre or main headquarters office

9. The main tasks of the field support will be to:

- act as the first line of support in the field to resolve the technical problems encountered by the enumerators and supervisors;
- fix the faults and operational difficulties related to the handheld devices and their operating system; and
- fix the faults and operational difficulties related to data transmission and the GPS.

C.318. The back office support, provided by the headquarters, will aim to:

- download and install electronic applications on the devices;
- take a back-up copy of the submitted data as required;
- format the device as required;
- expedite communications with the headquarter in cases of extreme emergency; and
- maintain the regional offices' equipment (desktops, printers, and access points).

C.319. This more specialist support provided by technical engineers at headquarters should be able to diagnose and resolve the more serious problems that cannot be dealt with either by the Field Support Team or IT experts at the call centre. It is important therefore that the HQ team has the ability to access field enumerators' devices using software developed for this purpose in order to resolve problems remotely, liaising with the technical managers in the field where necessary.

(b) Call Center

C.320. A call center can play an important role in providing technical support to field staff. The call center should be integrated with specialized software applications that are related to the enumeration in what may be termed a 'call center system', that provides the call centre staff with authorized access to the census information as needs demand, such as information on the field staff and enumeration status of housing units, as well as the actual responses submitted by the field staff for quality control purpose. This center should manage and record both incoming and outgoing calls with the ability to retrieve these calls as circumstances require.

C.321. The call center's main functions are to:

- receive and reply to citizens' (households') calls about any matter related to the census;
- provide logistical support for field staff in the local and regional offices;
- provide IT technical support for field staff in the local and regional offices; and
- resolve IT problems remotely by direct dialogue with handheld devices.

C.322. With particular regard to the fourth point listed, the support teams should have a procedure to resolve technical issues encountered in the field in a way that is secure, by establishing, for example, a remote access to the regional and local office computer. Then, if help is needed to resolve device applications, it should also be possible to connect the device to the regional and local office computer and project the screen of the device on the computer screen, so that the remote access is made also on the device.

C.323. In some countries, the call center is also used for reviewing and verification of data in order to fix data problems made by enumerators (such as incomplete questionnaires) by contacting households.

(c) Support in cases of emergency

C.324. It is advisable to consider a GPS-based solution to provide immediate assistance to enumerators in cases of emergency, such as threats to enumerators or extreme weather or environmental conditions. In order to be able to notify the supervisor of such circumstances, the enumerator should have access to the so-called 'red button' available through a mobile application. By activating this a threat alert will be sent to the dispatching application and 'rescue' measures can be initiated in the last known GPS location.

C.325. An emergency option should also be available in the event that the mobile operator's network does not cover the entire national area, making it impossible, for example, to send the collected data from the enumerator's device to the central server, or to collect the units scheduled to be enumerated on a given day. Such a solution could be based on the device's offline operation, or on an installed computer held by the field supervisor or regional manager, which the enumerator could use to send the collected data indirectly without the need of Internet access.

8.4. Management and monitoring systems

C.326. The availability of an efficient management and monitoring system is the key factor for successful field enumeration using an electronic data collection methodology such as CAPI. The information required for management and monitoring can be more easily collected and transmitted by management modules on handheld electronic devices. Performance indicators for the evaluation of the field enumeration can be generated from the data transmitted from the field in real time.

C.327. Such a management and information system should focus on aspects of the operation that matter most, in particular:

a. understanding the status of recruitment of field staff;
b. understanding the status of the progress of the field enumeration, ensuring that the field operation proceeds according to schedule and identifying levels of non-response or under-coverage;
c. identifying trouble spots;
d. responding to public concerns and issues;
e. ensuring that field staff are paid correctly and on time; and
f. evaluating the effectiveness and efficiency of the operation.

C.328. Management and monitoring systems can be created in different ways depending on the hierarchical structure of the management and supervision of field staff and the respective roles and responsibilities of headquarter, regional and local offices. A number of software solutions can be developed for management and monitoring which can be classified into two groups:

- data collection management and monitoring for field staff
- management and information system (MIS) for operational control

C.329. In general, these systems aim to monitor the progress and the quality of the enumeration, sharing performance indicators, reports and alerts for different layers of management. Management information is displaced in web applications that can be made available to all levels of the field staff, segregated by regions and small territorial divisions, controlled by user credentials, that may permit some visualization and clock others.

8.4.1. Data collection management and monitoring modules for field staff

C.330. During the data collection phase, it is essential for enumerators and supervisors to be able to see the enumeration status for each housing unit in real time to ensure as complete an enumeration as possible. In addition, supervisors should be able to control the quality of the work of enumerators, and require them to revisit households in order to make any necessary corrections, before transferring data to headquarters.

C.331. A number of software systems can be developed to monitor the fieldwork. These systems can be designed in different ways such as being a part of data collection application or as a separate system covering all modules used for management of the fieldwork or other methods.

(a) Fieldwork management systems

C.332. A special application can be developed for managing the fieldwork, especially for the use of coordinators, supervisors and enumerators working in the field, but which can also be accessible to headquarters staff to monitor the data collection process in real time and take follow-up action where necessary. This system can provide tools for identifying the field staff job titles and their assigned tasks, and the time required to complete these tasks. Such a system can play a key role in the success of the fieldwork and its completion within the requisite quality and time requirements. A specific user name and password for each job should be allocated as this system works through several web screens on computers. Such a Fieldwork Management System can include a number of modules:

a. *User management:* through which the regional coordinator can identify enumerators and their immediate supervisors according to hierarchical structure. It should also provide information on the handheld devices - type and features - used by each member of the field staff.
b. *Tasks distribution:* through which the work is assigned from the regional coordinator to the local supervisors and then to the enumerators according to the various tasks assigned to them.
c. *Data transmission:* through this module, the authorized staff (usually coordinators and supervisors) can view data transmission between the handheld devices and the central database.

d. *Work approval and review*: this module is used to review and approve the work submitted by the enumerators. If the supervisor refuses to approve the work, then the work is returned to the enumerator to make any appropriate changes. This module could also be used to review hours worked and mileages claimed when transportation is used in the field.
e. *GPS tracking:* this module allows the supervisor to monitor each enumerator's progress in his/her area, tracking their daily movement, in either an accumulative or real-time mode, and to display that on electronic maps.

C.333. Confidentiality of data in this system should be secured through the use of a unique user name and password.

C.334. Management and monitoring systems provides tools for the field staff for the management of all activities during the enumeration phase. These systems endeavour to fulfil the following goals:

(i) Regional coordinator`s module:

C.335. As has been previously noted, regional coordinators/managers are basically responsible for the high level of supervision of field staff and for monitoring administrative and operational activities to ensure that they are implemented as scheduled. They also have a responsibility for monitoring operational and IT-related performance during the field enumeration. The system developed for regional managers should allow them to perform the following duties:

- Assigning the enumeration areas to the field supervisors and to ensure all EAs are covered by the field staff;
- Monitoring daily progress of the enumeration based on operational performance indicators and reports generated by the system;
- Monitoring the changes in the number of the enumerators and supervisors and electronic devices to ensure there are no problems that may affect the performance;
- Good communication with headquarters and field staff on urgent issues;
- Ensuring timely payments of the field staff;
- Monitoring the work of the field staff at EA level using other modules developed for the enumerators and their immediate supervisors.

(ii) Supervisor`s module

C.336. This allows the supervisors to review the data collected by their enumerators before transmission to headquarters, and to communicate any remarks and instructions to them. Supervisors basically monitor the daily progress in each EA and evaluate the status of the enumeration of each housing unit. The system should allow supervisors to perform the following duties:

- Assigning the EAs to the enumerators and to ensure complete coverage with no overlapping or omission;
- Monitoring the daily progress of the enumeration in terms of the number of housing units visited and each enumerator`s assignments and their status;
- Approving or rejecting the completed questionnaires submitted by enumerators;
- Following-up non-response and refusals;
- Providing information for specific cases or situations or possible risks;
- Communicating with enumerators, other supervisors and coordinators;
- Displaying the entered data at aggregate and individual levels for checking purposes;
- Controlling data transmission to headquarters.

(iii) Enumerator`s module

C.337. This allows enumerators to provide information (daily) on the status of the enumeration at the housing unit level, showing which have, and which have yet to be, covered. The status of each

housing unit should be recorded after each completed interview or visit and should indicate one of the following outcomes:

- Completed,
- Refused,
- No contact,
- Interview rescheduled (including information on reason and appointment time/date),
- Vacant dwelling,
- Addresses/buildings not used for residential purposes
- Other explanation

C.338. Such a system can also be used for providing information on residential addresses/buildings not included on the EA map or address list and for communicating with supervisors and IT support teams.

8.4.2. Use of Management Information System for operation control

C.339. It is essential that a management information system (MIS) for any census field operation should be established to provide up-to-date information needed to monitor and manage the progress of the enumeration, and to facilitate the sharing of performance indicators, reports and alerts among field supervisors and controllers/managers working at local and regional levels and at headquarters. Such a system is fundamental for identifying problems and taking appropriate actions. Its value lies in its capability for real-time monitoring using the following tools and sub-systems.

(a) Tools for operation control

C.340. A number of tools can be developed for management and monitoring the field enumeration that are centrally managed. Some examples of these tools are explained below:

(i) Performance indicators

C.341. A number of key performance indicators can be used for monitoring the operation itself and, more specifically, any IT-related issues. For example:

C.342. *Operational performance indicators* such as*:*

- Number of enumeration areas by status (completed, refused, follow-up, no-contact, non-residential, etc.);
- Total of counts of population by sex, housing units, households, each by geographical areas;
- Comparison of housing units and population count with previous census results and population estimates as a growth rate;
- Average number of population/housing unit/household counts per day in the period of enumeration by geographical area.

C.343. *IT monitoring indicators* such as:

- Number of data transmissions per day by geographical area;
- Number and percentage of devices that have to be renewed by whether they are lost or damages, by geographical area.

(ii) Alerts for identifying potential risks

C.344. Other information that can be potentially useful in monitoring the field enumeration is what might be termed ‘supervision alerts’, created from a comparison of data actually collected during the enumeration with what might be expected, such as:

- Population count below/above expected
- Male population proportion below/above expected

- Proportion of population under X years and above Y below/above expected
- Housing units count below/above expected

C.345. These alerts can be used to evaluate geographical areas that may have a risk of failure to achieve complete coverage or of not completing enumeration on time. Criteria for identifying such areas can be determined by the statistical agency based on the experiences in previous censuses and current population estimates. These types of alerts can help census managers, especially at headquarters and regional level, to investigate unexpected results and identify any problems that need resolving during the field enumeration. Alerts tool should be linked with the performance indicators.

(iii) Geospatial information for monitoring

C.346. It is suggested that advantage should be taken of GIS tools for presenting data collected for monitoring the field enumeration. In particular, the data on performance indicators and alerts can be integrated with GIS that make it easier to recognise problematic geographic areas and to get a better view of regional performance.

(iv) Geo-tracking tool

C.347. Additionally, the MIS could make use of geo-referenced information on the location where the enumerator has started an interview (captured by the device's GPS), thus identifying possible enumerator fraud attempts. With this tool, it would be possible (as has already been noted) to track the daily movement of the enumerators, in either an accumulative or real-time mode, and to display that on electronic maps.

(b) Centrally managed sub-systems for operational control

C.348. The MIS for operational control may also comprise a number of software systems that can be developed to centrally manage the fieldwork:

a. Field Management and Control System: This system enables the fieldwork administration and the headquarters administration to review the data at both levels (individual and aggregate). It provides reports on productivity and performance indicators through tables, charts and electronic maps. This system may also provide interactive reports to keep regional coordinators/supervisors and headquarters informed about problematic areas.
b. Call Center System: This system can be used for monitoring data quality control by re-calling a sample of households whose data were collected during the census to verify the validity of the data entered, and can be used also to collect the incomplete data for some households.

Box 8.2 Fieldwork Management and Information System, 2017 Census of Palestine

This system enables the fieldwork administration and the headquarters administration to review the data at both levels (individual and aggregate). It provides reports on productivity and performance indicators through tables, charts and electronic maps. This system also provide interactive reports to keep regional coordinators/supervisors and headquarters informed about problematic areas.

The system has the following applications:

- **User management:** According to hierarchical structure, the Governorate Director can identify crew leaders and their immediate supervisors. In addition, supervisors can identify enumerators and their immediate crew leaders.
- **Work distribution:** EAs are assigned to supervisors by the Governorate Director and then to the crew leaders and enumerators by supervisors. Moreover, it is used to ensure complete coverage with no overlapping or omission.
- **Data transmission:** The authorized staff (central office, Governorate Director, supervisors and crew leaders) can view data transmission between the tablet devices and the central database.
- **Work approval and review:** Review and approve the work submitted by the enumerators. If the supervisor refuses to approve the work, then the work returned to the crew leader and enumerator to make any appropriate changes.
- **GPS tracking:** Allows the authorized staff (central office, Governorate Director, supervisors and crew leaders) to monitor each enumerator's progress in his/her area, tracking, online and offline, their daily movement and to display that on electronic maps. Providing information for specific cases or situations or possible risks as GPS signal weakness in EA.

The system is used to monitor the daily progress of the enumeration based on operational performance indicators and online reports generated by the system. Operational performance indicators (via maps and tables) are:

- Number of buildings in enumeration areas by status (completed, refused, follow-up, no-contact, non-residential, etc.).
- Total of counts of population by sex, housing units, households, each by geographical areas.
- Comparison of housing units and population count with previous census/previous stage results and population estimates.
- Average number of population/housing unit/household counts per day in the period of enumeration by geographical area.

The system has also provided supervision alerts for potential risks. Supervision alerts created from a comparison of data actually collected during the enumeration with what might be expected.

Box 8.3 Monitoring the progress in enumeration, Palestine, 2017 Census

Snapshot screen explains achievement follow up per enumeration area per building through different colors: (i) Blue means unvisited; (ii) Green means completed; (iii) Red means deleted buildings; (iv) Orange means non-census building; and, (v) Yellow means incomplete.


8.5. Logistics for storage, distribution and return of handheld electronic devices and accessories

C.349. The design of a large data collection process that deals with a vast number of electronic devices must be well planned, with all the business processes clearly defined. The accommodation of regional and/or local offices, where most of the census materials are to be kept when not in the field, must have the capacity to store the handheld devices safely and securely. There should also be a formal process to register and maintain an inventory of all the equipment and material that is stored there and/or is consigned to specified enumerators and supervisors, using a computerized warehouse system that can record the serial number of each device using a bar code reader.

C.350. To minimize the cost of transportation of electronic devices between the statistical agency's central administration and the field, manufacturers may be asked to deliver directly to the regional offices. In such cases, the equipment should be pre-prepared with all accessories and distributed according to the requirements of the fieldwork. It is also important to keep some of these devices as a contingency reserve, to be used to replace lost or damage equipment or to meet the requirements of additional field staff.

C.351. At the end of all fieldwork, the local census offices will be decommissioned and all equipment should be returned to the statistical agency either directly or via the regional offices.

8.6 Device use policy

C.352. It is very important to establish some terms and conditions that must be agreed with the field staff before the enumeration begins. This is essential to ensure that the devices are used solely for the purpose of the enumeration. The terms and conditions should be developed into a formal use policy, the provisions of which should be mandatory and agreed to before any enumerator, supervisor or other member of the field staff are allocated a handheld device or other electronic asset. The policy should address a range of user responsibilities and use conditions, including those that have an impact on the protection of the devices, data confidentiality, data quality and the efficient management of field operations, and should have provisions for sanctions to be imposed in the event of non-compliance.

C.353. The usage policy should address a number of specific user responsibilities and use conditions:

(i) Protection and proper handling of the devices

C.354. Since the risk of losing or damaging devices during use, transportation and storage is real, there should be provisions for the proper handling and physical protection of the devices, including accessories such as power banks and batteries, in order to keep them in good working conditions until their eventual return. To help protect their devices, enumerators should follow clear equipment care instructions, including the use of issued protective cases and screen protectors. Proper handling and care of the equipment at all times is particularly important, but particularly so in remote terrains and environmentally challenging areas, where infrastructure for communication and power supply may not be fully developed and where inclement weather or dust is a concern. In such contexts, each enumerator should be responsible for charging his/her device and power bank to guarantee work continuity. There should also be agreed procedures for reporting and disposing of damaged devices and accessories used in data collection.

(ii) Ensuring return of the devices in good condition

C.355. To ensure the adequate physical security of devices under the control of field staff, the device use policy should have provisions about returning the devices in good condition. One provision that could be employed to protect devices is to link the final payment to field staff to the return of any issued devices. (Some countries have conferred financially responsibility pertaining to the loss of devices to enumerators, believing that this would encourage enumerators to take greater care of issued devices.) There should also be agreed procedures for reporting damaged, lost or stolen devices immediately. Some countries offer the devices free or for a reduced price to enumerators at the end of enumeration if they have been well looked after and work has been up to a sufficient standard.

(iii) Securing data confidentiality

C.356. The use policy should have provisions to protect the devices from unauthorized access to the data collection application and data stored on the device. It is important to ensure that enumerators and other field staff using mobile devices and related software for network and data transmission or access will, without exception, use secure data management procedures. In order to ensure the security of census operations, enumerators, for example, should begin their work with a mobile application by logging in to the handheld device, and only then to the application, in a secure mode, that is, by entering user names and passwords uniquely issued to them.

C.357. Data should be transferred from the devices to central servers via secure channels. Where possible (for example, where the device is connected to the Internet), security measures could include tracking down the device based on GPS location and remote device resetting and data wiping. These could be enforced in a number of circumstances:

- where the device is lost, stolen or believed to be compromised;
- after a certain number of failed logon attempts; and,
- where usage is found to be non-compliant with use policy.

C.358. It is important that the collected data is not lost or rendered inaccessible just because a password for the mobile device has been lost or forgotten. Hence the use policy should provide for adequate recovery mechanisms to be in place. Where the infrastructure for mobile communication and Internet access are limited or non-existent, especially in remote locations, collected data might stay on the devices for several days before being uploaded. This means that, in such circumstances, enumerators must be able to authenticate themselves on the mobile devices without connecting to central servers.

(iv) Preventing unauthorized use of the devices

C.359. The use policy should have provisions to restrict usage of devices to authorized purposes only. The security of the devices and the data collection operation could be compromised by malware (causing, for example, the spreading of viruses) or unauthorized uses (such as transmitting data to an unapproved external devices; storage of data in unapproved applications on the device; consuming air-time and data quota for unofficial or personal activities such as making phone calls, sending SMS texting or surfing the Internet for private use; or, removing device's security controls via hacks, jailbreaks, security software/setting changes.) To prevent this, the use policy may restrict access to various device settings to prevent misuse or abuse of the device by field staff, and to secure the data, and maintain the software configuration of the device. This is usually achieved by installing specialized applications, which vary greatly between platforms and vendors in their capabilities, or through the application of password protection. It is important, however, that the restrictions do not conflict with the needs of field staff, particularly, enumerators for executing census related collection, communication and data transfer functions. Measures for protection against possible breaches and/or misuse may include establishing audit trails (to track, for example, instances of attachment of external devices). In this regard, field staff should agree to and accept, as part of their conditions of work, that their activities on the device and connections to data networks may be monitored.

(v) Confining device use to specific work areas

C.360. It is important to assign one device specifically to each enumerator (or any other member of the field staff) with a specific work area to prevent any overlap in work areas or data. Where possible (for example, where GPS functionality is integrated in the device), this could be achieved through the application of geo-fencing, whereby devices are set up so that they will only allow data collection to begin when the device is located in the correct area for the particular enumerator. Each handheld device in use by an enumerator can link a household with the enumeration area so that the records are tagged with the respective enumeration area to avoid duplication, and to aid operational control. Handheld devices can also be enabled to capture metadata on the location of the interview, time of day and other metrics to assist in monitoring enumeration progress and measuring data quality.

(vi) Preventing enumerators from entering fabricated data

C.361. Use policy should have provisions for preventing the possibility of enumerators entering fake, erroneous or falsified data (for various reasons including to simplify or mis-represent their workload or avoid travel to some locations) or breaching data confidentiality by giving access to data to unauthorized parties. This risk could be minimised by rigorous recruitment process and training as well as measures for checks of completed questionnaires or data abnormalities to detect possible fabricated data. These checks could include GPS readings to ensure the enumerator was in the correct location when completing the questionnaire and the use of timestamps to measure collection completion time. In some cases, enumerators may be informed of these checks for monitoring their activities, while in other cases they may not.

*(vii)*Measures for non-compliance

C.362. Use policy should have provisions for enforcing the policy so that any user found to have violated this policy may be subject to disciplinary or legal action.

C.363. Training on the proper handling of collection devices is very important. As noted above, enumerators should be trained in the use of the devices and related applications before going in the field and start collecting data. The training should involve the application of all relevant use policy provisions. During the testing phase of the data collection system, it is important to assess the use policies and their impact on the usability of the devices and execution of data collection procedures and operations. Training materials produced for any census text may need to be revised if subsequent changes are made to the adopted use policy.

9. Testing the data collection application and systems

9.1. Introduction

C.364. The success of a CAPI application depends substantially on the effort spent programming, testing and piloting the application, as well as on careful consideration to the underlying data management and transfer systems. The data collection application constitutes one of the most important elements in electronic data collection. Issues related to the questionnaire and/or the supporting infrastructure should be addressed as early as possible as problems may not be easily rectified at later stages of the field operation. Therefore, having systematic testing procedures in place is vital for data quality and for the efficiency and effectiveness of the data collection operation.

C.365. Testing applications is a very important phase of the software development process. The purpose of the testing is to verify and validate software, that is, all applications used within the IT system serving the census. Software verification makes it possible to control whether or not the produced software is in line with the assumptions, and validation is used to verify whether or not the software is logically consistent and complies with expectations. The software testing phase should be applied at each software development stage. But, before the testing, a test plan, case studies and scenarios should be prepared. The result of the tests is a report which serves as the basis for further production phases. The test plan should cover the specification of the subject of testing, the resources necessary for its implementation, the proposed course of the testing process and its scope, and also the testing schedule and products.

C.366. Testing can begin once the statistical office has a prototype version of the CAPI system. In most cases the initial version is raw and needs additional modifications. This requirement makes the development of the whole data collection process an iterative cycle of testing and improvements. In many cases an improvement may be a change in configuration of the system or in the recommended sequence of actions and does not necessarily constitute the modification of the source code.

C.367. ‘Testing’, however, is a broad term that incorporates many different methods or combinations of methods. This section summarises, and briefly describes, those tests that should be used to evaluate the electronic questionnaire and supporting IT systems. These tests have specific strengths and weaknesses that make them valuable for different types of problems. Consequently, they are useful at different stages of questionnaire development. In order to identify problems and to suggest adequate improvements, the use of a combination of tests is indispensable; in most cases, the use of one single type of test will not be sufficient. There are two major categories of testing methods – pre-field and field methods. This distinction is an analytical one, but nevertheless reflects some principal and operational differences. The appropriate combination of these tests determines their suitability for meeting the objectives of testing.

C.368. Test that could be used to evaluate the collection instrument and supporting IT systems include:

Functionality testing

C.369. The performance and the robustness of the CAPI collection application and other IT components should be tested during, and at the end of, the development process. Functional tests check whether or not the operation of the IT system is consistent with the functional specification and requirements. During such tests, a number of elements should be checked:

- all functions of the application;
- the system's usability (whether or not the user can move freely between the application's/system's screens, and the time needed to learn how to use it);
- displaying error notifications (whether or not, and how, they appear);
- the graphical user interface (GUI)'s operation correctness (the approach of presenting information and interactions with the user; and
- the communication between the application and the server.

Usability testing

C.370. The aim of this is to evaluate the human-computer interaction and the user-friendliness of the CAPI system. Usability tests are crucial from the user's perspective. They make it possible to assess the application's operational speed and other functionality, whether or not the application can be easily used by various users, and to evaluate differences between the designed interface and the users' experience.

Scenario-based testing

C.371. Several scenarios should be prepared with the input of subject matter specialists to be representative of the population being enumerated. The scenarios should be diverse, illustrating various situations and combinations of characteristics, not just the average/typical population profiles. During this testing approach, it is important to test not just that the proper situations are adequately recorded, but also that the CAPI system detects common reporting or entry problems, and issues reasonable warnings and error messages for such cases.

Extreme-scenario testing

C.372. Similar to the above, but with scenarios strategically chosen to illustrate extreme cases, such as extremely large households or areas of extensive multi-occupation (particularly student accommodation). Besides testing the logic of the census questionnaire and the validation of the data, this testing also verifies the performance of the CAPI system, determining, for example, whether or not the responsiveness of the device deteriorates in the extreme case, and whether or not the system provides adequate compression to transfer the data for extreme cases in a single transaction. It is important that this testing is performed on the actual devices and infrastructure to be adopted in the census so as to be to be informative about the expected performance.

Compatibility/Integration testing

C.373. Census data collection systems are based on numerous components developed in parallel, so integration tests are very important. It is thus crucial that the selected CAPI system is compatible with the other systems (for example the GIS application) with which it is expected to interact. Testing is thus performed to make sure the different systems can 'talk' to each other. In this testing phase, the focus should be on the specific formats of the inputs and outputs to the system.

Acceptability testing

C.374. This assesses the complexity of systems and processes and the corresponding training procedures and materials. Even if a system is designed to specifications, it may fail in the real world where the required actions might be just too complicated for the users. In this phase an analysis should be made on where most errors happen, and why. The system is then adjusted accordingly to mitigate for these risks. If possible, automatic checks should be introduced, but where this is not possible, corresponding training should be provided to minimize the chances of errors.

Infrastructure stress testing

C.375. This focuses on the stability of the CAPI system during an extreme use or under the influence of the external factors. Here the behaviour of the system should be investigated under particular conditions such as when: many users are accessing the system simultaneously; one of the servers involved in data aggregation is experiencing a hardware or power failure; and the communication lines are being affected by external factors, significantly reducing communication speeds, etc. Here the CAPI system should be tested as a whole, not just as a single module or a device.

Security testing

C.376. Census data must be adequately protected to assure confidentiality. The mobile data collection system must provide adequate security through a centralized access control over user accounts and aggregated dataset must be protected by an adequate encryption. Security tests consist of performing a controlled attack on the data collection system and associated IT systems. The tests are aimed at assessing susceptibility to hacker attacks. During the tests, the system should be analysed with respect to potential gaps and errors in the system. After the tests, a report should be prepared containing descriptions of the identified gaps in the system and possible defense mechanisms.

Protocol testing

C.377. This focuses on human perception, interaction and possible human errors. The purpose of this testing is to establish whether the CAPI system prevents most common human mistakes, which may result in a slowdown of the system or damage to or loss of the data. In cases where the system does not enforce a certain behaviour, an adequate protocol must be established for all users. For example, the system may provide a technical capability for the data to be exchanged between the interviewer's device and the central server, while leaving it up to the user to decide when and how often such data transfer must be performed. It is then up to the census protocol to establish the frequency and sequence of the data transfer sessions.

9.2. Installation of applications on devices

C.378. The task of installing the data collection application and associated systems on the handheld devices is a very critical phase of the production process in a census operation, especially so because this involves handling thousands of devices. If the devices are new, one effective practice is to request the manufacturer/provider to ship the devices with the first version of the applications already installed, and download future versions of the same applications by implementing a 'self-update' functionality. However, if this is not an option, another effective way is to make use of a mobile device management (MDM) software to enable the automatic distribution of applications and security protocols. It is important to note that the use of an MDM does not avoid the need to configure each one of the devices to recognize the server. This should be done as a first step, by installing some specific application or making a special configuration on each device, a process usually called "enrollment". Later the synchronization can be made automatically, so the distribution of new applications or new versions of the applications can be made by a management console or web application by the responsible team.

C.379. While performing tests of the collection application, the statistical agency must remember to test the software installation process, especially on handheld devices. The software installation process can be performed on site or on a remote basis. It is important to test the devices with regard to user authentication. In the field data collection process, revisions to the application on a remote basis should be planned. If it turns out that remote installations of revisions for mobile devices take too long, a suitable installation procedure during night time should be established or they should be performed on site.

C.380. Application testing should be performed both by the system's developers and testers, who should be the final intended users – in this case the enumerators. (If enumerators will not have been appointed as early as the testing phases, the testers are more likely to be statistical agency staff or others recruited for the purpose.) The objective of testing is to verify the accuracy of data recording and correction along all response variants. The system's reaction time to the transition path should also be checked. After data recording, inspection and saving on mobile devices, the test transfer of data from mobile devices to the server at the statistical office is crucial. It is also important then to check whether data transfer progresses without any failures. In this case performance tests and security tests should be carried out.

9.3. Pre-field tests

C.381. Pre-field tests are normally (although not necessarily) applied under laboratory conditions[27]. This means that the tests are not carried out in field conditions. Instead, 'laboratory conditions' refer to an observational environment which may partially or totally differ from the actual field conditions. These tests are generally used in the preliminary stage of the questionnaire testing process and mostly yield qualitative information. The initial test of the CAPI data entry system should be conducted within the statistical agency, ideally by staff members who are familiar with the questionnaire and subject matter. This will help to resolve the most obvious errors prior to the field test.

C.382. The execution of pre-field tests is fundamental in testing the effectiveness of the census applications while the applications are still under development. It is recommended that functionality tests and usability tests should be scheduled with real users during the development lifecycle (as noted above, if enumerators will not have been appointed as early as the testing phases, the testers are more likely to be statistical agency staff or others recruited for the purpose). Anticipating potential problems and challenges at the beginning of the project is fundamental in keeping project budget under control. Changing features of the applications in the post-testing phase is costlier than modifying the applications in the earlier phase of development.

C.383. Feedback is fundamental to the development of the application, so a frequent testing process is essential to check the systems requirements and to discover missing features or defects. A good usability test can be conducted by relying on scenarios derived from previous collections that replicate realistic data collection situations. Then a group of users could perform the list of tasks based on the scenarios using the software, while another group observes and takes notes. Another effective method to test the software usability is the A/B Test, where two or more versions of the software are compared, where these are very similar, except for some variation that might affect the user´s behavior. This kind of test, while more expensive (the development team must build many versions of the system) is very powerful to drive to correct decisions.

C.384. The management information systems (MIS) for monitoring and managing field operations should also be subject to various kinds of tests. The most important feature to be verified is the ability of the systems to deliver good management indicators that help to conduct the field enumeration according to established procedures and protocols. It is important to note that an effective MIS does

[27] Italian National Institute of Statistics, ISTAT. Handbook of Recommended Practices for Questionnaire Development and Testing in the European Statistical System. 2006.

not have to generate a vast amount of reports, but only those necessary to communicate information clearly and efficiently, including via statistical graphic, tables, charts and cartograms.

C.385. During the pre-field tests phase, it is possible to use tools to make sure the server-side applications are sufficiently scaled to support the workload expected in the census itself. There are many tools available on the market that could help to automate this kind of test, making it possible to adjust various parameters that could represent an almost real production workload. These tools could simulate many important scenarios of the data collection process, including user navigation on a website or load test a data reception server.

9.4. Field tests

C.386. Field tests are those tests used to evaluate the data collection application and associated systems under field conditions. This means that the test is carried not in a laboratory or office setting but in a way very similar to actual fieldwork, where the majority of the conditions mirror the real census environment. Field testing often involves bigger sample sizes that allow sufficient data to conduct quantitative analyses. The range of field tests available to census managers and designers which meet different purposes is listed at section 6.1 above.

C.387. Testing in the field is a crucial stage in the development and assessment of a census questionnaire (whether electronic or paper) along with the development and testing of associated procedures and instructions. No matter how much work has been done, the questionnaire has to be tested under field conditions. Though field tests usually involve a larger number of units than pre-field tests, the scale of testing units is usually still smaller than for full pre-census tests (or pilots).

C.388. The field tests present the first opportunity to test the entire CAPI–based data collection system in the environment in which it is to be used. During this stage, interviewers and supervisors should conduct realistic interviews with real households. This provides both the opportunity for assessing the training experience for the field staff and a test of the data entry system. This is the moment where a group of different users, that includes experts and beginners put the devices and systems under tests and check, for example, if the handheld devices are suitable for the data collection. If the census timeline permits and procurement of the devices has not occurred yet, more than one device should be tested, varying the screen size, manufacturer or hardware specifications. This exercise could yield important insights regarding the equipment quality and the ideal screen size for the census.

C.389. All components of the system should be checked by various tests. These tests may be done in phases. System components requiring checking include: synchronization with servers at headquarters; accessing work assignments; completing several interviews with real households; transferring completed questionnaires and allowing for supervisors' checks and approval; receiving the data at the headquarters and enabling additional checks; implementation of additional validation rules; and testing of the database structure. Important aspects like load tolerance and system integration should be verified and to identify any problems or areas for improvement.

C.390. Also, it is a crucial moment for testing the management information systems, as a relatively large number of users would be deployed, providing the opportunity to monitor the field operation. The team or persons responsible for keeping track of the data collection operation should observe if all the available reports, charts and indicators are sufficient enough to monitor the collection operations. With regard to the use of mobile devices, the network coverage should be tested if cellular networks are proposed to be used for data transfer.

9.5. Modifications to applications and systems based on field-test

C.391. A natural outcome of the field tests is a list of observations on the data collection application, device, data transfer system and the process of collection. This must serve as input to the process of decision-making for further modifications and refinements of the data collection system. Taking this process into account, the schedule for the preparations of the census must allocate sufficient time for the modification of systems necessary at the end of each field test.

C.392. As a general rule, two or more phases of testing are recommended. If a collection application has undergone changes following the results of testing, a new round of testing is normally indispensable. This involves testing the application at an early stage of its development, making revisions to it based on the test findings, and then testing the revised application again. This process may be repeated through two, three or even more phases of testing. Different methods of testing may be used during each phase of testing. In ongoing surveys, the evaluation of former survey waves can provide important input for questionnaire revision.

C.393. Based on observations and results from the pre-field and field tests, problems with field procedures and the data collection application should be resolved. If necessary, changes should be made to the collection application and associated systems. The result of this task is an improved version of the data collection application and its associated systems.

C.394. The collection application, incorporating the revisions suggested by the pre-field and field tests, should be used to train those enumerators and supervisors taking part in the pilot census. The field practice should also test the communication and data transfer procedures and the entire network infrastructure. Complete interviews, implementing the interviewing protocol established for data collection in the field, should be carried out. The final collection application should be prepared based on observations and results from the field practice.

C.395. However, one challenge that is often observed is that the testing period is often among the first ones to be cut when the development schedule has to be reviewed or shortened. A mistake that is often made is that there is not enough time planned in the schedule to make changes based on test results.

9.6. Pilot census

C.396. The pilot census is a broader field test that allows the statistical agency to test and review the whole census operation. All the questionnaires and systems should be adopted in the pilot census with a view to identifying any necessary adjustments that need to be done before the real operation. With regard, specifically, to the data collection elements the pilot census should target some key objectives:

- Checking the process of enumeration using the handheld device
- Testing the enumerator data collection applications
- Testing the GIS systems and GPS accuracy
- Testing the effectiveness of the MIS
- Testing the effectiveness of the process of training field personnel
- Checking the administrative procedures for payment of staff

C.397. The purpose of conducting the pilot prior to the census itself is to assess the full range of aspects of the census operation, from acceptability of the data collection application, to the enumeration procedures, to the various stages of data processing. Whereas field test can be restricted to the test of the collection application and the mode of data collection, the objective of the pilot census is to test all systems and their inter-operability. During the pilot census, all the adopted organisational and technological assumptions must be verified, along with the accuracy of procedures and the clarity of instructions. The pilot census also enables the testing of all applications used for data collection and the entire management application. The management application's functionality should ensure the monitoring of the census' progress along all data collection channels.

C.398. During the pilot census enumerators conduct interviews with sampled respondents by recording responses in a form implemented in the application installed on the mobile device. Data obtained by enumerators are transferred, depending on the data transfer protocol, either to the communication server directly or to the supervisor's application, whence after approval they will be sent to the database. Another important area of analysis is the functioning of IT tools used in the pilot census. It should be borne in mind that each IT component can potentially disrupt the operation of the system as a whole. Therefore, when testing the IT system all components should be tested based on well-planned and prepared test scenarios.

C.399. Before the pilot census all the training materials and all the systems should be in their final version, but with the capacity to make some minor corrections only, as any major changes should have been effected in the light of previous field tests.

10. Re-use and disposition of devices

C.400. Census operations relying on mobile data collection systems require large quantities of mobile devices. Even for countries with relatively small population sizes, the number of devices required to equip every enumerator can run into the thousands. The total cost of acquisition of these devices is substantial. The first challenge with such a large investment is the fact that the devices are only required for a short period of time during field enumeration. Since population and housing censuses commonly occur only every 10 years (in some cases, every 5 years) the devices cannot generally be re-used in future censuses as they would by then become obsolete. This necessitates advance consideration of what measures can be taken to re-use the devices given their limited life-span.

10.1. Re-use

C.401. The second major consideration by the statistical office when making procurement decisions on mobile devices, after factoring in the specific requirements for the census data collection, is the requirements of any next-in-chain user. The re-use of such devices can make an important contribution to the economy of the country by optimizing scarce financial resources as well as reducing environmental footprint. The evaluation team tasked with selecting the mobile devices should conduct trials of different devices to establish their suitability not only for the application in the census but with an eye to their compatibility with the requirements of any potential subsequent user in terms of technological standards, security and IT infrastructure. Factoring in re-use in other statistical (or non-statistical) applications when making purchasing decisions is especially suited to countries where data collection is routinely performed by different government department or ministries (agricultural surveys, health surveys, facilities surveys, etc.). As noted earlier in section 1.6, pooling the devices may reduce the cost of the acquisition and resolves the question of the disposition of the devices after the census.

C.402. Apart from other government departments, alternative re-users of the census mobile devices could be other public sector bodies such as schools, hospitals, libraries, law enforcement, or utility service providers. The census agency should work closely with potential government agencies in the planning phase of the census to assess whether there would be an interest in such use of these devices and to ensure that such devices could be used in non-statistical activities. The devices could be donated to these users to maximize the benefits from the original investment.

C.403. Collaboration among countries is another mechanism by which mobile devices could be acquired for mutual benefit. Cooperation between countries could also result in the donation of devices acquired by one country resulting in tangible benefits for others. Such cooperation usually comes along with technical assistance that could be instrumental in sharing experiences and transferring valuable technical skills. In arrangements where the devices are loaned, it would be important to take into consideration certain factors that could have an impact on decisions. These include: who will be in charge of shipping costs; the terms and conditions of the loan, including for replacement of damaged items; and, the schedule of device return and conditions.

C.404. There are, however, some challenges associated with plans for re-using mobile devices, among which are:

- the physical condition of the devices could be degraded, for example, screens could have reduced sensitivity
- the battery life decreases with time and intensity of use; replacements may be needed
- device warranty and technical support agreements may have run out
- software version and compatibility may be an issue
- removing all stored data from previous data collection may be difficult
- tracking of all assets (for example through use of bar-code technology)
- wiping software configurations, including applications, in accordance with agreements and laws
- some hardware features may have been disabled on devices by the manufacturer at time of acquisition; a check that all the necessary features are present for new data collection should be made
- devices should be checked for compatibility with IT infrastructure/platform for re-use.

10.2. Disposition

C.405. In cases where handheld devices have to be recycled or disposed of (instead of being re-used), the statistical office should remove any sensitive data. The task of wiping all sensitive data from storage devices such as hard drives and memory cards is often difficult because of increasing reliance on flash memory instead of magnetic disks (which can easily be cleared through the process of degaussing—exposure of magnetic media to a strong magnetic field in order to remove stored data). Simple deletion of items would not suffice for clearing sensitive data from devices. 'Clearing' information is a level of media sanitization that would protect the confidentiality of information. Clearing must not allow information to be retrieved by data, disk, or file recovery utilities. For example, overwriting is an acceptable method for clearing media. There are overwriting software or hardware products to overwrite storage space on the media with non-sensitive, random data.

C.406. For some media, however, clearing would not suffice and data purging may be required. Data purging is a term that is commonly used to describe methods that permanently erase and remove data from a storage space. There are many different strategies and techniques for data purging.

C.407. Devices that have become obsolete or are damaged and fail to meet performance criteria should be properly disposed of in accordance with relevant laws and regulations, such as environmental legislation covering the disposal of hazardous materials. Once an asset has exited the inventory, agencies should ensure that updates are made to accounting and inventory systems, as appropriate. The decision to dispose of mobile devices should not be an afterthought. There should be a well-established decision process in place that takes into account the information security governance of the organization.

Chapter D - Data Collection Using the Internet

1. Introduction

D.1. The use of the Internet to conduct censuses and surveys (not only to collect data but as a means of disseminating the subsequent results) is not a new phenomenon; many statistical organizations have used this approach in the recent years because it offers a great number of advantages. However, Internet data collection presents additional challenges and risks, in particularly for large-scale statistical operations such as population and housing censuses, which are the most complicated and extensive of data collection operations.

D.2. The main purpose of conducting a census has remained the same over the centuries: to count persons, households, dwellings, farms etc., and there are numerous advantages to maintaining the enumeration methods that are already in place. Such advantages include preserving: the trust in the proper functioning of the current collection process; the knowledge of the existing systems by census staff; comparability with previous censuses; and the familiarity of the public with the procedures for submitting their information to the statistical agency. Indeed, the operational complexity of census data collection is one of the main reasons why many countries tend to retain the well-established method of enumeration they have used in previous censuses. However, the rising costs of data collection, particularly at a time of global economic restraint, if not austerity, together with developments in technology and higher expectations from the public and governments have forced national statistical organizations to rethink how censuses should be conducted.

D.3. For the 2020 round of population and housing censuses, as has already been noted, an increasing number of countries are considering, or are already implementing, changes in enumeration methodology. In the context of this chapter such changes include switching from a face-to-face interview to self-enumeration, or more specifically, using an electronic questionnaire accessible via the Internet to facilitate self-response instead of using self- or interviewer-completion paper questionnaires.

D.4. In some countries, legislation has been introduced that permit or even require citizens to conduct business with the government online. Other countries are, however, more reluctant to adopt Internet data collection, arguing that it will not necessarily improve response rates or reduce costs of collection, and that it will increase both real and perceived confidentiality and security risks. Nevertheless, in the countries where Internet data collection has been introduced, it is proving to be an efficient way of achieving significant cost savings while improving data quality. This move to an online data collection methodology is illustrated in the results of 2013 survey of practices and approaches of countries in the UNECE region [Reference here], which reported that 17 of the 49 responding countries used the Internet to collect data in the 2010 round of censuses compared to just a handful of countries (5) that did so in the 2000 round. Moreover, the survey went on to report that the majority of UNECE countries (some 33 in all) are planning to employ such an approach in the forthcoming 2020 round. There is also significant interest to use the Internet to collect data in censuses in other parts of the world. According to the results of the UNSD survey which was conducted in 2016, 6 countries outside the UNECE region used the Internet to collect data in the 2010 round and 20 countries are planning to use the Internet for collecting data in the 2020 round of censuses.

D.5. Population and housing censuses require a complex series of interrelated processes. The risks and the investments required to add Internet data collection, as well as the impact of such modification to the enumeration methods already in place, will differ depending on whether or not the current methods include self-enumeration and whether interviewer-assisted face-to-face enumeration is done electronically or using paper questionnaires. Such factors must be taken into account when deciding whether or not to introduce internet collection. More specifically, if introducing online collection also requires introducing self-enumeration (which is generally the case), the resulting enumeration process

will be significantly more complicated than data collection by interviewers alone; however, the potential for efficiencies and cost savings is also much greater. The implications are not the same for those situations where introducing Internet collection only means replacing paper questionnaires by online ones.

2. Using Internet self-response as a collection mode

D.6. Internet response entails the collection of respondent data via the submission of a questionnaire online. As noted above, using the Internet as the medium for data collection means that the census collection methodology will, generally, need to be self-enumeration rather than interview-based. The Internet option can, however, be incorporated into any of the traditional methods of delivering and collecting census forms (for example drop-off/pick-up, mail-out, mail back). A high level of internet self-response could yield significant cost savings over paper-based census collection operations or even greater savings over interviewer-lead collection methods, be they either face-to-face or telephone interviews.

D.7. Face-to-face interviews are sometimes seen as the best collection method in terms of data quality. There is an expectation that interviewers are able to guide respondents through the questionnaire and to clarify and queries that the respondents may have, thereby improving the likelihood of fullest coverage and complete and accurate responses to questions. However, interviews conducted in person or by telephone have their limitations and tend to be prone to errors, especially in the context of a census. Most often, field enumerators and their supervisors are only temporary workers with no experience and limited training, appointed only for the duration of census data collection. Experience has shown that they can make more mistakes during interviews, as well as omit more questions, compared to questionnaires completed by respondents electronically. With validation edits and automated flows, online questionnaires tend to produce more complete responses than questionnaires filled out by census enumerators on the door step.

2.1 Advantages of internet collection

D.8. As noted earlier, the impact of adopting Internet data collection will be different for censuses that already use paper self-enumeration compared to those that rely on interviewer-assisted methods. The benefits of introducing online data collection are broad; regardless of the existing enumeration methods, such benefits include:

(i) *Improved coverage and data quality*

D.9. In any self-completion paper questionnaire, it is common for respondents to make errors when recording their answers, resulting in data that are not valid for estimation and analysis. Invalid responses include blanks, multi-ticks, out of range values and partially answered responses (particularly, for example, in questions on occupation and industry requiring write-in answers). Referred to as item non-response, this can be unintentional, for example where respondents miss a question or think they can tick more than one option, or intentional where a respondent either does not know or does not want to provide, the answer. The inclusion of automatic sequencing of questions and the implementation of real-time pre-programmed edit checks to identify user error, made possible by using an Internet option, can help to reduce (but not totally eliminate) item non-response and invalid responses prior to the submission of the questionnaire online. Moreover, the inclusion of drop-down menus, help functions or buttons for difficult questions and to screen out ineligible respondents, and additional examples, instructions, or formats makes it easier for respondents to navigate the questionnaire, result in better item response rates and better coverage of the target population and hence better data quality.

D.10. The automatic coding and interactive editing of answers simplify the processing of online questionnaires compared to paper ones and lead to fewer capture and processing errors.

D.11. Large households often require more than one paper questionnaire; the process of completing multiple questionnaires is more complex and time-consuming both for respondents and interviewers, and the risk of incomplete questionnaires is higher. Online questionnaires, which allow for an unlimited number of respondents, simplify this process and reduce the risk of omitting household members (typically, the census requires responses from all people living in a dwelling). Moreover, the linkage and processing of such multiple paper questionnaires is much more challenging as additional forms may get misplaced or lost.

D.12. With electronic questionnaires, there is no printing and despatch of forms required. This could leave more time to decide on the final design of the questionnaire, assuming that there still enough time to build and test it. Essential last-minute changes are easier to make, should a critical issue be discovered, for example, with the wording of a question or an instruction, or should new requirements or changes to policies occur. Clearer questions and instructions, in turn, lead to higher data quality. Paper forms that have to be printed and distributed well in advance of the census do not permit such flexibility.

D.13. As noted above, paper questionnaires are limited in the number of questions and instructions, whereas online questionnaires may include more questions to screen out ineligible respondents or to include less obvious categories of residents, resulting in better coverage of the target population (and potentially less follow-up required to resolve inconsistencies in the questionnaire or for quality control).

D.14. Particularly in those censuses carried out by interview, when the questionnaire is completed by the census enumerator at the time of the visit it is possible that the person responding on behalf of the household (most often the head of the household) will not know, or may not have ready to hand, all the requisite personal information about other household members (relating, for example to income, educational qualifications, or age of dwelling), with the consequence that the enumerator will either have to return at a later – and possible less convenient - date or leave some questions unanswered. By contrast, when self-completing an Internet questionnaire, the respondent can more readily consult with co-habitants in order to return the correct responses.

D.15. Furthermore, self-completed questionnaires are not subject to potential interviewer bias, social desirability bias or measurement error. For example, interviewers may paraphrase the questions, or omit reading portions of the questions including response categories or example (particularly in the case of multi-dimensional topics such as disability), or lead the respondents. Moreover, if the agency is able to implement a collection strategy that will generate a high Internet take-up rate around Census Day, a greater proportion of the population will respond on, or close to, the reference day, thus reducing the level of recall error experienced when interviews take place over an extended period of time because of the enumerator's workload.

D.16. Electronic data collection may allow the statistical agency to include hard-to-reach population groups more easily. Often, young adults (particularly students,) and persons living in secured accommodations to which access is restricted, do not respond via the more traditional method. Immigrant communities and some people with disabilities may also find it easier to complete an Internet form than a paper questionnaire. These groups are also more likely to be using the Internet for other purposes, and therefore, if available, this option should be promoted to these groups as a means of encouraging their participation in the census (see also section (iv) below).

D.17. However, it should be noted that broadband coverage, sufficient to allow for an Internet response, may not be universal throughout the country. In such areas, additional – and more traditional - field enumeration operations will be necessary to maintain coverage. This is noted in the section 3 below on the challenges with Internet collection.

(ii) *Potential cost savings*

D.18. The largest share of the costs of traditional census-related operations is attributed to the pay and training of field staff, particularly the large numbers of enumerators required to cover the whole population; in addition, if there are remote or hard-to-reach areas, the costs of bringing teams of enumerators to these areas could be significant. Such expenditures would be reduced with the introduction, or the increase, of self-response (more significantly for the former), to which online questionnaires would contribute. However, as labour costs, printing and mailing costs, area and density, and Internet take-up rates will differ for each country, so will the cost savings. Furthermore, it should be noted that field costs will not be eliminated altogether, as there will usually be a necessity to deploy field staff to carry out follow-up activities to pursue non-response and to undertake post-enumeration surveys to measure coverage and quality.

D.19. Also, countries should be aware that systems and processes that allow for the return of census forms online will also need to be developed (particularly so for first timers). These may increase some costs, but on the other hand, other elements of cost savings will be possible through the reduced infrastructure concomitant with an online collection methodology. Also, the costs of printing paper questionnaires, their storage before and after collection (for some countries a long time after collection), postage and delivery/return costs, and the processing costs associated with scanning and data capture, would all be reduced. However, scanning and Intelligent Character Recognition when using paper questionnaires are in themselves cost efficient. Therefore, countries will want to assess whether or savings in data capture costs are more or less than the costs of developing and implementing the Internet system, bearing in mind that such developments costs might also benefit other parts of the national statistics agency if the technology can be employed in other, non-census, data collection activities.

(iii) *Greater convenience and lower response burden*

D.20. With greater access to, and use of, electronic devices, people are increasingly switching to them for activities such as information gathering, personal and social communication, banking, and shopping. In fact, some people use digital media almost exclusively, having abandoned, for example, paper books, printed newspapers, and their CD and DVD collections. Moreover, and particularly in the case where a country is moving from an interview-based methodology, the option to self-complete the census questionnaire at a time and day of their own choosing (as opposed to only when the interviewer visits) allows respondents more flexibility and convenience, thereby helping to reduce response burden, and hence increase the response rate.

D.21. In fact, research shows that people clearly display response mode preferences (online versus paper questionnaires, for example). The tendency to respond in a particular mode is a preference that can sometimes be explained by demographic factors, but not always. Providing an alternative option of responding online caters both for those who would prefer using an electronic means of communication and those who prefer the more traditional mode.

D.22. An Internet option also makes responding more convenient for people with special needs. For example, online questionnaires facilitate the process of reading a questionnaire by including large fonts or voice recognition tools for persons with disabilities. Also, electronic data collection allows the statistical agency to offer questionnaires in several languages for the convenience of the public - particularly immigrant communities – thereby providing a service that may be impracticable with paper questionnaires due to the prohibitive costs of printing and processing them.

(iv) *Improved timeliness*

D.23. A key benefit of online data collection is the much more rapid receipt of data, made possible by the immediate transmission of responses and the subsequent automated processing. This time gain results in faster access to field operational information, giving managers more control over the data collection process. For example, a lower than acceptable response in one geographic area may lead census management to decide to stop collection elsewhere, so that a greater effort may be focused in

the area with low response. Real-time transmission of responses also allows responding households to be quickly identified and immediately removed from the non-response follow-up operations.

D.24. Another area that benefits from electronic data collection is the timeliness of the subsequent dissemination of the census results: the automated capture and processing of data speeds up all subsequent steps after collection, such as coverage checks, edit and imputation, and the production of estimates, before dissemination is possible. This allows for the disseminate of data much sooner, making the census generally more relevant for users.

(v) *Privacy and other benefits*

D.25. Completing a questionnaire with an interviewer can make some respondents uncomfortable for various reasons, including: revealing personal or sensitive information to a stranger; having concerns about data confidentiality; or not trusting the identity of the interviewer. The option of self-responding online provides a level of privacy and security that may be absent in interviewer-assisted methods.

D.26. Electronic data collection is more environmentally friendly than paper data collection. The benefit to the environment is obvious; less obvious perhaps, but nevertheless important, is the benefit coming from the improved perception of the statistical agency by the public. Moreover, providing the option of responding online helps create a more positive and modern image for the statistical agency, thereby making it more likely that the public will cooperate with the agency during its data collection operations.

D.27. Internet collection also permits the statistical agency to integrate its contact strategy and collection operations with social media channels, such as Facebook and Twitter. Advertising the start of the census campaign, links to questionnaires, and subsequent reminders may be posted on these channels. This makes it possible both to reach a broader audience and to send the message repeatedly at a fraction of the cost required for other channels (such as advertisements in the national press or on TV or radio).

D.28. Internet collection generate a large amount of metadata (such as the date and time of the response, length of the response process, corrections made by respondents, instructions consulted, edits triggered, etc.) that could be analysed later to improve future collection methods and questionnaire design and content.

D.29. Finally, if the agency has the IT capacity, the transition towards internet data collection can also be a good opportunity (as noted in section (ii) above) to develop corporate solutions that will benefit not only the census but also other statistical programmes within the agency, allowing economies of scale for both the agency and the census program itself. Corporate solutions also permit the agency to develop more robust solutions for data collection and to deploy a more rigorous risk mitigation strategy for maintaining corporate software applications. Examples of such solutions include common internet applications, collection management systems, management information reports, as well as shared financial services.

D.30. A summary of the main advantages of Internet data collection is set in Table E.1.

Table E.1: Summary of the advantages of internet collection

COST SAVINGS	• Fewer interviewers mean lower expenditures on pay claims • Lower costs of printing, mailing, processing, and storing paper questionnaires
IMPROVED DATA QUALITY	• Automatic sequencing of questions and edit checks reduce invalid responses • Drop-down menus and help functions facilitate response process and increase item response rates • Automatic coding of answers reduces capture and processing errors • More complete questionnaires and easier processing for large households • Easier to make last-minute changes to improve questions / instructions, which helps reduce recall and measurement error
BETTER COVERAGE	The ability to include more screening questions helps improve coverage • Access to hard-to-reach respondents that would not have otherwise responded
GREATER CONVENIENCE AND LOWER RESPONSE BURDEN	• Provide an option of electronic response to those who would not have responded using another mode • Additional option for a response mode caters to those who prefer internet • Allows to facilitate response process for persons with special needs If internet collection means introducing self-response, then also: • Gives respondents greater flexibility to complete questionnaire • Provides level of privacy that is not present in interviews
MORE CONTROL OF OPERATIONS AND FASTER DISSEMINATION	• Faster access to information about collection operations permits management to take action to intervene where required • Automatic data capture reduces processing time, allowing earlier dissemination
OTHER BENEFITS	• Environmentally friendly • Positive and modern image of the statistical agency • Easier integration with social media channels means greater likelihood of reaching a broader audience at a lower cost • Development of corporate solutions to benefit a variety of programs and deployment of integrated risk mitigation strategies

2.2 Challenges with Internet collection

D.31. Despite numerous advantages, online data collection also presents many challenges, risks, and additional requirements. While, as noted above, the Internet option may be incorporated into, and combined with, any of the traditional methods for delivering and collecting census forms, the key factor in deciding whether or not to use the Internet option is to ensure that every household and every individual is counted once and only once, particularly if a multi-modal approach is adopted. The particular key challenges include:

(i) *Reliable linkage between each household and its geographic location*

D.32. Without the existence of a good and comprehensive address register, and, most importantly, efficient and accurate ways of keeping it up to date, there is a high risk of missing dwellings, particularly if field enumerators work only on a subset of housing units or if postal invitations to complete questionnaires online are not delivered to units not on the register. Thus, such a register might seem to be necessary pre-requisite in conducting any form of traditional census, whether or not an online data collection option is adopted. But in the case of Internet collection, it is doubly important not only that each address can be identified but also that a unique link between the address identity and the online questionnaire security code (see below) is established. Such a link helps to ensure that the level of over- or under-counting is kept to a minimum while, at the same time, allows field management information to more readily assess locals levels of coverage and response.

D.33. For countries without an effective address register the challenge of managing an online data collection operation becomes more difficult, but not impossible if GIS can be utilised to map dwellings or enumerators list housing units during the field enumeration, so that they can be accurately and uniquely identified on the ground by enumerators before and/or during the enumeration. Where the address register is only partially complete, the statistical agency may wish to employ an online data collection only in those parts of the country (often in the more urbanised areas) where there is greater confidence in the coverage and accuracy of the register. The requirement for an address register is discussed in more detail below.

26. But whichever enumeration approach is adopted, the identification of dwellings with multiple occupation, that is, where two or more households live in premises with the same address and from which more than one household questionnaire (whether paper or online) is required, remains a perennial problem.

(ii) *Coordination of multi-mode collection operations*

D.34. For countries that chose to adopt a multi-modal approach to data collection and where some paper forms are still collected by census enumerators (rather than mailed back), it is necessary to have timely feedback regarding the response status of the dwelling to avoid enumerators following-up households that have already responded online. This will prevent unnecessary field visits, and will reduce both costs and respondent burden on self-responding households. Confirmation codes should be provided to households responding via the Internet to avoid confusion and harassment if field visit should occur anyway.

(iii) *Systems infrastructure*

D.35. Electronic data collection requires the development and application of appropriate hardware and software to handle the large amounts of data to be received, transmitted, processed and stored. Other than the investment in the physical assets required for this purpose (servers, connections etc.), there is a large cost associated with the development of software tailored to the needs of the data collection operations.

D.36. There is also a cost related to the one-off need of having highly-specialised staff to develop and put in place the system infrastructure. As the census occurs only decennially (for most countries) and over a relatively short period of time, and involves the whole population it is unlikely that the statistical agency will already have the necessary infrastructure to cope with the peak demands. Depending on the resources available, it may be less expensive, and less risky, to contract-out (outsource) some or all components rather than acquiring new staff or investing in training. (The pros and cons of outsourcing elements of the census operation are usefully set out in the 3rd revision of the UN's Principles and Recommendations (United Nations, 2015).)

D.37. There has to be a willingness for collaboration within the statistical agency among the many parties involved in the development and the implementation of internet collection operations: computer science specialists, programmers, developers, statisticians/methodologists, subject matter specialists, project managers etc.

D.38. If the development of internet collection is intended for broader use than just the census, then software development should ensure that the requirements for regular and *ad hoc* surveys in social statistics can be met and that resources are made available to reconfigure the census software and the production environment for other types of surveys. In addition, consultations should be held with representatives of involved parties to ensure that such systems are generic enough, yet sufficiently specific, to address the data needs of each user.

D.39. Respondents should also be offered the option of completing their census questionnaire online using different types of devices, including mobile ones. Thus, the layout of the web page must be designed for various screen sizes (ranging from smartphones to tablets) and for different input methods, such as touch input or keyboard and mouse input. This requires additional development and testing.

(iv) *Confidentiality and security of data*

D.40. In the same way that paper questionnaires may be lost at any point from their completion to their delivery, census information submitted electronically is also vulnerable to risks specific to digital data. Too many online responses at any one time may cause the server hosting the collection portal to crash, and respondent data may be corrupted or lost in the process. Staggering the delivery of questionnaires or invitation letters, or requiring people outside predetermined target populations/areas to contact the census agency before they can use the Internet form, may be a means of restricting use of the Internet form at any one time.

D.41. There is also a risk that respondent data may be intercepted during transmission or compromised when delivered to the statistical agency. Special measures must be taken to ensure that digital data will be delivered via a secure connection from an external network to an internal storage location, as well as to prevent malicious attacks from the outside. For this purpose, some statistical agencies store respondent data on an internal network that is not accessible to hacks or viruses.

D.42. In addition to those systems infrastructure requirements designed to meet security and confidentiality challenges, Internet response will likely be insufficient to reach the all the expected response targets set out by the statistical agency. Therefore, the online self-enumeration method should generally be offered as just one among a set of options in a multi□mode collection process. Such an approach carries its own special challenges.

(v) *Extended collection period makes it harder to capture a picture as at Census Day*

D.43. Usually, with multi-mode collection, there is a self-enumeration phase prior to sending enumerators to follow-up non-responding households. While generating more self-response close to Census Day can be an advantage (as explained in the previous section), it also may have the effect of making the collection period longer. This is problematic for any kind of census, but even more so for countries using a *de facto* concept (where people are enumerated where they were present on the Census Night as opposed to the place of usual residence).

D.44. The longer the elapsed period before follow-up (contact with enumerator) the greater the risk of capturing an inaccurate snapshot of the country relating to Census Day. Moreover, a longer collection period makes the census more susceptible to unexpected situations that may disrupt collection operations, halt them for some time, or even stop them altogether. Examples include: natural disasters (fires, hurricanes, earthquake, etc.); events related to political or social issues (riots, demonstrations,

postal service strikes, etc.); and other generally unpredictable events (terrorist threats, power outages, etc.).

D.45. Longer collection may also result in coverage issues. Multiple contacts at the same dwelling over a longer collection period combined with the fact that all dwellings in the country have to be contacted introduces the risk of multiple responses from the same household. Respondents may move during the collection period and complete a questionnaire at their old and new residence; respondents may also complete more than one questionnaire if contacted several times or if responding for both their main and secondary residence, resulting in duplicate responses. Such duplication distorts the picture of the census results and leads to over-coverage or even under-coverage if, as a result, other households are missed.

(vi) *Higher risk of introducing bias due to a mode effect or nonresponse bias*

D.46. Mode effect refers to differences in responses caused by the mode of enumeration of the census (or survey) (for example, online, paper questionnaire, interview etc.). In the context of a census, the basic demographic questions typically included on the questionnaire are usually straightforward and hence not particularly sensitive to mode effects. However, there have always been significant differences in some socio-demographic and housing characteristics of Internet respondents compared to those who respond on paper, in particular differences related to age, education, marital status, ethnicity and labour force status [Reference required]. Reasons for this may be attributed to different characteristics of Internet respondents themselves; for example, people with higher levels of education are more likely to respond online. However, some studies have demonstrated that after accounting for the effect of such differences in the characteristics of Internet respondents, very few mode effects have been detected - at least in a census context [Reference required].

D.47. Using a multi-mode approach, the risk of non-response bias effects is mitigated compared to single-mode surveys (for example, older respondents to paper-based surveys versus younger respondents to internet-based ones).

(vii) *High initial cost*

D.48. The process to develop and test an Internet data collection system and online questionnaires is long and complex, and the initial investment to introduce electronic collection requires significant financial resources and expertise. Net cost savings may not always be achievable, at least initially. For the first-time implementation, take-up rates may be difficult to estimate since tests and pilot censuses are not always representative. Also, given the rapid advancements in technology, it is not safe to assume that the same technology can be reused 5-10 years down the road without at least some revision or upgrades. There are, of course, ways to reuse the existing technology, but further investment will usually be necessary to upgrade to new technologies and to expand Internet take-up capacity to meet increasing demand.

2.3 Requirements for data collection via the Internet

D.49. In this digital age, not using Internet as a mode of data collection might be perceived publicly as old-fashioned, and the pressure for using more modern methods is becoming increasingly irresistible. However, this factor alone should not be the main motivator for moving towards online collection. Methodological reasons, improvement in response and data quality, cost savings, and potential gains in efficiency should be the deciding factors.

D.50. As noted above, several countries have already used the Internet for their census enumeration operations. Some have adopted this method more recently, while others have been offering it for more than 15 years. The extent to which Internet is offered and promoted also varies from one country to

another and has evolved over time, as well as from one census to the next. The experiences and lessons learned from other countries should be considered in any decision to implement electronic collection, but intrinsic differences between countries should also be taken into account. It is important to keep in mind that what works for one country may not work for another.

D.51. But before even considering the infrastructure requirements and cost implications of internet collection, the socio-demographic characteristics of the country's population and other considerations must be carefully reviewed. Some of these factors are, indeed, essential for Internet collection to have a chance of success.

(i) *High literacy rate*

D.52. In order to introduce any kind of self-response, the proportion of population that is illiterate, or has very low level of education should be small: someone in the household must be able to access, read and respond to the questions (whether online or through a paper questionnaire). While literacy rates may seem too low initially to even consider implementing Internet collection, experience in some countries has shown that encouraging the young (and more literate) generation to help their parents, for example, by exposing students at schools to the idea of completing census questionnaires online, may resolve this issue. In addition, the availability (and legal acceptability) of an online questionnaire in the spoken languages or in the local dialects of the country should also be a factor to consider when determining the proportion of the population that may actually self-respond using the Internet.

(ii) *High rate of access to computers and computer literacy*

D.53. The majority of the population should have access to computers, laptops or other electronic device before Internet collection may be effectively introduced. The population may be highly literate, but if poverty, remote location (often resulting in poor broadband coverage, or some other factors are preventing people from being able to own a computer or other device, or to use one on a regular basis, then it would be challenging to obtain a reasonable response rate online. Implementing electronic collection in places where only certain groups (most often, the wealthier or urban populations) use computers regularly could introduce a bias.

D.54. Computer literacy usually goes hand-in-hand with computer access; if a household has a computer, most likely, at least one member of the household knows how to use it. Therefore, access to computers is a greater issue than computer literacy. As with the low literacy rate issue discussed above, lower rates of computer literacy in the country – and therefore lower expectations in Internet response – may be mitigated by having the younger generation help their older family members, as well as promoting computer literacy in places like schools, libraries, and community centres. Finally, the fact that the popularity of a range of mobile devices is increasing mitigates the need for high computer literacy, given mobile devices are usually easier to use than laptops or desktop computers.

(iii) *High rate of access to the Internet*

D.55. An obvious requisite for achieving a good online response is having a widespread Internet coverage: a significant portion of the population should have access to Internet using a personal computer (desktop or laptop) or a tablet if an online option is to be considered. However, access to the Internet does not have to be not limited to access at home: Wi-Fi access allows more locational flexibility. Partnerships with local authorities can also be established to use community facilities as public hubs where Internet access can be granted (for example, at libraries, schools, municipality offices, community centres etc.).

D.56. Of less control by the census organization, however, is the level of broadband coverage available throughout the country. Internet response is more easily and speedily completed using broadband connection. Those areas where such connection is not widespread will tend to experience

far lower levels of online response. Generally, however, such areas are in the more remote rural parts of the country where the different socio-demographic characteristics of the population will tend to introduce bias in the responses.

(iv) *Increasing use of mobile devices*

D.57. Smartphones are becoming increasingly more popular worldwide, but such devices are not the optimal vehicles for filling out census questionnaires. Depending on the complexity of the questionnaire, it may or may not be possible to complete it on a smartphone. In any case, questionnaire design for mobile devices should be taken into account when deciding on electronic collection. In particular, the different appearance of questions, display of available answer options through the provision of drop-down menus, and placement of help text or instructions on different smartphone models may impact respondents' ability to answer or even their decision whether or not to respond to a question at all.

D.58. Indeed, though tablets and smartphones are increasingly becoming more popular as replacements for desktop computers or laptops for general use, the limited analysis available on this subject seems to indicate that most people tend to use desktops and laptops when carrying out official business – such as completing a census questionnaire – online. However, technology and people's habits regarding the use of technology are changing very quickly and the same studies also indicate that the younger generations tend to use smartphones in higher proportion, and more than tablets. The balance of these preferences will thus influence the design of a country's online questionnaire and its supporting features.

(v) *Public trust and acceptance of the Internet for official business*

D.59. The level of public confidence and trust in the level of protection offered by the Internet varies from one country to another. In many countries, internet is seen as a safe, if not the safest, mode to provide confidential and sensitive information. In these countries, respondents may prefer not to give personal information to a census enumerator in a multi-step paper-handling process (in which greater risks of accidental or deliberate unlawful disclosure are perceived) but have more trust in a secure Internet connection. In other countries, however, the public acceptability is lower; in such countries, added measures would have to be taken to reassure respondents that their information would be kept safe and confidential if submitted online.

D.60. Level of confidence is also greatly influenced by the type of data being collected. Basic demographic questions typically asked in a short-form census tend to minimize public concerns about breaches of confidentiality, whereas more detailed questions on a long-form, including such as income, religion and occupation, may influence negatively this trust.

D.61. Moreover, the public's trust in, and attitude towards, the national statistical agency itself also comes into play, as well as the way the population usually interacts with the government for other reasons. In countries where online communication with official departments is widely used (for example, to complete and submit income tax returns, applications for passports, and payment of benefits), the public's expectations regarding the availability of an Internet response option for the census are higher. To this end, many countries have adopted a common and recognisable visual theme (or brand) on all their websites, increasing the level of confidence of the public when providing confidential information to the government.

(vi) *Making reasonable assumptions about take-up rates*

D.62. Taking account of the outcome of the issues covered in sections (i)-(v) above, those national statistical agencies contemplating adopting an online data collection methodology for the first time will need to assess the likely take-up of Internet response to ensure that the option is both viable and cost-

effective. A level of take-up needs to be achieved such that the cost of developing and implementing an online questionnaire and secure response mechanism is at least recovered by the savings made in reduced field and data processing costs.

D.63. The potential numbers of online respondents will of course, vary from country to country, as will the minimum level of response needed for any Internet-based service to be viable, but estimates of the potential volume of take-up can also be estimated from the experience of other countries who have introduced an online system. The 2013 UNECE survey referred to earlier reported, for example, that in the 2010 round of censuses the proportion of census information collected online (in those countries that carried out a traditional census with at least some degree of online collection) ranged from two thirds In Estonia to just 16 per cent in the UK. But even in the latter case the lower than expected level of take-up was sufficiently high for the innovation to be deemed cost-effective enough to be worth repeating in the 2020 round.

(vii) *Availability and quality of address/building/dwelling register or list*

D.64. As noted above, the availability of a register or a list is not an absolute requirement before implementing electronic collection; however, it will have an impact on which approach is feasible. If an address register exists, the mail system may be used to send the census material inviting households to respond; if no register exists, enumerators can deliver census letters or questionnaires using information available to the statistical agency gathered from a pre-enumeration dwelling-listing exercise. A mixed approach can also be used if the register is incomplete or if listing is required prior to the delivery of questionnaires; for example, in rural or remote areas. Even in countries where a good address register exists, mixed approaches are very often required because there is always a proportion of the country for which the address register is incomplete or simply non-existent.

D.65. A separate issue and a key factor to be considered before introducing electronic data collection is the capability to manage collection operations in such a way that every household and every individual are counted once and only once. This issue has already been identified above as a challenge to Internet collection; its resolution requires the ability to provide a reliable linkage between households and their geographic locations as well as access to timely information to update the response status of households/dwellings during collection operations.

(viii) *Legal authority*

D.66. In most countries, the preparation and conduct of a census, regardless of the methodology adopted, requires a legal basis, which may prescribe, in particular, provisions relating to the obligation of citizens to provide complete and accurate census information and the means of collection of such information. In countries that lack permanent or primary legal authority for the taking of periodic censuses, or where secondary legislation is required to enable a particular census to take place, it is important to act early to establish the necessary legal authority.

D.67. The legislative process, and the timeframe necessary to complete it, will of course, vary from country to country, but sufficient time should be allowed for the completion of such a process well before any activity that is dependent on the legislation is scheduled to begin. This is particularly so in the case countries moving from a census methodology based on a long-standing tradition of field enumeration to one based primarily on the collection of data online. It will usually be the case that such a transition should be achieved gradually and that the provision of Internet collection should be just one of a number of options by which the public can submit their census returns.

2.1 A first step towards the use of the Internet in future censuses

D.68. As noted above, the collection of census data online should not be seen as a stand-alone method; instead, it should be considered as an important component of a more optimal and efficient multi-mode

approach. In this context, the Internet solution should not be rejected simply because it does not work in every area of the country or for every group of the population. If the background, the constraints, or the characteristics of the population differ depending on the area of the country, a mixed approach that is tailored to the specific situation in the area (rural versus urban, remote versus easily accessible, heterogeneous versus homogeneous population etc.) can be adopted. Most of the countries that are already using the Internet as a response mode have started with such tailored designs which were then progressively expanded in the push for greater online usage. Even in countries that try to maximize Internet response rates, face□to□face interviews are still used in areas or situations where literacy levels are low, where special problems exist, or where the terrain or climatic conditions impose constraints.

D.69. Society is changing. In most countries, computer literacy is increasing and, as noted above, the proportion of the population using the Internet for various purposes is growing at a fast pace. The decision of moving towards online data collection should be forward-looking – a part of a longer-term plan, rather than being based solely on the current situation and conditions. For example, the current levels of Internet penetration may not justify a full-scale implementation of online collection, but if the situation is expected to change in the next ten years, it may still be viable to introduce Internet collection on a smaller scale.

D.70. The implementation of an online data collection methodology can also be seen as a first step towards the development of alternative methods of future data collection more generally, such as the use of administrative data to supplant data collected traditionally from respondents in the field. Even in countries that are moving towards a register-based census, there is often still a need for collecting those data not readily available from administrative records for a sample of households; introducing electronic collection will facilitate the transition to the use of multiple sources of data.

D.71. The requirements of the systems infrastructure and the cost associated with it are also key factors in deciding whether Internet collection should be adopted. However, since the necessary infrastructure is proportional to the extent to which it will be used, the costs and other required investments should also be lower if it were implemented on a smaller scale. Finally, if introducing online collection is a part of a longer-term plan or corporate strategy, cost savings at initial implementation should not necessarily be the principle goal.

D.72. A pilot test or a feasibility study should be conducted to evaluate the Internet as a practicable response mode. The following are some of the suggested objectives that would help assess the success of internet collection. To:

- obtain a measure of public acceptance and take-up rate
- obtain a measure of the impact on overall response rates and costs
- obtain a measure of the distribution of returns over the collection period and some measure of IT infrastructure requirements
- evaluate the quality data submitted compared to the data provided by similar respondents using self-completion paper questionnaire or via interviews
- determine the impact on the management of collection operations
- obtain some measure of the preference of, and convenience to, users, and the impact on response burden; for example, whether the Internet option reduces the burden, or whether multi-mode contact increases the burden or has an influence on response propensity, etc.
- obtain information from respondents on how to increase internet response propensity
- evaluate the impact on under-enumeration or overcounting.

3. Implementation process

D.73. Any strategic change in the collection methodology could have an adverse impact on the coverage and the quality of the census; therefore, any such change requires careful consideration, planning and testing before implementation. Examination and testing of possible improvements in

census processes may be conducted during the inter-censal period, taking advantage of the experience in other countries.

D.74. Many countries that have adopted internet collection have done so progressively, with realistic and reasonable expectations, taking an incremental approach. Many countries started with a pilot test integrated to regular offline census operations, followed by a conservative approach in rolling out electronic collection for the next census. Countries with a five-year cycle have more flexibility and opportunities to implement changes more progressively; countries with a ten-year cycle can compensate by conducting more tests between censuses.

D.75. In line with the guidelines presented in the United Nations *Handbook on the Management of Population and Housing Censuses Revision 2* the introduction and the implementation of a new collection methodology should follow the standard census phases. The standard census phases are: planning, preparations (which include questionnaire development and testing), enumeration, data processing and evaluation. The planning phase is discussed in this section, and the other phases are covered in the following sections.

3.1 Planning

D.76. The identification and the scheduling of the various phases of Internet data collection implementation will provide the basis for planning. The matter of how to best implement Internet collection will be specific to individual countries and will differ according to local circumstances. Initially, though, these actions should be done at a high level, then developed in more detail into the different activities that make up each of the census phases. The activities can then be further broken down into tasks in order to establish resource estimates and responsibilities, as well as to confirm the dependencies and the timing of interrelated tasks.

3.1.1. Planning phases

D.77. The planning phases of the implementation process should include:

- an assessment of the local circumstances (refer to section B-3)
- a review of the experience of other countries and an assessment of applicable methods: differences should be understood and only the method(s) that are practicable should be considered
- an establishment of viable options with pros and cons clearly identified
- the selection of the preferred strategy, which includes:
  - decisions about technology, resources, and the balance between in-house work versus outsourced contracts (if applicable)
  - setting reasonable objectives and reachable targets
- a risk analysis along with contingency plans
- an implementation plan, including a realistic testing strategy with room for alternatives and time to make adjustments following the tests
- a short-term and a long-term vision
- an evaluation plan

D.78. The planning phase should encompass all development-related activities, such as questionnaire design and testing, establishing publicity and communication strategies, developing promotional and communication instruments and strategies, and designing or adapting the systems for data processing. Furthermore, it should include the development of a plan for the management of integration of collection operations in any multi-mode collection context. Among other things, the plan should include different milestones for finalizing the identification of both the high level and detailed business requirements, and should be aligned with the development and the testing strategies and schedules. Having such a plan is important, especially given the fact that introducing Internet self-response means relying more on systems that present new risks.

D.79. Planning of such a large operation must be a dynamic process; developing efficient mechanisms to make adjustments to the original plan and to communicate them is critical to the success of the operation. The ability to respond to unforeseen complications and to adapt the implementation process as required will also be key to the success of the process. Finally, encouraging open communication among the many stakeholders involved in the adoption of Internet collection (including the general public) will foster close collaboration as well as a sense of working towards a common goal, thereby increasing the likelihood of success.

3.1.2. Setting reasonable objectives and reachable targets

D.80. Predicting the likely Internet take-up rate is probably the most difficult task of the planning phase, particularly when online collection is implemented for the first time. As noted above, the potential level of take-up may be estimated by assessing the proportion of the population able to access the Internet, the different types of Internet connections which may impact the choice of responding online, and the general use of the Internet for other purposes (for example, online banking, filing tax returns, shopping). Also important is the need to be able to assess the profile of when internet responses can be expected to be submitted in order to built sufficient capacity into the system. This is dealt with in more detail in Section 6.

D.81. The take-up rate is, moreover, greatly influenced by the level of promotion of the online response option and the intensity of the push for Internet as the preferred response mode in the communication and advertising strategy. The ease of obtaining alternative response options, such as paper questionnaires, is also a key factor. Experiences of other countries may be used to assess the extent of the take-up as well as the impact of the communication strategy and the advertising campaign. However, this must be done with caution in view of the numerous differences between countries, in particular, with regard to the public's attitude to, and confidence in, the increasing use of new technology.

D.82. But despite the fact that predicting the Internet take-up rate is difficult, it is also one of the most important parameters to predict. For planning purposes, multiple targets may have to be used. For example, when planning for field capacity, a conservatively low take-up rate should be used, but when planning for the capacity of the systems, a higher rate should be used. However, being conservative has the inconvenience of reducing the potential cost savings. A reasonable compromise should be found, and a risk mitigation strategy put in place.

4. Contact and communication strategy

D.83. Communication and promotion activities are important elements in the enumeration phase of any census – irrespective of the mode of data collection. As noted earlier, however, it is unlikely that an Internet response option will be either feasible or acceptable to the entire population, therefore requiring the option for respondents to submit their census returns by alternate modes of data collection. In most countries where online self□response has been implemented, this has been offered on the basis of voluntary participation rather than being the sole mandatory option; in this context, in order to achieve the desired levels of response rates, it is necessary to develop effective methods of communication and contact with potential respondents. It is important to establish a simple, unifying and readily identifiable census brand, with a slogan and logo, at the outset of the campaign which can be utilised throughout the entire census operation. The main elements of a general publicity campaign are helpfully set out in the *Conference of European Statisticians Recommendations for the 2020 Censuses of Population and Housing* (UNECE, 2015).

D.84. The communication and contact strategy should include all data collection channels but should be aligned with the way in which the Internet collection is integrated as a component of a more complex multi-mode collection plan. For this reason, the strategy for contacting and communicating with potential respondents is a key element that needs to be determined early in the planning process.

D.85. There are several ways in which internet collection can be implemented; the typical approach to multi-mode collection methodology entails a phase of self-response using internet, immediately followed by a non-response follow-up phase conducted either in the field or by telephone interviewer. Among the countries that have adopted Internet collection, the main elements in the contact and communication strategy should aim to determine:

- how the households are invited to respond by Internet
- how many times they are contacted
- whether the option of self-responding by completing a paper questionnaire is offered

4.1 The multi-phase contact approach

D.86. The development of optimal contact and communication strategies is critical for attaining high Internet self□response rates. Among the countries that have adopted online data collection, a common feature of the contact strategy is the use of a phased approach to communicate with respondents: households are asked or reminded to complete their census questionnaire, preferably by Internet if the paper option is available, at specific times during the collection period. Each phase, or wave, aims to generate more self-response, and the final phase or wave is the non-response follow-up operation conducted in person by census enumerators or by telephone.

D.87. Respondents can be contacted in various ways described as either 'push' or 'pull' methods. Pull methods are more generic and centre around a national publicity campaign. This is a vital component of pre-enumeration activity in its own right as it is important to inform the public about the census generally and to help resolve concerns in order to encourage participation. Such a campaign should start well before the enumeration phase in order to ensure the widest possible coverage, but not too far in advance that the intensity of the publicity starts to dissipate by Census day.

D.88. Push methods are more direct and can encompass invitation letters, postcards, emails, texts, phone calls, paper questionnaires, FAQs (Frequently Asked Questions) brochures, etc. The most appropriate means of contact depend on several factors, but the availability of a contact frame (an address directory, a phone or email list from administrative/third-party sources etc.) is a key determinant. If an address list exists, census materials can be sent by post; otherwise, they can be delivered by census field staff. When mailing census material is not possible, multiple waves delivered by census staff may significantly increase the cost. It that case, generic ad-mail may be a less expensive option. The collection strategy can also include a combination of contact approaches.

D.89. Determining the most optimal means of contact for each wave should be evaluated as part of the complete contact strategy – in conjunction with the other waves (including non-response follow-up) and also the communication strategy. Logistic constraints should also be taken into account. For example, compromises to a more optimal strategy may have to be made due to limited capacity of the postal service, or any other unavoidable delays. The timing of the contacts can also be influenced by the capacity of the systems infrastructure. For example, staggering the mail-out may be a good way to spread the response over several days to avoid internet peaks that the capacity infrastructure could not accommodate – though, of course, the aim should always be to maximise response as near to Census Day as possible.

D.90. The optimal combination of steps establishing the contact strategy, as well as the timing of each wave, should also be developed, tested, and refined, taking into consideration demographic, socio-economic housing and geographic variables in order to better understand and plan for response propensities. Communications that are effective in motivating self-response should be developed in a similar manner.

D.91. For those countries where completed census forms are collected by census enumerators (rather than mailed back by respondents), an added complication is providing suitable and timely feedback to

field managers in order for them to update their own collection control information so that enumerators do not visit households that have already returned questionnaires. For this reason, some countries avoid overlap between the enumeration and the non-response follow-up phases by leaving a gap between the two operations, so as to allow sufficient time for the planning of the non-response follow-up operation to account for the results of self-enumeration.

D.92. Many countries have adopted, or are currently testing, a variety of approaches for introducing the Internet response option as well as the contact and the communication strategies that go with it. The aggressiveness with which the use of the Internet option is promoted has changed over time and varies from country to country.

4.2 Should the paper self-response option be offered?

D.93. While the Internet undoubtedly provides a more convenient response mode for a significant and increasing proportion of the population, offering a paper questionnaire as an alternative option is likely to result in fewer cases requiring completion during the non-response follow-up operation.

D.94. Even though the proportion of the population preferring to complete a paper questionnaire is decreasing, there will usually be a significant number who prefer the paper option and may not self-respond otherwise. The reasons usually invoked for preferring the more traditional mode include:

- paper questionnaire is quicker/easier to complete than an electronic one online
- lack of computer literacy, no Internet connection, no access to high-speed/broadband Internet, problems with the Internet service or domestic computer hardware
- household computer used by many people resulting in limited accessibility
- security and confidentiality concerns

D.95. Paper questionnaires for self-enumeration can be made available to the respondents at various times during the enumeration operation – and even during the non-response follow-up phase. While there are many opportunities for offering the paper option as part of the multi-mode collection strategy, these options can be grouped into three main categories described below.

4.2.1. Paper questionnaires sent at initial contact

D.96. Paper questionnaires can be included in the initial package of material mailed or delivered to households. Where an Internet option is being offered that can be done in a letter accompanying the questionnaire, at the very least, but it is preferable that the internet option be clearly promoting on the paper questionnaire itself by including a unique Internet access code that the respondent can then activate online.

D.97. This approach is by far the least aggressive method in terms of encouraging respondents to choose the Internet as the mode of response. As a consequence, in countries where this approach has been adopted, the majority of respondents still tend to prefer to complete the paper questionnaire delivered to them rather than completing a questionnaire online. This is the case even for countries or local areas where the Internet is widely used and where a high Internet take-up rate would be expected. However, if maximizing the level self-response (whatever the mode) is the main objective of the field operation and reminders are not possible, this option may well be the best approach for first-time countries.

D.98. A variation on this approach might be to offer the option of response mode in advance of the main enumeration period by asking respondents, through a postal delivered invitation, to pre-register for an Internet questionnaire. Paper questionnaires would then only be sent out to those households wishing to respond in that way, thus reducing the distribution costs while, at the same time, providing some further indication of the likely online response rates.

D.99. Thus, a cost-benefit analysis should be carried out (ideally supported by a test) to determine what is globally the most optimal option, when taking into account every aspect. For example, the benefit of any approach that would enable respondents to pre-register their intentions to complete their census online – such as the savings made in printing, distributing and scanning fewer paper forms – might be outweighed by the cost of providing and online system that would need to accommodate a much larger proportion of Internet questionnaires. Moreover, there is always the risk that respondents' circumstances or attitudes might change in the interim period between registering and Census Day so that they would decide to complete a paper questionnaire after all. Also, there would be the challenge of providing any sort of print-on-demand service for the supply of paper questionnaires, which might result in the need to produce a large number of such forms in a short time frame.

4.2.2. Paper questionnaires sent during the reminder phase

D.100. An alternative to sending paper questionnaires at first contact is sending or delivering only invitation letters providing the Internet access code initially and then providing a paper questionnaire with a reminder in the event that an online response is not submitted. In some countries, however, the first reminder is in the form of a letter or a postcard only. Emphasizing and encouraging the Internet response option during both the initial and the reminder letters and making the paper option less easily available creates a more effective way to maximize the Internet take-up rate.

D.101. Paper questionnaires sent as reminders should also offer and promote the option of responding by Internet. On many occasions, respondents will prefer to respond online even after receiving the paper questionnaire.

D.102. Sending a paper questionnaire in a later phase, after sending an invitation letter as the initial contact, gives a stronger impression of the increasing importance and urgency to respond to the census, compared to the strategy of starting with a questionnaire package followed by reminder letters. Also, a different look and feel of the paper questionnaire delivered at a later stage is likely to catch the respondents' attention, and the format of the questionnaire package may motivate respondents to take action more rapidly, ultimately leading to a higher self-response rate.

D.103. Questionnaire packages should be sent to non-responding households only; from a logistics point of view, however, setting up this *on-demand* process may represent a challenge. Typically for non-response follow-up, questionnaires are printed in advance and include generic unique identifiers or barcodes, as well as the unique Internet access codes. A process must therefore be set up to link the non-responding household to the generic questionnaire, and to print the appropriate address on the questionnaire or on the questionnaire package. Ideally, this *on-demand* process that allows sending census material to non-responding households only should also be used for the reminder letters, but it is more important for questionnaire packages because printing, storage, and mailing costs of such packages are more significant.

D.104. Another alternative approach that has been adopted is sending a second paper questionnaire as a reminder, even sometimes during non-response follow-up. However, a careful estimation of the costs should be done to ensure that the limited returns generated by this second wave are worth the investments of printing and mailing or delivering another round of questionnaires.

4.2.3. Paper questionnaires available on request

D.105. If the prime objective is only to maximize the overall self-response rate, regardless of mode of response, then offering respondents the option to request a paper questionnaire should be considered. Typically, this option is communicated by including a telephone number to request a paper questionnaire on the invitation or the reminder letters, and setting up an automated system that will receive respondents' requests and arrange to have the paper forms delivered. In countries where such

systems have been implemented, the efficiency of the process is proven, and the vast majority of the callers have ended up completing and returning the paper questionnaire that they had requested.

D.106. As with the case of the despatch of paper questionnaires at the reminder phases, this process requires finding an easy way to link on-demand pre-printed generic questionnaires to specific households. And once again, the paper questionnaires sent in response to received requests should also offer and promote the option of responding online. For various reasons, some respondents may yet choose to respond online instead of completing and returning the paper questionnaire that they have just requested. For example, a different household member may open the package, or the respondent may look at the questionnaire and realize that it would be easier to complete it online.

D.107. Many factors influence a respondent's likelihood to request a paper census questionnaire. A recent analysis done in Canada in 2016 on the topic indicated that age is the most influential factor, correlated with many other population characteristics. A respondent is more likely to request a paper form if they have one of the following characteristics: age above 65 (and even more likely when age was above 75), female, separated relationship status, or lives alone. In contrast, a respondent is less likely to request a paper form if they have one of these characteristics: age below 65 (and even less likely when age was less than 45), male, single relationship status, lives with children aged 18 and under, or has a postsecondary education.

D.108. The easier it is for the respondent to find the telephone number and request the questionnaire, the more questionnaires will be requested, and eventually completed, but sometimes this is at the expense of an Internet response. Making the paper questionnaire option less visible (for example by only offering this option to those respondents who call the help line and ask specifically for that) is likely to increase the Internet response rate since the respondents who are somewhat indifferent to the mode of response will use the only option they see. However, those who demand more adamantly a paper questionnaire are more likely to wait for the non-response follow-up. Once again, this is a question of compromise between self-response and Internet response, and the potential gains generated by the paper option in order to reduce the non-response follow-up workload. The decision should also be influenced by the possible reaction of the population, in particular if paper questionnaires were available in previous censuses and if completing the census is mandatory (which it usually is).

4.2.4. Choosing the most appropriate contact approach

D.109. Sometimes, countries that have been using a traditional self-enumeration methodology with paper questionnaires for several successive censuses are more reluctant to discard them completely to move towards a totally online self-enumeration. Such countries usually have a well-established expertise and the infrastructure for handling and processing a large number of paper questionnaires, where maintaining the paper option does not add insurmountable challenges, and where maintaining high self-response rates is probably the most important factor when setting objectives for the collection strategy**.**

D.110. However, it is possible that even though abandoning the paper self-response option may result in a lower self-response rate, the additional cost required to retain this response mode will not be justified. It may be acceptable to suffer an small increase the non-response follow-up workload in order to make significant savings by simplifying the self-enumeration process.

D.111. For countries where Internet collection would be a first attempt at self-enumeration, expectations for self-response targets would be lower, and even though offering multiple mode options for self-responding would certainly generate more self-response, high self-response rates may not be an absolute requirement providing there are effective alternative data collection strategies in place to make up for any shortfall in online response.

D.112. Another consideration regarding the use of paper questionnaires for self-response is whether paper questionnaires are used for other purposes, such as during non-response follow-up activities. If a large quantity of paper questionnaires is required to be processed regardless of the self-response strategy, having paper forms as an additional option for self-response does not necessarily add to the complexity of the logistic operations.

D.113. As noted above, the experiences of other countries when introducing electronic data collection should be considered; however, all these considerations must be carefully analyzed, evaluated, and tested in the context of the particular national situation, and the most appropriate solution will be specific to each country. It is important, for example, to take into account the differences related to labour, mailing, delivery and printing cost, as well as the appropriate expectations in terms of volumes and response rates referred to above.

4.3 Examples of multi-phase approaches used in different countries

D.114. As has been noted several times above, several countries have already introduced Internet collection and implemented a multi-phase approach for contacting households. The table below presents a selection of examples. Table.E.2 also presents, in particular, Statistics Canada's experience acquired over 10 years including three censuses and several tests.

Table E.2: Examples of multi-phase contact strategies used in different countries

AUSTRALIA (2016)	• PHASE 1: Most households received a letter with a unique Census Login, and instructions on how to complete the Census online. • PHASE 2: Reminder letters were sent to every household that hasn't responded to the Census • PHASE 3: Visit from Census Field Officers Paper forms still available to households that require them, and could be requested through a dedicated paper form request line. Each paper form was delivered with a reply-paid envelope.
CANADA (2016)	• **WAVE 1**: A letter, received eight days before Census Day, inviting respondents to complete the Census by Internet using a personal Secure Access Code, and offering the possibility of requesting a paper questionnaire by calling a toll-free number; • **WAVE 2**: A reminder letter, received just after Census Day, reminding non-respondents to complete the Census questionnaire (also offering the possibility of requesting a paper questionnaire); • **WAVE 3**: A questionnaire packaged received about one week later. This package contains a new access code for Internet. The letter accompanying the package contains more direct wording concerning the mandatory requirement to complete the census. • **WAVE 4**: Telephone voice broadcast messages sent after Wave 3. Phone or personal visit by a census enumerator start about one week after reception of Wave 3.
ESTONIA (2011)	• **WAVE 1**: e-census for one month, where all permanent residents of Estonia can complete the census questionnaires online by themselves.

	• **WAVE 2**: interview census where enumerators visit those people who did not complete the questionnaires during the e-census. Interview census lasted about seven weeks. There was a pause of 18 days between e-census and interview census for rearranging the working lists of non-enumerated respondents
JAPAN (2015)	• **PHASE 1**: Enumerators distributed internet IDs to all households • **PHASE 2**: Enumerators distributed questionnaires to households which have not responded through the Internet. Questionnaires were submitted by handing over to enumerators or by postal mail • **PHASE 3**: Non-response follow-up by field enumerators
KOREA (2011)	• **PHASE 1**: Internet option available for 10 days just before Census Day. Incentives included handing out gifts by drawings and giving students two-hours credits for volunteer work. • **PHASE 2**: Field interviews during 15 days just after Census Day.
LATVIA (2011)	• **STAGE 1**: During 12 days, residents had opportunity to fill in the questionnaires on the Internet, authorising with the identity code and passport number, Internet bank ID of five banks and e-signature. To ensure the safety of personal data, after two days, it was not possible to sign in using the identity code and passport number. • **STAGE 2**: Field interviewers visited residents at their homes. Stage 2 started five days after stage 1 and lasted 2 and a half months. • **STAGE 3**: Considering the high interest of the population and its willingness to fill in the questionnaires on the Internet, as well as approval of the Population and Housing Census commission, a third stage was implemented, in which residents not taking part in the 1st and 2nd stage of the Census had an opportunity to fill in the Census questionnaires on the Internet or to visit some of the 37 regional centres, and fill in the questionnaire. Stage 3 took place immediately after stage 2 and lasted 10 days.
LITHUANIA (2011)	• **STAGE 1**: e-census for 16 days, where residents were afforded an opportunity to enumerate themselves electronically. • **STAGE 2**: a population survey – interview, where those who had not participated in the e-Census were visited by interviewers. Stage took place about three weeks after Stage 1 and lasted about one month.
SPAIN (2011)	Census Day was November 1st. Census is mostly based on the information available in the Municipal Registers and other registers. The population census (long form) collects the information from a sample of approximately 12 per cent of the population.

	• **PHASE 1**: mid-September: sending of letters to dwellings selected in the sample. Thereafter, people may respond to the census questionnaire online. • **PHASE 2**: October: mailing of paper questionnaires to non-responding dwellings • **PHASE 3:** October – November: sending of reminder letters to non-responding dwellings • **PHASE 4:** November/December: field enumerators conduct the Building Census (all dwellings). • **PHASE 5**: January/March: field enumerators complete collection of population census information (sample).
UNITED KINGDOM (2011)	A fully traditional 100 per cent field enumeration, self-completion Census, with Census Day being 27 March. • **PHASE 1**: Mail-out of paper questionnaire packs 7-19 March to ensure delivery one week before Census Day. Questionnaire included Internet access code for those respondents wishing to use online option. • **PHASE 2**: Mail-back of completed paper questionnaires or online response 8 March – 5 April. Although Census Day was 27 March, questionnaires received before then were accepted to allow response for those who would be away from home on Census Day. Online response system was active during period 4 March-22 May. • **PHASE 3:** Initial follow-up of non-response 6-16 April, carried out through doorstep visits by enumerators, targeting poorly performing areas where the return rate was below the expected level. Duplicate paper questionnaires were delivered if necessary. • **PHASE 4** Further follow-up was carried out 20 April-6 May during which all non-responding household were visited at least once. • **PHASE 5:** Independent interview-based post-enumeration Census Coverage Survey (1 per cent sample of all households) carried out 6 May - 2 June.

Box E.1 - Statistics Canada's Wave methodology – A decade of experience

The Canadian Census is held every five years. The 2006 Census was the first Canadian census to offer the Internet option to almost all Canadians. A secure access code (SAC) was provided on each paper questionnaire delivered, and 18.3 per cent of households completed their census online. During the 2006 Census, a study was carried out to test sending a letter with a SAC rather than a questionnaire. Such a letter increased the use of the Internet but showed a potential for increasing the amount of non-response. In order to both encourage response by Internet while mitigating the risk of a decreased overall response, a new collection methodology was introduced: the Wave Methodology. In preparation for the 2011 Census, various combinations of modes of contacts were tested. The main conclusions were: i) an Internet promotion letter generates less self-response than a questionnaire, but when combined with appropriate reminders, the effect becomes the opposite, ii) areas in the country with lower propensity of responding by internet should still receive a paper questionnaire at Wave 1. Based on the conclusions of the tests, the following strategy was developed for the 2011 Census:

Group 1: Dwellings with higher propensity for Internet response – 75 per cent of the dwellings	**Group 2: Dwellings with lower propensity for Internet response – 25 per cent of the dwellings**
Wave 1: Invitation letter	Wave 1: Questionnaire package
Wave 2: Reminder letter	Wave 2: Reminder letter
Wave 3: Questionnaire package	Wave 3: Automated phone messages

The strategy yielded to the following results for percent response by channel:

Collection Method	**Mail**	**Internet**	**NRFU**	**Non-response**	**Total**
Group 1 – letter	16.1%	71.6%	9.8%	2.3%	100%
Group 2 – questionnaire	50.1%	25.8%	20.8%	3.4%	100%

During the 2011 Census collection, a Live Test that was conducted. The test consisted of switching the collection methodology for some areas. Some Group 1 areas that were supposed to receive the letter at Wave 1 received the questionnaire (identified as G1 – questionnaire below) and vice versa: some Group 2 areas received the letter instead (identified as G2 – letter below). This test between comparable panels showed that: i) sending a letter at Wave 1 increased the internet response rate, ii) scenario "Wave 1 letter, Wave 2 reminder letter, Wave 3 questionnaire" lead to a smaller field NRFU workload than scenario "Wave 1 questionnaire, Wave 2 reminder letter, Wave 3 telephone voice broadcast message".

Collection Method	**Mail**	**Internet**	**NRFU**	**Non-response**	**Total**
G1 – letter	16.3%	71.6%	9.8%	2.3%	100.0%
G1 – questionnaire	53.3%	32.3%	12.1%	2.4%	100.0%
G2 – letter	23.4%	57.3%	16.4%	3.0%	100.0%
G2 – questionnaire	50.0%	25.5%	21.1%	3.4%	100.0%

Based on these results obtained in 2011, all mail-out areas (about 82 per cent of the dwellings) received the Group 1 treatment for the 2016 Census, leading to the results below (for comparison purposes, the table also shows the results in List/Leave areas, where questionnaires were delivered by census enumerators):

Collection Method	**Mail**	**Internet**	**NRFU**	**Non-response**	**Total**
Group 1 – letter (Mail-out)	12.7%	76.2%	9.4%	1.6%	100%
List/Leave	64.1%	23.6%	11.1%	1.2%	100%

4.4 The communication strategy

D.115. A communication strategy is key for maximizing the overall response rate regardless of the mode of data collection, but should give particular focus on the online response option, particularly where this is being adopted for the first time. Such a strategy should include the material sent or distributed to the household as well as the aligned publicity campaign and should aim to cover the entire population.

D.116. A key aspect of a communication strategy aiming at generating self-response is to encourage and motivate households to respond to the census, and not just simply to inform them that the census is coming. To this purpose, respondents must be reminded of the importance and relevance of the census (with simple case study examples) and they must be informed that responding to the census is quick, easy, and secure, in particular when responding online. It is also useful to remind households that their obligation to participate in the census is mandatory (if applicable) and that penalties can be imposed for non-compliance - though the degree of emphasis given to this somewhat negative aspect of publicity will be a matter for the particular statistical agency to decide.

D.117. Some of the common prejudices that should be addressed by the communication strategy are: that there is no hurry to complete the census; that completing the census questionnaire will take a lot of time; that the census is not relevant for particular sub-groups of the population; that the census is an infringement of a person's human rights; or that the personal information supplied by respondents will be accessible to others. Both the increasing diversity of national populations and the societal apathy towards officialdom in general, make these messages increasingly difficult particularly for some key population groups such as ethnic minorities, migrants and young adults, who are the very groups for which census information is critical.

D.118. The communication strategy should thus be designed as a social marketing campaign, with the emphasis placed on research, segmentation, targeting, and positioning. Statistical analyses should guide the design, the implementation, and the monitoring of communications activities. The strategy should be tailored to specific populations to encourage early participation in the census and should include targeting hard-to-reach audiences, for whom the difficulties may arise from social, linguistic or geographic circumstances. Particular targeting (especially though social media channels) of those population sub-groups who would be expected to be more computer literate will help to encourage a greater use of the Internet as the response mode. It is important to understand which areas are more or less predisposed to self-respond or to respond at all, and which key socio-demographic characteristics have to be considered in the execution of communication activities.

D.119. The timing of the contacts, the evolution in the tone of communicated messages from one phase of the enumeration to the next, and the look and feel of the material are all important elements that need to be considered carefully. Given the large volumes of printed materials and the messages in various media, it is worth investing human and financial resources in order to determine the optimal communication strategy, keeping in mind that small changes may have a significant impact on respondent behaviour. Even a small impact on a small proportion of respondents may still represent significant savings, given the size of the population. In this context, a multi-step testing strategy should be put in place and various options should be compared.

(ix) *Invitation and reminder letters*

D.120. Special attention should be paid to determine the content and the look of letters delivered to households, for both the initial invitations and follow-up reminders. The letter should include:

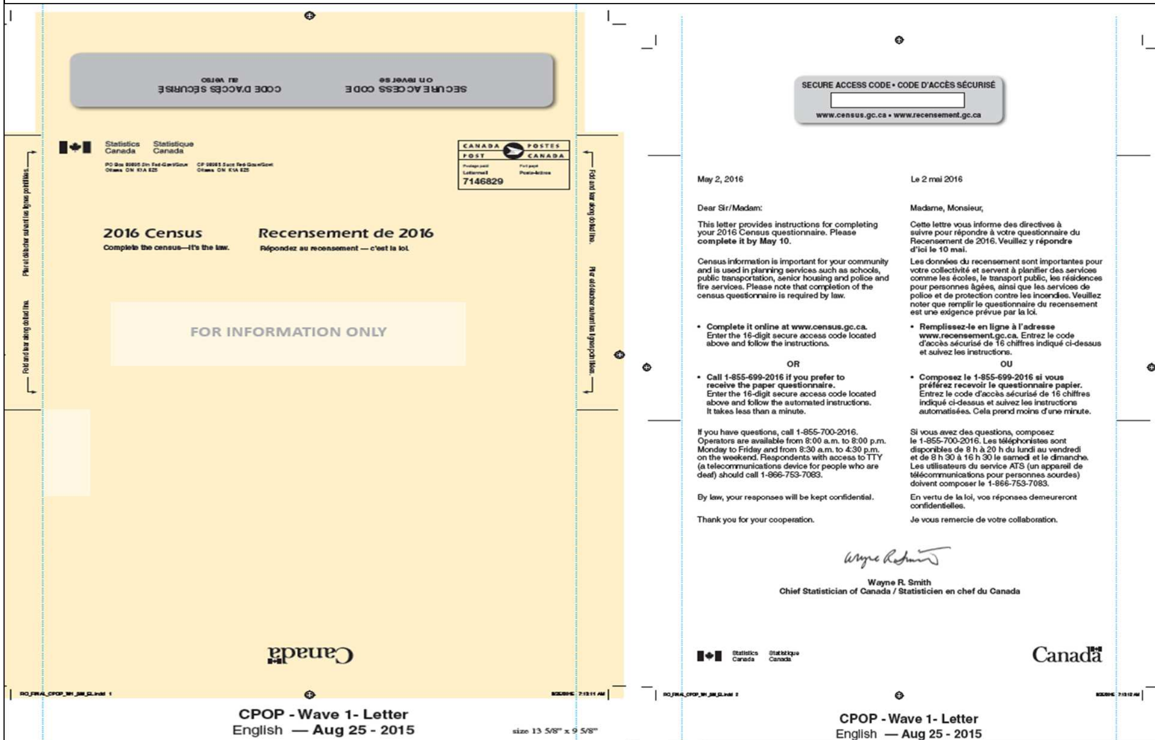
- A short introduction informing respondents about the census – what it is, why the information is collected, and why it is important. This portion should be short and it should use examples that will be relevant for a variety of respondents. The examples could be related to services planned with census information, such as health care, schools, employment etc.

- There should be some emphasis on the instructions on how to access the online questionnaire (for example, by using the access code printed on the letter, or the paper questionnaire itself) and, if applicable, instructions on how to use alternatives response modes (for example, how to request a paper questionnaire). The instructions on how to access the online questionnaire must be clearly visible and easy to understand, and must give the impression that completing the questionnaire online is quick, easy, and secure. Above everything else, this is probably the first thing respondents should see. They have to realize quickly that the process is quick and easy, and that they should act promptly and not put the letter aside.
- Instructions on how to obtain help, for example, a website address, a help-line number, or if applicable, a teletypewriter (TTY) number etc.
- The deadline for responding. The deadline can be a specific date or a specific period (for example, respond within the next 10 days). It is important to understand the impact of using the date as a deadline versus a period. For instance, a specific date will likely create a peak of responses around the deadline and particularly on that specific day. For a *de facto* census (in which people are enumerated where they are present on Census night) this may be desirable; however, if there is a risk that the systems infrastructure will not be able to accommodate a high number of concurrent users, a period would be more appropriate. A period deadline rather than a date deadline may also be a better option for situations where the letters are received by the respondents (either mailed or delivered by census enumerators) over a longer period of time. The strategy may differ for the initial invitation letter and for the reminders. For example, it may be better not to put emphasis on any deadlines in the reminder letters, since their key message is "do it now!"
- Assurances about the security and confidentiality of the information provided. If completing the census is a statutory requirement, a note indicating the mandatory nature of the census, at least in the reminders (if applicable) should be included. Informing respondents that census enumerators will follow-up any non-responding households may also be a good way to persuade respondents to complete their census form, but can also give the impression that they can wait until the enumerator calls.
- Some households that have already responded will, inevitably, receive a reminder letter if, for example, they responded after the list of non-responder was extracted from the reminder list. Many such households may be irritated to receive such a reminder, and this is likely generate calls to the help-line. To reduce the volume of such calls, it is recommended that some acknowledge this possibility should be given in the reminder letter by adding a note to thank those respondents who have already responded. However, this aspect should not be over-emphasised as it may otherwise detract from the key message of the reminder; nor should the note give the impression that the letter is a generic one sent to every household, and that the statistical agency does not actually know if the household has responded or not.

D.121. The manner in which information is expressed in the invitation and reminder letters should, therefore, be carefully thought out. Any census logo and/or brand should be prominent, and bold font might be used to highlight key information but should not be over-used. Spacing between sections and paragraphs is also important, as is the location of the access code for the online questionnaire in order to make it prominent. Key instructions should be clearly standout from the regular text. Colour may be used, but printing will be more expensive.

D.122. Example of the letters sent out in the several waves of Canada's 2016 Census field operation are shown at Box E.2.

Box E.2 – 2016 Canadian Census of Population: Example of wave letter content and format: Format of a wave self-mailer



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2016 Census / Recensement de 2016

Complete the census—it's the law. / Répondez au recensement — c'est la loi.

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Canada

CPOP - Wave 1- Letter
English — Aug 25 - 2015

size 13 5/8" x 9 5/8"

SECURE ACCESS CODE • CODE D'ACCÈS SÉCURISÉ
www.census.gc.ca • www.recensement.gc.ca

May 2, 2016

Dear Sir/Madam:

This letter provides instructions for completing your 2016 Census questionnaire. Please **complete it by May 10.**

Census information is important for your community and is used in planning services such as schools, public transportation, senior housing and police and fire services. Please note that completion of the census questionnaire is required by law.

- **Complete it online at www.census.gc.ca.** Enter the 16-digit secure access code located above and follow the instructions.

OR

- **Call 1-855-699-2016 if you prefer to receive the paper questionnaire.** Enter the 16-digit secure access code located above and follow the automated instructions. It takes less than a minute.

If you have questions, call 1-855-700-2016. Operators are available from 8:00 a.m. to 8:00 p.m. Monday to Friday and from 8:30 a.m. to 4:30 p.m. on the weekend. Respondents with access to TTY (a telecommunications device for people who are deaf) should call 1-866-753-7083.

By law, your responses will be kept confidential.

Thank you for your cooperation.

Le 2 mai 2016

Madame, Monsieur,

Cette lettre vous informe des directives à suivre pour répondre à votre questionnaire du Recensement de 2016. **Veuillez y répondre d'ici le 10 mai.**

Les données du recensement sont importantes pour votre collectivité et servent à planifier des services comme les écoles, le transport public, les résidences pour personnes âgées, ainsi que les services de police et de protection contre les incendies. Veuillez noter que remplir le questionnaire du recensement est une exigence prévue par la loi.

- **Remplissez-le en ligne à l'adresse www.recensement.gc.ca.** Entrez le code d'accès sécurisé de 16 chiffres indiqué ci-dessus et suivez les instructions.

OU

- **Composez le 1-855-699-2016 si vous préférez recevoir le questionnaire papier.** Entrez le code d'accès sécurisé de 16 chiffres indiqué ci-dessus et suivez les instructions automatisées. Cela prend moins d'une minute.

Si vous avez des questions, composez le 1-855-700-2016. Les téléphonistes sont disponibles de 8 h à 20 h du lundi au vendredi et de 8 h 30 à 16 h 30 le samedi et le dimanche. Les utilisateurs du service ATS (un appareil de télécommunications pour personnes sourdes) doivent composer le 1-866-753-7083.

En vertu de la loi, vos réponses demeureront confidentielles.

Je vous remercie de votre collaboration.

Wayne R. Smith
Chief Statistician of Canada / Statisticien en chef du Canada

Statistics Canada / Statistique Canada

Canada

CPOP - Wave 1- Letter
English — Aug 25 - 2015

Content of Wave 1, Wave 2 and Wave 3 letters

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Thank you for your cooperation.

(x) *Envelopes*

D.123. The first thing to determine is the format of the package. The use of a regular letter inserted in a regular envelope is the most commonly used format, but using a *self-mailer* is also an alternative. A self-mailer is a one-piece document, folded, perforated, and glued on the sides; respondents would tear along the dotted lines to open the letter and see its content. Aside from being environmentally friendly, self-mailers eliminate the insertion step and may also appear more official to the public not used to receiving such type of mail.

D.124. A decision should be made between adopting a more modern and dynamic look or a more neutral and official look. A more dynamic look can help promote a positive and modern image for the statistical agency especially when aligned with the other publicity elements, but such type of mail may also be confused with junk mail. As with the letter itself, the use of a census logo or brand will help to clarify to the recipient the source and purposes of the mail.

D.125. The messaging on the envelope is also important. Key short sentences may be added to highlight the importance of the census, its mandatory nature, or the urgency to respond. Appropriate wording should be carefully chosen and tested. For example, the use of *Final Notice* instead of *Second Reminder* on the last reminder could have a more powerful impact, but it can also be perceived adversely and induce a negative reaction.

(xi) *Paper questionnaires*

D.126. While the inclusion of a letter in the initial questionnaires packages is optional, the inclusion of a letter in questionnaire packages that are sent as reminders is desirable. The elements discussed in the previous sections regarding the content and the look of letters and envelopes also apply to the letter and the envelope of a questionnaire package.

D.127. The instructions for offering the Internet option should be clearly visible, both on the paper questionnaire itself and on the letter included in the package (if applicable). Such an option as presented on both letter and questionnaire should be perceived as a more convenient way to respond. When sent as a reminder, it should not be assumed that the non-respondents had delayed responding because they were waiting for the paper questionnaire and would thus not wish to respond online. On receipt of the paper questionnaire the non-respondent might considered it to be a more daunting way to make the census return and might then prefer to respond online. Thus, as suggested above, even the questionnaires sent to those respondents who have specifically requested a paper questionnaire should prominently show the Internet access code.

D.128. Also, an instruction for those who decide to respond online to disregard the paper questionnaire could be included (that is, not to complete or return it if they respond by Internet), to avoid confusion on part of respondents as well as multiple responses (even empty questionnaires) from the same dwelling.

(xii) *Postcards*

D.129. Postcards are cheaper and easier to produce, but space available on them is limited and they cannot contain confidential information, such as an access code to an online questionnaire. However, postcards can be used as an economic way of sending generic reminders or as notice of visit cards left by census interviewers during field enumeration. In this context, the card should remind non-responding households about the different options to self-respond, placing more emphasis on the Internet option.

(xiii) *Automated phone calls or text messages*

D.130. As a reminder, automated phone or text messages can be sent to non-respondents, if phone numbers are available and can be linked to the non-responding dwellings. Experience has shown, however, that the impact is usually limited. But given the operation is inexpensive, it may be worth it. The messages can be generic by referring to the material already received by the non-respondents to complete their census online, or if the technology and legislation allow it, can be personalized by including a link or an identification number that the non-respondents can use to go online more easily.

(xiv) *Emails*

D.131. Sending emails is not a common practice among statistical agencies, but the availability of email registers is increasing, making this mode of contact more appealing. A challenge is to be able to link the email address to the appropriate dwelling and to avoid duplication. As with postcards, however, it may not be appropriate to transmit online questionnaires access codes though this medium.

D.132. While email may be seen as a convenient means of contacting respondents, email messages may often be removed from the recipient's inbox by junk mail filters or deleted by respondents who may perceive them as junk mail. Also, respondents may read the email at a time when they are not immediately able to access or complete their census questionnaire, and they may subsequently forget to do so when they are able to. However, email contact may encourage increase a proportion respondents to complete their census return by using their smartphone (if such an option is available), but, as discussed earlier, it should be realised that smartphones are not a particularly suitable vehicle for filling out long census questionnaires, and this may affect the quality of the collected data.

(xv) *Other forms of electronic initial contacts and pre-registration*

D.133. With a constantly increasing proportion of the population in some countries relying solely on the Internet for conducting their social and personal activities, reducing the reliance on paper material and postal service delivery has to be considered and investigated. A few countries have undertaken some initiatives, for example, by considering or developing a pre-registration process, in which respondents are invited to register their address in order to be contacted electronically to receive instructions and their access code to complete their questionnaire online. Such a process has been tested on a few occasions, with limited success. However, in a transition period where a traditional one-size fits all solution is becoming outdated for an increasing portion of the population, research and innovation on 'opt-in' or 'notify me' strategies should not be aborted just because of an initial mitigated success.

D.134. Pre-registration options vary by country. If this is to be done electronically a list of emails is required as a basis, but in some countries other platforms exist. For example, the postal service may offer an electronic mailbox for managing bills and financial statements to their clients (for example, *E-Post* in Canada and Switzerland) or some governments offer online accounts for their interactions with their citizens (such as *My Gov* in Australia). Other alternatives have also been tried, such as the use of Quadratic Residue (QR) codes or Augmented Reality (AR) applications. One of the main challenge in using alternate or external platforms, systems or applications is to be able to link the users to their address. Confidentiality or security concerns may also arise. As noted above, invitations to pre-register can, alternatively, be sent out by mail. Paper questionnaires would then only be sent out to those households wishing to respond in that way, thus reducing the distribution costs while, at the same time, providing some further indication of the likely online response rates.

(xvi) *Online questionnaire design*

D.135. The ultimate goal of providing and encouraging the Internet option is to make to self□response that much easier and convenient that respondents would choose this option over any other response mode. The Internet form design plays a key role in ensuring a positive experience for users. The overall

experience of responding electronically includes factors such as usability, convenience, speed, and the general 'look and feel' of the website. To meet this broad range of expectations, respondents should be offered the option of completing their census questionnaire online using different types of devices, including mobile ones. This provides a higher level of convenience and ensures the broadest access possible to those without a traditional in-home internet service.

D.136. Whatever the device being used for accessing an online census, screens must be easy to read, and the questionnaires easy to understand and complete and the journey through it intuitive; this means, for example, having a reasonable number of options included in drop-down menus, checking that questions are as short as possible so that they can fit onto one screen yet still be comprehensible, and using response options (buttons, check-boxes) that are easy to select and cancel.

D.137. There are several additional aspects to consider. For example, people using online forms will expect that a certain amount of guidance will be offered and that they will be sequenced through the form in such a way so that questions that are not relevant (such as questions on employment for persons aged under 15) are filtered out. Moreover, there should provide some means of letting respondents know that they are not answering questions as required.

D.138. Also, language needs should be addressed. The statistical agency must determine the benefit of offering Internet questionnaire in the more commonly used languages in the country (including not only official and other indigenous languages but also and those of the main immigrant communities).

D.139. Such aspects of online questionnaire design are clearly going to be more challenging in the context of mobile devices with smaller screens, but, nevertheless, they must still be considered so as to minimise the mode effects discussed earlier. Such effects can also be reduced if the online text (both the wording of the questions and the self-help instructions) is the same as that on the paper questionnaire. In addition, the completed responses must be processed quickly to eliminate wait time between screens and eliminate respondents from abandoning their online questionnaires before submitting them.

D.140. The online questionnaire is discussed further in the section *Development of data collection application and portal*.

5. Identification and authentication of respondents

D.141. The statistical agency has to decide whether or not to administer Internet self□response by issuing households with unique identifiers to access their census questionnaires. The benefits of issuing such identifiers include a better identification of the responding households (by providing a stronger link between the household and the address of the dwelling), an ability to deliver different census forms to different households (if applicable), a reduced risk of impersonation, and a reduced risk of duplicate/multiple online responses. Another important advantage of using unique identifiers is to better ensure the *actual* security and confidentiality of the information supplied, and (just as important) the *perception* of greater security and confidentiality on part of respondents which will encourage self-response.

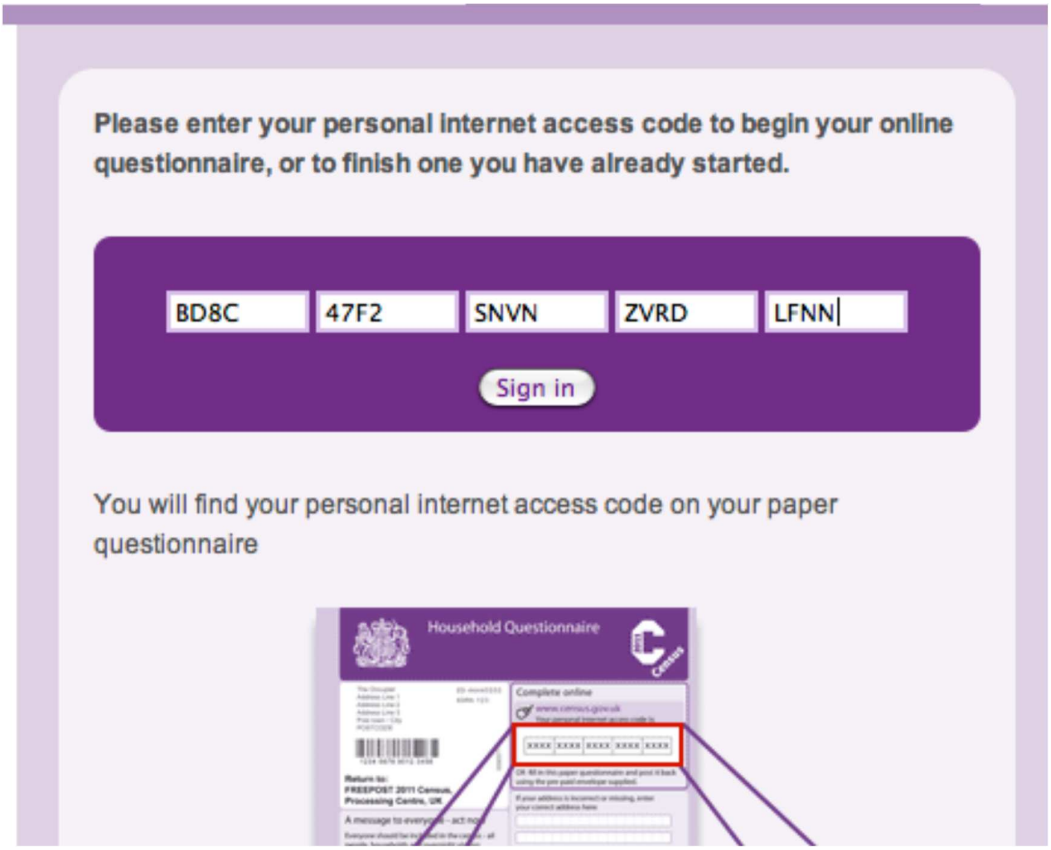
D.142. The challenges of using unique identifiers include the availability of a confidential method of delivering the identifiers to the household (postcards, as discussed earlier, are not advisable for this purpose), the proper linking of identifiers to households, and the increased risk of non-response should the household mislay the identifier or not have it readily available. The pros and the cons of using unique identifiers should be considered with these points in mind.

D.143. Access to individual applications should require a login and password, along with adequate access settings. The login should be a unique sequence of characters assigned to individual households; these might be based on data derived from administrative sources such as address registers or other

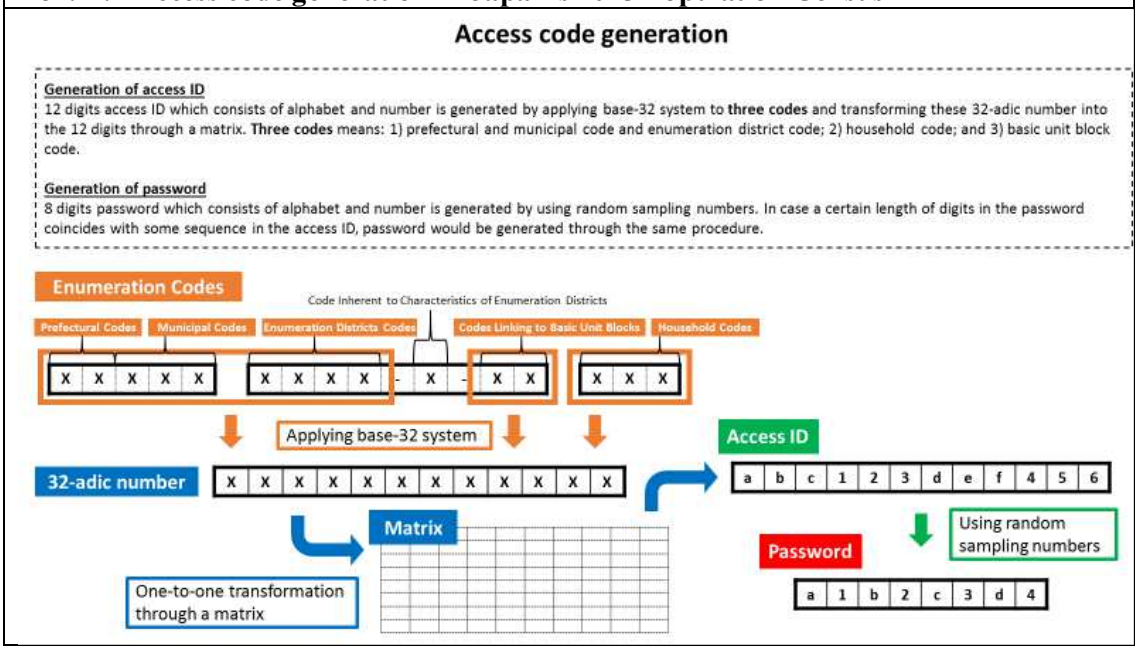
registers such as national or personal identification numbers (PINs), names, internet bank ID, e-signature or other additional information (such as place of birth, mother's maiden name) that can authenticate the respondent's identity. Secure access codes can also be created and linked to the household when the frame is created or via another process if generic access codes are pre-printed on census material beforehand. The codes must be unique and impossible to duplicate fraudulently. Ideally, they should be randomly generated, although some combination of alpha characters may need to be removed from the code to avoid printing offensive words. The number of alphanumeric characters should be high enough to ensure that when inputting random codes (either by mistake or intentionally), the chance of entering a valid code should be small enough that a genuine mistake in entering a valid code should not lead to another valid code.

D.144. On the other hand, the codes should not be so complicated that they create confusion and frustration for the respondents when trying to enter them. Grouping characters (for example, having 4 groups of 4 digits each, separated by a space or a dash, instead of a series of 16 digits with no spacing) will make it easier for respondents to avoid errors. It may also be desirable to avoid repeating the same character several times in a row, or using characters that can create confusion (for example 1 vs I or 0 vs O (if both alpha and numeric characters are used) unless they are clearly distinguishable. Codes should therefore not comprise fewer than 8 (which would compromise confidentiality) nor more 20 characters (which might discourage response). With 20 characters the change of a third party guessing a valid code is 1:69 trillion). An example (from the 2011 Census household paper questionnaire in England and Wales) is shown below.

Box E.3 Example from Canada



Box. E.4 Access code generation in Japan's 2015 Population Census



D.145. The agency may choose to allow respondents to log in without secure access codes. Such non-ID processing can be the only way to access the questionnaire, or can be a simpler option, for respondents who cannot retrieve, or prefer not to use, the access code they have received. In this case, address searching and matching and GIS tools must be available, and respondents must be able to identify their own address from a list, or at least be able to provide their address if it is not included on the list. It must then be decided what to do with any unlinked addresses. Field staff can perhaps validate and link such the addresses, or the agency may decide that respondents cannot complete online questionnaires if the address is not found. Non-ID processing is more prone to fraud so if this adopted, it may be a good idea to re-contact a sample of households for quality control purposes. A strategy should also be in place to prevent a larger scale fraud.

D.146. Alternative (or additional) measures to protect the identification form against unauthorized attempts to automated authentication, such as CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) technology can also be applied. Widely used in online transactions more generally, CAPTCHA is a safety tool enabling the transmission of data. As part of the online account set-up procedure, an image should be used, the content of which must be read by the respondent and entered in the indicated window. The respondent should normally be allowed to attempt as many as three times (or another (but more than once) at authenticating and setting up the account. If all such attempts end in failure, the system should provide an additional functionality enabling user verification or assisting the respondent via the dedicated census helpline. In the event that such assistance is required the helpline operating system the purposes should send to a report to IT system designed for self-enumeration with a request to provide support in the respondent's identity verification process. To use this function, the respondent should be obliged to provide the helpline with contact number with the aim of resolving the difficulty.

D.147. Some countries may wish to make available a demonstration version of the online census form prior to the census enumeration period in order to enable potential respondents to familiarise themselves both with the authentication method and the content of the census questionnaire. Knowing how easy (or difficult) it is for them to complete and what information it requires, will enable respondents to plan more easily the time required to complete the questionnaire and may better encourage a response online.

D.148. The period during which the password required to log in to the census form should remain valid for a clearly specified time. This will be particularly helpful both for those questionnaires that contain a large number of questions and which will require correspondingly more time to complete, and in the event that the respondent may have to discontinue the completion process and return to it at a later date. To facilitate this latter situation the Internet system should provide for a 'save and come back later' function for respondents (particularly those in large households) who are unable to complete the questionnaire in one session (see below for more details).

D.149. To accommodate those households who, having started to make an Internet response, decide to abandon this methods in favour of completing a paper questionnaire, a function should be available to enable them to do so. There should, however, be safeguards to prevent duplicate returns relating to the same person - using both the online or paper questionnaires - from being made, while providing for specified household members to make an individual return via a different medium from the rest of the household.

6. Development of data collection application and portal

D.150. As noted earlier, the overall experience of responding electronically (in terms of usability, convenience, speed, and the general 'look and feel' of the website) should be positive. Accessing and completing the online questionnaire must be easy and convenient for the respondents. The Internet form design plays a key role in ensuring a positive experience for users. Respondents should also be offered the option of completing their census questionnaire online using different types of devices, including mobile ones. The screens of online questionnaires must be easy to read and understand, and to complete, no matter what devise is used – although, as noted above some devices such as smartphones may have a limited capacity to display census questionnaire screens effectively.

D.151. Successful conduct of a cost□effective large-scale Internet-based self□response enumeration requires developing, testing and refining business rules, requirements, and assumptions for the data collection operation. Questionnaire design should go through several phases of stakeholder involvement including subject matter, user experience (UX) specialists and survey questionnaire design specialists. All systems developed to support Internet self□response must have the capacity to handle the anticipated response loads. Another issue that needs to be considered is security of information transferred through the Internet, and which is covered in the next section.

D.152. As has been previously noted, there is a cost related to the need of having highly-specialised staff to develop and put in place the system infrastructure. Depending on the resources available and the expertise of the statistical agency, it may be less expensive, and less risky, to contract-out/outsource some or all components rather than acquiring new staff or investing in training (see United Nations, 2015). A transition towards Internet data collection can also be a good opportunity to develop corporate solutions that will benefit not only the census but also other statistical programmes within the agency. Such solutions include common Internet applications, for example systems that generate questionnaires in a repeatable fashion, allowing the same layout, navigation and validation features within all online questionnaires produced by the agency. Other common solutions include collection management systems, management information reports, as well as shared financial services.

6.1 Design of the online questionnaire

D.153. Accessibility and usability should be driving factors in the development of the online questionnaire systems, and particularly its design. Questionnaires should be fully accessible and adhere to recognized and accepted guidelines, such as the Web Content Accessibility guidelines (WCAG, developed by the World Wide Web Consortium). Website accessibility for persons with disabilities

should also be a priority. This includes physical disabilities such as visual or hearing impairments, other cognitive limitations or functional limitation due to age, for example.

D.154. The specific design of any questionnaire is the result of a collaboration between subject matter and questionnaire design specialists. They should work together to determine how the overall questionnaire should flow and in what order to introduce concepts to the respondent. Designing the questionnaire includes deciding on the format (of the form itself and the questions), the use of skip patterns or additional routing questions, validation messages, and other functionalities of the application.

D.155. The general design of the questionnaires should be the result of a careful process of classifying the various elements so each one could be given an appropriate visual weight. For example, question numbers could be shown in a muted but larger font, allowing the user to quickly scan the page for the next question or instruction. Wherever possible, the wording of questions and response options (if not the layout) should be consistent with those on the paper questionnaire so as to avoid, or at least minimise, mode effect bias resulting from online and paper respondents thinking about, and responding to, questions differently. However, it is inevitable that some instructions on how to complete questions will differ between the two modes. For example, it is clearly more sensible to ask respondents to 'enter' rather than 'write' in a response when using the online questionnaire.

D.156. The routing through the Internet questionnaire should be intuitive to make the online experience as painless as possible. If not, there is a risk that respondents will abandon partly completed questionnaires, and that their commitment to engaging with the census – whether online or on paper – would be adversely affected. Respondents need to be able to:

- move easily to the next question, and to review previous answers;
- see, at a glance, how far through the questionnaire they have progressed;
- stop, and resume, at any time;
- be told if their response was not as expected, and be told what was expected; and
- be routed past questions that were not relevant.

6.1.1. Census portal and login screen

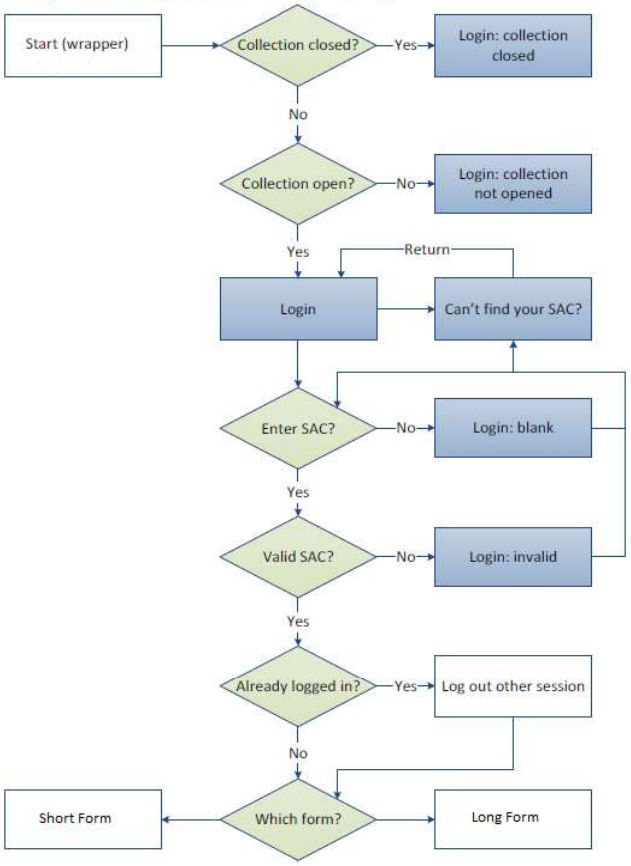
D.157. Aside from the census questions themselves, the design of the online questionnaire must include the design of other functionalities for an optimal experience from the respondent's point of view. The 'portal' refers to the online questionnaire itself, plus these additional functionalities. A good example of these added functionalities would be a banner at the top of the page that could include links to the FAQs, an 'About the Census' section or a 'contact us' option. When the respondent is logged in, a logout option should also be available.

D.158. When accessing the census website, respondents must be provided with simple instructions and a list of systems minimum requirements to be able to complete the questionnaire. This introduction page (sometimes called the wrapper) can also include a reminder about the confidentiality of the information provided, and related aspects such as informing the respondents about the automatic timeout after a certain period of inactivity.

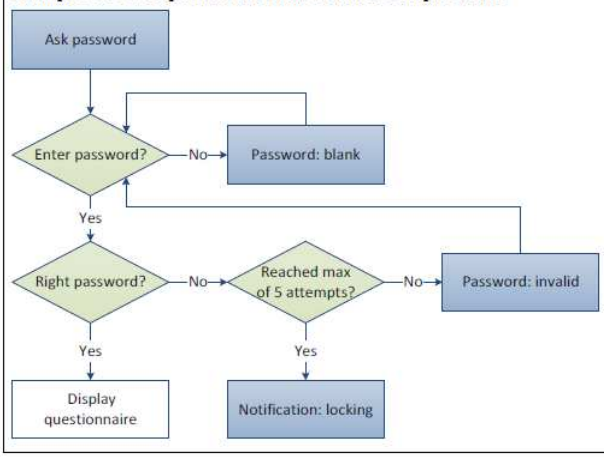
D.159. The login screen should be simple, and logging in should be straightforward. If secure access codes are used, it is possible to include an image of either the invitation letter or the paper questionnaire to clearly indicate where to find the access code. The page could also include a 'Can't find your secure access code?' link.

D.160. Examples of flow chart describing the online questionnaire login and logout processes (with or without the 'stop and save' options and the use of passwords) are presented in the next pages.

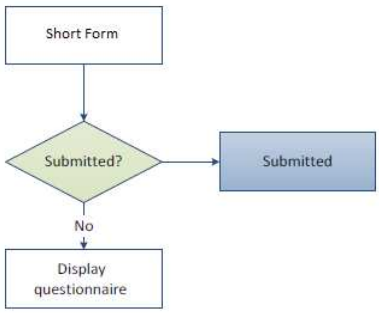
Example 1: Online questionnaire flow chart: Login



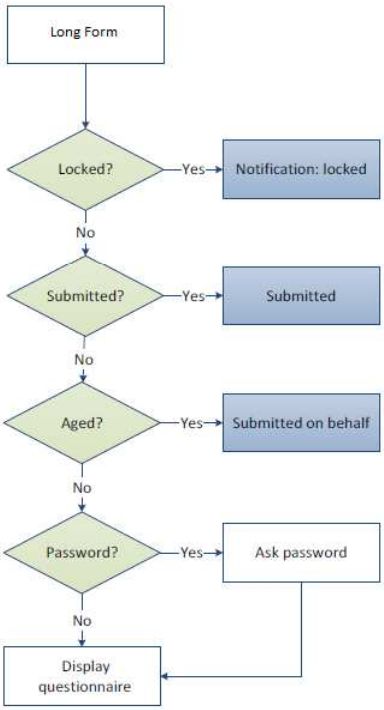
Example 2: Online questionnaire flow chart: Use of passwords



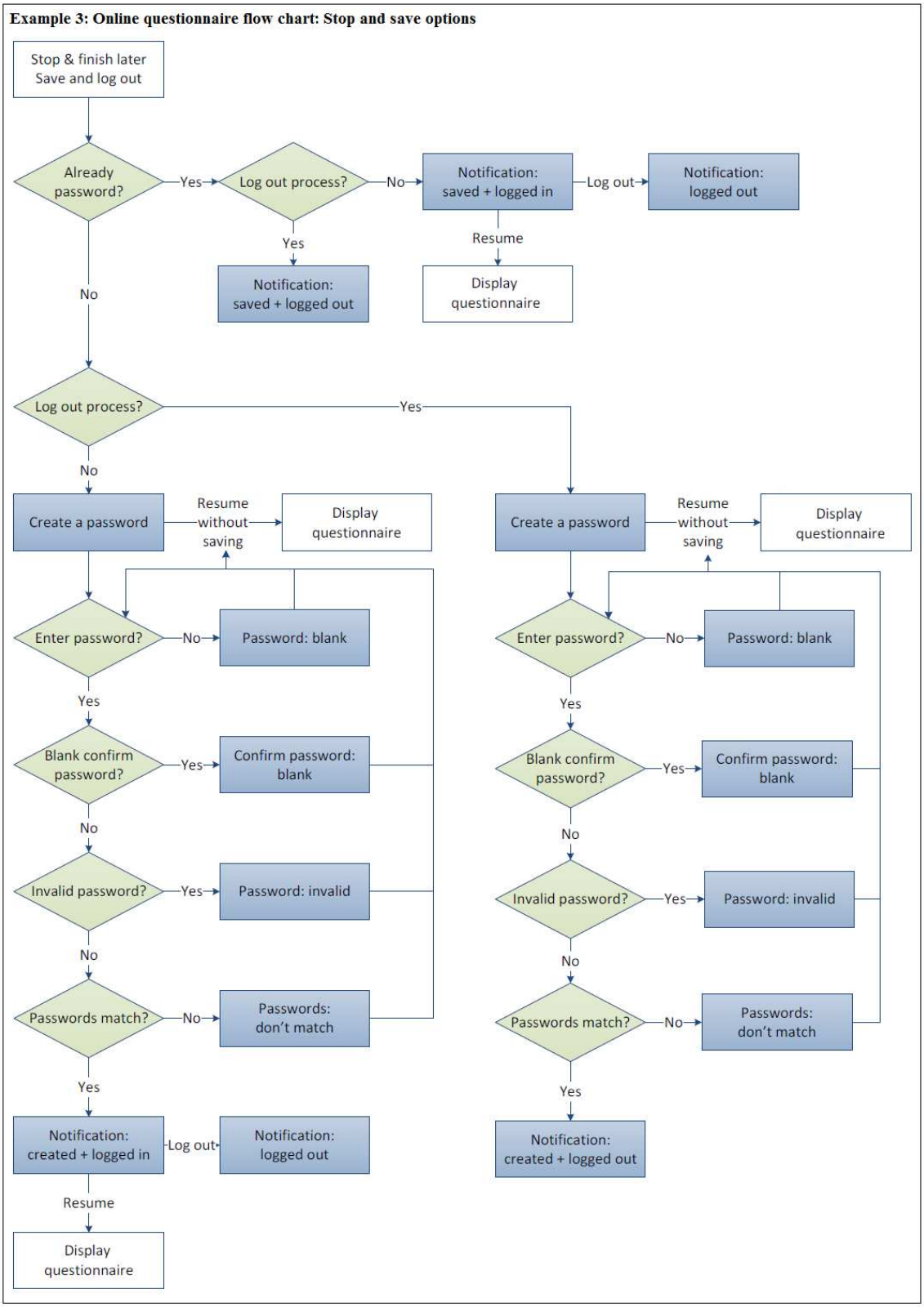
Example 1a: Online questionnaire flow chart: Login (Cont., no save option)



Example 1b: Online questionnaire flow chart: Login (Cont., save option)



Example 3: Online questionnaire flow chart: Stop and save options



6.1.2. Format of the online questionnaire

D.161. Online questionnaires are usually presented screen by screen, each of them displaying either a single question or group of related questions that can be seen, answered and saved without scrolling. Two options are possible: the matrix format and the sequential format. The most appropriate format depends mainly on the type of questions, and the two formats can be used in the same questionnaire.

- *Matrix format*: With the matrix format, each question appears only once, and response options are repeated under the name of each person in the household. Usability tests have demonstrated that this format reduces the response burden, since respondents have to read each question only once and can then respond for all members of the household. Another advantage of the matrix approach is that it reduces the number of screens and, as a result, minimises the requirements with regard to system infrastructure. This approach is the most commonly adopted. It is most appropriate for sections of the questionnaire that contain questions that are not dependant on the responses to previous questions.
- *Sequential format*: With the sequential format, all questions are asked about one person at a time. As a result, questions are repeated as many times as there are persons in the household. The sequential format supports increased customization of questionnaires. For one, it allows a respondent's name to be directly incorporated into each question. This option is preferable for more complex sections where there is a stronger dependency between questions and where answering for every household member all at once would confuse the respondent. Good examples are those questions on labour market activities and income questions. Usability tests have indicated that it is easier for respondents to focus on one person at a time in responding to these particular questions. Also, the sequential format is more appropriate in sections of the questionnaires that contain more automated skips, and/or when individual household members wish to respond to their own questions.

6.1.3. Automated skip patterns

D.162. Automated skip patterns allow respondents to bypass any irrelevant questions. In addition to improving quality, automated skips result in a general perception among respondents that the online questionnaire is 'intelligent (as well as being shorter than it actually is)'. This responds in part to the high expectations that the general public has with regard to online questionnaires. However, an overly complex online questionnaire with many skips will require additional testing and may introduce other problems or risks further down the road.

D.163. Where questions are numbered, skipping to a question that is not sequentially the next in line may cause confusion among the respondents. To avoid this, whenever routing is adopted an explanation should appear at the top of the relevant screen. Thus, for example, in skipping Question 10 on term-time address the instruction to Question 11, for example, might say "You have been automatically directed from Question 9 as you are not a student".

D.164. Residency and occupancy status of the dwelling are among the aspects that can benefit the most from online questionnaires. The concepts and definitions related to residency and occupancy status are complex, and online questionnaires allow for additional filtering of screening questions, as well as better help tools.

6.2 Residency status

D.165. Instructions on whom to include on a census questionnaire (depending on whether the census is a *de facto* or *de jure* count) can be provided on paper questionnaires, but space is limited. With an online questionnaire, however, additional questions can be asked in order to assist the respondent in determining which individuals should be enumerated at the dwelling. Typical examples are temporary or foreign residents, residents temporarily away on Census Day, persons with more than one residence,

roommates, students attending school elsewhere, child in joint custody, spouses temporarily away for work, persons who recently have moved out of the household or have died, newborns or persons who recently moved in, visitors, etc. In such cases, the respondent can enter the number of individuals of whom they are unsure, select the reason for the uncertainty in each case and then proceed to answer a series of questions to determine whether each individual should be included in the questionnaire or not. At the end of this process, a confirmation screen can indicate the list of individuals that should or should not be included in the questionnaire. An option for those individuals that the software application cannot determine whether they should be included or not is to omit them from the questionnaire and for field staff to contact the dwelling during non-response follow-up.

6.3 Occupancy status

D.166. Determining the occupancy status of a dwelling, or even if the address refers to a valid dwelling or not, is neither easy nor straightforward. Again, many situations can occur, and the differences are often very subtle. In traditional paper questionnaire-only censuses this sort of information was often recorded by the enumerator rather than by the householder. There is also a risk of false declaration by respondents who, for example, avoid having to provide personal information by declaring their dwelling to be unoccupied. In this context, it may be preferable to rely on the traditional approach and instruct the enumerator to determine if the dwelling is unoccupied or invalid. However, enumerators also make mistakes, and determining the true dwelling status as at Census Day becomes more and more difficult as collection progresses.

D.167. Thus, it may be a better option to take advantage of the online questionnaire, and present respondents with a list of options as to why no one lives at the dwelling or why the address does not relate to a valid dwelling. Reasons can include: secondary residences; houses for sale, under construction, or under major renovations; buildings being demolished, business, commercial or other non-residential premises; or simply that the dwelling does not exist. After selecting a reason, the respondent could also be asked to provide their name, address and telephone number for quality assurance purposes. If sufficient information is provided by the respondent, no further follow-up is conducted by field enumerators for that dwelling.

6.4 Online questionnaire standards

D.168. When developing the online questionnaire, the following Internet standards should be followed:

- Check boxes to indicate that multiple responses are possible, and circles (or radio buttons) to indicate that only one response is allowed (with hard edits that do not allow respondents to choose more than one answer).
- Drop-down menu format for selecting items form a list to reduce response burden. In general, drop-down menus work very well and respondents find them easy to use and data quality is good. But care is needed because once a selection is made in a drop-down menu, one must click outside of the menu (or use the tab key) to move the browser's focus away from the drop-down list. If the scroll wheel on the mouse is used while the drop-down menu is still 'selected' – for example in an attempt to scroll down to the next question after responding – the response will be changed, sometimes without the respondent noticing. The result in such situations is that for a small proportion of respondents, their answer will tend to be moved to responses lower – often the last – on the list. Edit and imputation strategies can, however, be put in place to detect and remedy this problem.

6.5 Validation messages

D.169. As has been referred to earlier, one of the main advantages of online questionnaires is the possibility of using validation edits to detect and correct missing information, errors or inconsistencies. Validation messages can be triggered for multiple reasons. Common ones include:

- Non-response: when respondents have not answered a valid question

- Partial response: when respondents provide only a partial response to a question, for example, if the city or postal code name omitted from an address.
- Invalid response, for example:
  - For numerical responses when respondents enter a number outside of the range established for a particular question (such as where the number of weeks unemployed in the year is greater than 52 or the number of cars owned by the household is greater than 20)
  - When an alphanumeric character is entered where a number was required, for example, if a non-numerical value is entered in a numerical or currency field (such as 1-2, abc, $1.20). A particular validation message can ask the respondent to remove periods, commas, spaces and special characters. If JavaScript is enabled, it is possible to simply prevent the user from entering non-numeric characters.
- Amount verification: for questions related to money amounts whenever the amount in a response appears unusual.
- Multiple response: when the respondent indicates contradictory responses for related questions. Note that an alternative to multiple response edits is to restrict possible answers from a drop-down menu to a subset of customized choices, based on the response(s) to previous question(s). However, this is only possible when JavaScript is not disabled on the respondent's device.
- Consistency verification: when more details are required such as where the respondent provides an insufficient response to question on occupation, language spoken or a country (of birth, of residence, etc.), certain entries can trigger a validation message asking the respondent to be more specific. For example, if the respondent enters 'Chinese' in the question asking for mother tongue, a validation message can appear asking the respondent to enter the specific dialect (such as Cantonese, Mandarin, etc.).

D.170. The error message can be triggered as soon as the respondent enters an invalid value, or when clicking the 'Next' button. In this case, the information on the current page is validated, and, if necessary, the application displays the same screen again noting any problems. There are several ways to inform the respondent of the error or inconsistency; for example, the question and field requiring attention can appear in red, or a red arrow can highlight the missing response, or a pop-up window can be displayed.

D.171. Decisions on the extent of response validation to be adopted should be guided by some key objectives: to achieve consistency in responses between online and paper questionnaires; to provide a degree of reassurance to the respondent that they are providing the required information; and the need to strike a balance between encouraging the respondent to complete every question and making the checks so stringent, that it increases response burden. This third point is particularly important, thus when implementing online edits in an application, the census agency has to keep in mind that complex edits can increase the burden on respondents to provide precise responses and therefore increase the time required to complete the questionnaire. The benefits in data quality obtained from complex edits need to be weighed against the increase in respondent burden to achieve an appropriate balance. For this reason, it is preferable to keep the online edits relatively simple. A partly-completed questionnaire is better than no questionnaire at all. The decision should also be based on the results of usability tests of the Internet application.

D.172. In general, complying with validation messages should not be mandatory, and respondents should be able to ignore them and continue completing their questionnaire, to avoid frustration and the risk of respondents dropping out. These are referred to as soft edits, and the missing or inconsistent information can be edited later by statistical validation processes. Also, although validation messages have a positive effect on item non-response, some Internet respondents feel that they absolutely must provide an answer in order to be able to continue when faced with validation messages. This may create undesired situations, such as false responses if respondents simply do not know, or do not want to provide, the answer to specific questions. In these cases, rather than leave it blank, respondents may provide an answer that is valid but incorrect. Such difficulties often stem from the respondent having to answer questions on behalf of some other household member.

D.173. For example, a study[28] showed that Internet respondents who initially left the day of birth blank, were more likely to enter the 1st of the month (in comparison to other dates) after seeing the non-response validation message. The same study showed that when prompted with a non-response validation message for a missing postal code of a previous address, many respondents who did not remember their previous postal code entered their current postal code instead of leaving this field blank. Another example, also from the same study is related to a question about the number of hours worked. For respondents who did not work, they were to select the checkbox 'None'. However, some respondents entered '0' in the hours worked field instead. A validation message appeared asking them to enter a number between 1 and 168. Many respondents therefore changed their answer to 1.

D.174. A corrective action should be mandatory only for critical questions, for examples questions that impact the rest of the questionnaire such as the number of residents, their names (a given name and/or a family name) and their age (completed age can be sufficient if the date of birth is unknown). In these cases of non-response or invalid responses, referred to as hard edits, a message should appear that prevents the respondent from continuing with subsequent questions or pages.

D.175. Additional validating *questions* can also be added in order to confirm the answers to key questions. This differs from validation *edits* because validating questions are asked to confirm every answer, not just the out-of-range or incorrect answers. For example, validating questions can be used to confirm age or income. Confirming the age (through asking both questions on date of birth and completed age at the time of the census) could be particularly important as the requirement to respond to some subsequent parts of the questionnaire (such as the questions on economic activity) will vary depending on the age. Confirming income (by, for example, asking about different sources of income) could also be desirable because the concept is usually complex, sometimes requiring multiple questions, and respondents can make mistakes. These confirmation screens provide respondents with the opportunity to verify their responses and make changes when required.

D.176. A further facility to make it easier for respondents to complete the questionnaire is to pre-populate particular fields where a response given to one question is also required later in the questionnaire. A typical example is the names of each household member given first in an initial listing.

6.6 Progress through, saving, and submitting, the questionnaire

D.177. When being routed through the Internet questionnaire, and particularly where there are a number skip options, it is helpful to respondents if their progress through the questionnaire can be monitored. For this purpose, a progress bar can be shown on each screen recording where the respondent has got to in the questionnaire. It should be updated as each question is visited, and completed responses indicated by a 'Done' message while those questions that are not relevant can be reported as 'Skipped'. The application should not permit the respondent to answer questions out of sequence and jump ahead; questions not yet visited can either be indicated as 'To do' or greyed out if not relevant.

D.178. It can also be convenient for respondents to have the option of saving the questionnaire they have started and returning to it at a later time to finish it. Such an option is particularly convenient for longer questionnaires especially if the respondents need to consult documents (such as birth certificates or tax files) or to refer to other household members, to answer some questions. For security reasons, respondents should be asked to set a password before being able to save their questionnaire. Upon return to finish their questionnaire, they can be prompted to enter their original access code and their password. Again, for security reasons, respondents should be given a limited number of attempts to enter their passwords correctly. If they are unsuccessful, the case should be blocked.

[28] The Internet: A New Collection Method for the Census. Proceedings of Statistics Canada's International Symposium, 2008, Catalogue no. 11-522-X, by Anne-Marie Côté, Danielle Laroche, Statistics Canada

D.179. Allowing respondents to save their questionnaires will, however, delay the questionnaire submission. Also, after having saved their questionnaire, some respondents may not return it. Thus, it may be preferable not to offer the save option, in particular if the questionnaire is short.

D.180. In the case where respondents do not come back, it must be determined what to do with the incomplete questionnaires. The information already saved but not yet submitted can nevertheless still be accessed by the census agency, on the basis (as noted above) that a partly-completed questionnaire is better than no questionnaire at all. Measures would need to be taken to ensure that such information is not duplicated on any subsequent paper questionnaire. Or another option is to leave the case open and send reminders or attempt non-response follow-up. In such cases, the respondent should be advised of this by informing them, for example, that "After <Date>, your questionnaire will be considered partially completed and automatically submitted on your behalf. You may be contacted to complete any unfinished questions through our follow-up programme".

D.181. Similarly, it is possible that the respondents will not save their questionnaire but will abandon it or be timed out. It must be decided if these responses should be deleted, or kept and processed, either right away if they meet certain minimum content criteria, or at the end of the enumeration if the respondent never comes back and cannot be contacted during non-response follow-up.

6.7 Should online questionnaires correspond to the paper version?

D.182. As has been noted earlier, if a multi-mode collection approach involving paper questionnaires is used, in order to minimize the mode effect (that is, differences in responses due to the method used) and to facilitate the integration of data received from different response channels, it is preferable that the online versions of the questionnaires corresponds as closely as possible to the paper versions in terms of question wording, instructions and presentation of response choices.

D.183. However, web questionnaires offer a wide range of opportunities to improve quality and this should not be discarded simply to mimic the paper version of questionnaire. In particular, if it expected that the Internet response will be greater than the response by paper, Internet should be considered the primary mode of contact and the online questionnaire should take advantage of all the possibilities offered by the available technology. Also, attempting to adhere to the conventions of the paper questionnaire while at the same time incorporating many web questionnaire standards and conforming to the guidelines for presentation of government web sites could be a challenge.

6.8 Mobile-friendly responsive design

D.184. Many countries follow standard guidelines on web usability to ensure all government websites are recognizable, easy to use and optimized for a wide variety of devices, including mobile devices. The layout of the web page should be designed for various screen size of the mobile device (from smartphones to tablets) and for different input methods, such as touch input or keyboard and mouse input. Statistical agencies using Internet collection should prepare for an increase of mobile users.

6.9 Capacity and other systems issues

D.185. One of the biggest challenges regarding Internet collection is related to the size of the infrastructure (such as servers, storage devices and communication vehicles) required to cope with the demand. The most important factors for determining the capacity and the cost of the infrastructure necessary for the online data collection are:

- the average number of pages a respondent will see
- the average time spent per page
- the number of simultaneous users at the busiest time (typically around Census Day)
- the total number of responses expected

D.186. The risk of not being able to handle the Internet demand is a very important issue for a census. Respondents who cannot access the system or who cannot navigate through the questionnaire at a reasonable speed might become frustrated and not respond at all. This has the potential of impacting data collection operations, specifically the non-response follow-up activities, but also the negative image it projects on the statistical organization more generally and on the census itself.

D.187. The statistical agency should undergo several rounds of stability and performance testing leading up to the census. Performance targets are particularly hard to establish when Internet collection is being implemented for the first time, but nevertheless, realistic targets should be determined and large-scale simulation of users should be conducted to ensure that the systems and the infrastructure will be able to handle the large volume of sustained access required in the census itself.

D.188. Aside from capacity, maintenance or technical problems will also affect the user's experience if they occur. A communication strategy must be developed and an escalation plan must be in place to report the problems and resolve them in a timely and efficient manner. In case these situations occur, resolving the problem will be accelerated and negative impact will be reduced if the communication strategy and responsibilities have already have been defined.

6.9.1. Communication strategy for high volume, maintenance and technical problems

D.189. In the event of a high volume of response at any one time, a graceful deferral page informing respondents of the situation should be presented to new users trying to log in. A high threshold point (when to activate the deferral page) and a low threshold point (when to remove the deferral page) should be determined in advance, and the values should be set in order to ensure that the respondents already logged in will not be affected and will be able to complete and submit their questionnaire, without a hitch.

D.190. The regular maintenance of the systems is the easiest situation to plan for, and respondents should be warned in advance. A permanent message can be in place if such maintenance always occurs at the same time, but to avoid unnecessary distraction - since most of the users will not be affected - it is preferable to activate a temporary warning messages only when the maintenance is about to occur (for example, 90 minutes beforehand) without necessarily preventing the respondents from logging in. Depending on the length of the questionnaire, new users should be blocked closer to the start of the maintenance (for example, 30 minutes beforehand). Respondents already logged in should be advised to submit (or save their questionnaire if applicable) before the maintenance.

D.191. Temporary or permanent technical problems are harder to predict, but as soon as any such problem occurs, a deferral page should inform the respondents that the application is temporarily (or permanently) unavailable and should invite them to come back at a later time. The appropriate mitigation and communication strategies should be applied, depending on the severity and the timing of the problem. For example, if the problem occurs close to the deadline to respond, a high volume of respondents may call the help line to be reassured that they will still be allowed to respond later.

7. Support for respondents

D.192. An important component of implementing electronic data collection is providing support to respondents completing online questionnaires. Support should be available for different types of issues such as: technical problems; requests for completing the online questionnaire in different formats (for example, with recorded text for visually impaired respondents); and the actual content of the census questionnaire – in case respondents have difficulties understanding what is being asked of them. Support can be provided in a number of ways such as help buttons, instructions, additional help materials available online (such as a set of pre-prepared Frequently Asked Questions), and a dedicated call centre set up to assist respondents with any issues they may have.

7.1 Online support

D.193. Online support should include instructions and contextual help materials for completing the online questionnaire, particularly for those census questions that are more likely to be perceived as difficult. Help buttons, relevant examples, guides, and Frequently Asked Questions (FAQs) and answers (easily accessible online) should explain the census questions and why they are being asked, as well as provide any additional information required to answer the question (such as reference period, to whom questions apply etc.). These types of online support are well suited for helping respondents with the content of the census questionnaires. Additional online support options may include live chat and social media. It is also important to keep in mind that a good online support is likely to reduce the volume of calls to the help line.

(i) *Frequently asked questions*

D.194. These questions should include questions both about the census generally and how to complete the online questionnaires, including information about protecting respondent confidentiality, who to include in the census form, and how data collected will be used; as well as more detailed and subject-matter/ content-specific questions; guidelines on who to contact and where to go for further details or instructions about the census; as well as technical details about completing an online census questionnaire. The FAQs tend to focus on the more difficult census questions as well as census questions that may be perceived as being sensitive. The goal of providing context about why these census questions are asked and instructions on how to answer the questions is to inform and reassure respondents and encourage them to respond to all questions within the questionnaire.

(ii) *Help text embedded in the online questionnaire*

D.195. A help button embedded in the online questionnaire is a useful addition and can contain similar information to the FAQs. The Help text should, however, contain more detailed information about each specific census question. Again, it is important to include the reasons why specific census questions are asked so as to provide context and legitimacy for each question, and to provide instructions and clarification on how to answer each question, including the number of allowable responses to ensure a detailed response is provided.

(ii) Questionnaire guide

D.196. A questionnaire guide would include similar information as the FAQs and the Help text within the questionnaire. This guide however could be made available to respondents before the start of collection to provide context about census and an overview of how and why census questions are being asked.

7.2 Census Helpline (Call Centre)

D.197. Providing assistance via call centres/toll-free telephone helpline is essential. Respondents will require help for various reasons and at various times during the data collection phase. Any form of self-response generates questions from respondents who have difficulties completing questionnaires without assistance, and the Internet option makes no exception. Indeed, there are additional issues pertinent specifically to the internet option, which make the provision of a helpline even more crucial.

D.198. Census helpline operators should be provided with a 'Quick Reference' sheet that contains the most frequently asked questions, along with various contact numbers. This is to ensure a rapid turnaround time when answering respondents' questions. A 'knowledge-base' electronic system can also be developed to provide an easy way for the operators to find more specific answers and

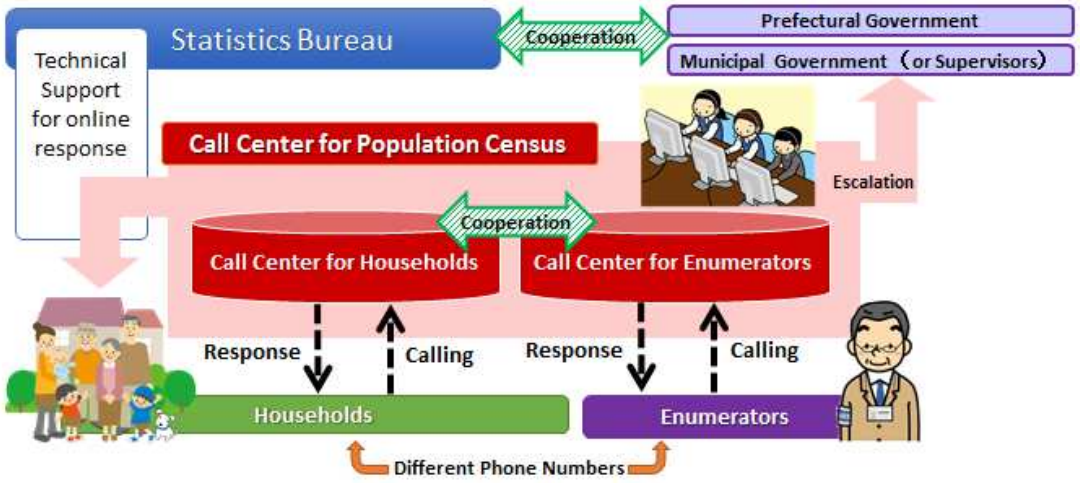
instructions. It should be kept in mind, however, that even though a majority of callers will ask about a relatively small number of similar questions or issues, the helpline operators will also have to answer frequently asked but very specific questions or will have to deal with unusual and exceptional situations. In this context, not only knowing the information but also knowing how and where to quickly find the information is important. Furthermore, the helpline staff should be trained to help respondents either self-completing the online questionnaire, or could complete a census questionnaire with the respondent over the phone.

D.199. Aside from questions regarding the census, the use of the Internet application, the login process, or other technical difficulties, some respondents will call the helpline to obtain a new Internet access code because they either did not receive, or have lost, their questionnaire or letter with the original access code. An important concern is ensuring the correct linkage of the questionnaire to the household, both at the initial contact or delivery of census materials and at the time of response, when an attempt from the household is registered in the online system. The latter is straightforward if callers to the helpline are able to provide a number that uniquely identifies the household; otherwise, helpline operators must be able to link the household based on its address or location using some kind of address search tool. Procedures need to be put in place for situations where operators cannot find the household's address and therefore link it properly.

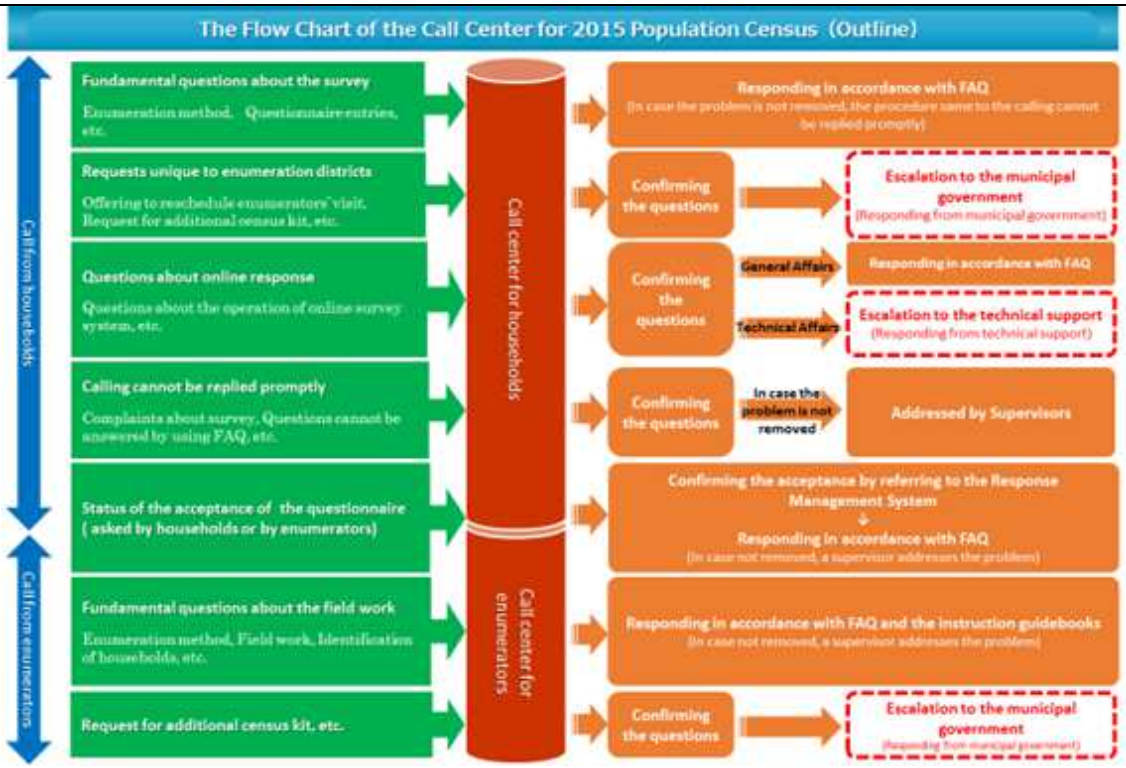
D.200. The introduction of a multi-phase approach will also result in additional calls to the census helpline. A typical situation is when a respondent completes their questionnaire after the initial contact, but not soon enough to be removed from subsequent list of non-response addresses. They will receive the reminder (letter or paper questionnaire) and wonder if the questionnaire they had completed online has been received. It is important for helpline operators to be able to reassure the respondents that their questionnaire has been successfully received (if this indeed the case).

D.201. As well as providing a toll-free telephone service, contact with the helpline should also be facilitated through email communication.

Box E.5. Call Center Scheme for Japan's 2015 Population Census



Box E.6. Flow Chart of the Call Center for Japan's 2015 Population Census



8. Management and monitoring of Internet response

D.202. Monitoring, controlling and tracking Internet response is key to the success of a multi-mode data collection operation. Management information reports are required to ensure that the expectations with respect to response levels are met and to ensure a good coordination between the different collection modes so as to avoid unnecessary multiple contacts and the associated increase in costs and response burden.

8.1 Models for delivery and collection of questionnaires

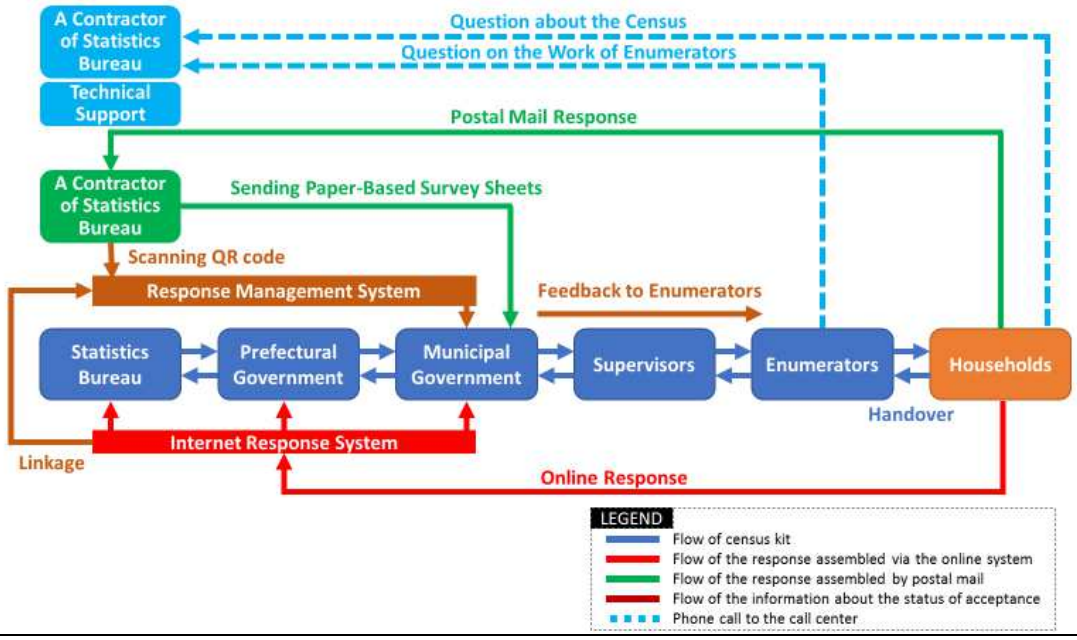
D.203. Assuming that the collection strategy includes multiple waves and modes of contact and response, it is paramount to come up with reasonable estimates of the amount of census materials required for the different types of contact/follow-up as well as the number of staff needed for face-to-face and/or phone interviews, in the light of the anticipated level of Internet take-up. Developing a predictive model to forecast daily and cumulative responses is a good way of ensuring that the collection operations proceed as planned.

D.204. Prior to the enumeration, the model can be used to plan the volume of census material for printing, collection and processing purposes. For example, predicting daily responses will help with determining how many reminder letters have to be printed, what should be the capacity of the IT infrastructure, and how many field staff will be required during non-response follow-up.

D.205. The initial predictive model has to be based on planning assumptions, but once collection has started, it can be updated dynamically with more accurate metrics based on the received data. The usefulness of such a dynamic model extends beyond simply monitoring Internet responses, since the model can also be used more broadly to optimize the human and the financial resources in pursuit of response objectives.

D.206. During collection, the model can be used to monitor progress and to address any serious deviations from the planned progress in a timely manner. In order to monitor the progress and be able to react with appropriate measures where necessary, key reports must be available both to local census managers in charge of field operations and at the head office of the statistical agency. Active management is important and obtaining information regularly is vital for identifying potential issues or monitoring progress and outcomes.

Box E.7 Enumeration workflow for Japan's 2015 Population Census



Box E.8. Enumeration in 2015 Census of Japan

Enumeration was conducted with three data collection modes provided sequentially to households. Internet response was the first option for data collection which was followed by self-enumeration with paper questionnaire sent by respondents via post office or collected by enumerators. In the 2015 census, 36.9% of the total households answered the census questionnaire online. The following are main phases of enumeration:

(1) Setting Enumeration Districts
Japanese government set enumeration districts on the previous year of conducting census. Each enumeration district includes approximately 50 households, and uses as the frame for sampling surveys conducted by national and local governments. In addition, Japanese government set Basic Unit Blocks (BUBs) of which range is delimited by road, river, etc. and relates to geographical characteristics and addresses. They are not rectified unless municipal domains or landforms change, and are useful for time series analysis. Census data can be disaggregated both by enumeration districts and by BUBs. Each household can be designated by using codes which consists of: two digits in prefectural code; three digits in municipal code; four digits in enumeration districts code; one digit code inherent to characteristics of enumeration districts; two digits code linking to BUBs and household code. The household code is generated by enumerators when conducting census.

(2) Enumerators' Work before Field Enumeration
Based on the maps provided by municipal governments, enumerators visited their areas and updated the list of housing units and buildings and their addresses in their enumeration districts. Enumerators also provided pre-printed access code for Internet questionnaire - starting from one and increasing by one- to every households.

(3) Enumerators' Work during Internet Response
Enumerators distributed "Internet Response Kit" including access ID, initial password and guidance, to every households. Access ID was generated by applying base-32 system to the codes designating every household, and thus, access ID and the code correspond one-to-one. If the number of the kits was not enough for an enumeration district, the enumerator asked to the municipal government to provide additional IDs and passwords, and the government was able to issue them by accessing the common national network system.

(4) Procedure of Internet Response
Respondents accessed the internet response system by using access ID and password, and filled in the questionnaire form. After completing the form, respondents had to change the initial password. Unless the password was changed, the system did not accept or save the form so as to protect the input information. In case of failure to provide correct ID, the system requested respondents to fill the address of households, and Statistical Bureau of Japan (SBJ) notified the correct enumeration district to enumerators through municipal governments by using a list linking address to enumeration district.

(5) Distribution of Paper Questionnaire
The statuses of response were assembled in the national management system, and municipal governments told enumerators the status. Enumerators distributed paper questionnaire to the households which were not filled in the online questionnaire.

Introducing the online questionnaire to entire country in the first phase of the enumeration has decreased the cost of paper questionnaire by 20%.

8.2 Information needed for monitoring

D.207. With Internet collection, the quantity of metadata created and the potential for analysis are great. However, it is important to identify and make available the essential information required during collection, and set aside the rest for more exhaustive analysis and evaluation after collection.

D.208. Examples of recommended reports and metadata that should be available on a daily basis during collection include:

- Tables and graphs showing the Internet returns (daily, cumulative, at both the national and local levels of geography, by form type (if applicable)
- IT reports to monitor the stability and capacity of the IT infrastructure (including peak times, number of concurrent users, etc.)
- Counts of all saved, autosaved (timed out or abandoned sessions, if applicable) and submitted questionnaires (including multiple sessions)
- Counts of submitted incomplete questionnaires (including last question answered)
- Comparisons between actual returns and planned returns (based on predictive model).

D.209. Examples of recommended reports and tables that should be available after collection include:

- Number of edits (validation messages) that are triggered in a given session (for mobile, tablet and PC respondents)
  - Number of times an edit was seen by the respondents, and how many times this resulted in a correction.
  - The analyses should distinguish edits that are on-path and edits that are off-path. (Off-path refers to when respondents change their flow in the questionnaire by going back to a previous question and change their answer. Validation messages that are off-path are of interest since they can provide an indication of how many respondents changed their flow in the questionnaire because of a validation message.
- Table that indicates how many times the help pages were viewed (by device) and combined with household and respondent characteristics of users who consult the help pages).
- Rate at which respondents logout/autosave/save/submit on different devices
- Page of last activity, by device
- Comparison of socio-demographic variables for households (and individuals) using different devices
- Item non-response rate for submitted responses obtained (by mobile, tablet and pc)
- Average time to complete a questionnaire (by form type (if applicable), language, and device), considering only sessions where the respondent logs in and submits in a single session
- Average time between a save and the next login (by form type and language, if applicable)
- Average time between the first login and the final submit when the respondent saves at least once (by form type and language, if applicable)
- How many households submitted multiple questionnaires (multiple online questionnaires using multiple access codes, or multiple questionnaires from different response mode
- Analysis of residency questions (including validation messages and use of help functions related to such questions).
- If applicable, analysis of the requests for paper questionnaire (questionnaire request system, including day of the request compared with day of the response received)

8.3 **Coordination with non-response follow-up**

D.210. At a basic level, multi-modal data collection operations require that timely information be provided to census enumerators so that they do not visit households that have already submitted a census

form. This is both an efficiency issue and a public relations issue. Modern technologies provide opportunities to improve the management of field operations and thus the quality of the census itself.

D.211. Ideally, an integrated collection system would be available that would centralize control of all collection operations into a single platform. An integrated field communication system can utilize and further develop the already existing infrastructure; however, if the statistical agency does not have the knowledge or the capacity to develop and run the management and the monitoring of the systems in-house, it will need to rely on outsourced contractors for key parts of the solution.

D.212. Communicating information related to Internet responses to field managers and enumerators depends on the systems and the technology available, as well as how communication already takes place for other purposes; for example, when assigning cases to field staff. In some countries, a web platform is available for the enumerators to obtain their workload and to report their progress. The same platform can easily be used to inform enumerators of the details of self-completion in their areas.

D.213. Another possible solution is combining the systems and processes developed in-house, call centres, and mobile telephone technology. A prerequisite is that the statistical agency should have a central register of all enumerators, their enumeration areas, and their mobile phone number. The agency must also establish an electronic central register of all census questionnaires received either by mail or via the Internet, which could then be compared against the census frame (an address register or other source) to identify households that have responded. This register would require the unique identification number for each form and/or address (such as geographic coordinates, internet access code, barcode information etc.). The identification number would permit the linking of the household to the appropriate area and the enumerator responsible for it, with the ultimate objective of removing the self-responding households from the enumerators' assignments.

D.214. Finally, non-response follow-up procedures need to have the flexibility to adapt to situations where respondents will have already completed their census questionnaires without the enumerator receiving any information about this. Cases where respondents claim to have completed a questionnaire already could be set aside or put on hold for a certain number of days, depending on how fast the Internet registration process is and how quickly the enumerator's information gets updated. The follow-up could then resume if no registration signal has been received for the household after this period. A confirmation code provided at the end of self-response could also be used by enumerators or field managers to avoid harassment of genuine respondents.

Box E.9 Online Questionnaire for Non-Response Follow-Up, 2017 Census of Chile

During the 2017 census in Chile, the Online Platform for following up non-response (SAC, *Sistema de Atención de Citaciones*, by its acronym in Spanish) was implemented. The SAC provided the citizenry with an online platform in which they could enter their information as part of the process of coverage recovery of census data.

The 2017 census was carried out with a de facto enumeration and included a phase of coverage recovery in the weeks following the census day. When a private dwelling did not have residents present during the day of the census (19 April 2017), the enumerators left a notification with a geographical code for residents so that they could provide their information in two ways: by going to a local census office or by entering the information in the online platform.

Information about the online platform was provided to the citizenry on Saturday, 22 April, by a press conference and by social media. The public was informed about the existence of the system following the day of the census so that they did not lose interest in remaining in their homes on the day of the census. The system was available for three weeks, until 15 May 2017. Of all the information collected on the days following the census and compiled by citations, approximately 30% came from the online platform.

Entry to the System

The entry key to the system was both the number of the portfolio (a unique number for each enumeration area) and the number of the dwelling. These numbers came from the notification left by enumerators. In addition, the national identification number (a unique number for each person in Chile) and an email address were requested. A safe activation link was sent to the email address for entry to the system. The system also used reCAPTCHA to assure that it was a person (not a robot) that was entering the information and thus to avert attacks that could destroy the functionality of the site.

These security measures in the entry to the system enables the subsequent validation of the data of the portfolio and of the national identification numbers. This validation prevented fictitious data from being entered into the system.

Development of the System

The SAC was developed by an external company with the technical guidance of the National Statistics Institute (INE). The decision to use an external company was based on the need for specific knowledge of security in order to implement a solution that would guarantee confidentiality and secure access to the data. The solution required an expert team in SQL Server 2014.

The main security components of the system were ASP.NET Identity, the pattern for development Model -View Controller (MVC), Control of Persistence, and encryption of the Database (transparent encryption and encryption by columns).

The SAC was designed as a responsive web page to enable the correct visualization of the page from different web browsers and from different devices (desktop and mobile devices).

The Internet option for improving census coverage was used first time in the 2017 census of Chile. This experience provided an opportunity to have better understanding of challenges and opportunities in adoption of the Internet as a data collection mode in future censuses.

9. Security

D.215. The physical security of personal information provided by respondents must be of fundamental importance and be built into the whole of design of the census. To ensure adequate security of the data provided online the agency should use an electronic platform with strong access controls, firewalls and encryption. As already noted, a secure login process and strong encryption are key elements in helping to prevent anyone from eavesdropping or tampering with census information. Both internal and independent external security reviews should also be performed to ensure (and report) that the systems are secure.

D.216. To protect the security of personal information on the Internet, the following safeguards should be incorporated:

- Strong encryption technologies to ensure security of data passing between respondents' computers and the web server.
- Data submitted to the web servers must be encrypted before being stored and remain encrypted until they are transferred to the high-security internal network.
- Census data must be processed and stored on a high-security internal network.
- Powerful firewalls, intrusion detection and stringent access control procedures to limit access to back-end systems and databases.
- Only census employees who have proper authorization and who have affirmed an oath of secrecy can access census data and only from secure locations.

D.217. Furthermore, the Internet application should be designed to ensure that after using it, no software trace (zero footprint) is left on the respondent's computer. It should also be timed out after a short period of inactivity (for example after 20 minutes) and respondent data should be no longer available.

D.218. Contingency plans for dealing with, for example, possible temporary interruptions should be developed to prevent from any malicious attacks. The plans should include a communication strategy to reassure the respondents in such circumstances that the confidentiality of the personal information was not compromised.

10. Testing and evaluation strategy

10.1 Testing strategy

D.219. Pre-census tests (or pilots) provide a useful vehicle for planning and developing all elements of the actual census. Census tests can be conducted as a national sample (useful for testing content, mail and/or Internet response, and other questionnaire-related features of the census), or as a site test (useful for testing operational procedures). Other pre-census testing could involve cognitive testing of the questionnaire in its different formats and languages (if applicable), research and testing of the automated processes for address list development, questionnaire or letter addressing and mail out, data collection, data capture, data processing, improved cost modelling etc.

D.220. In the context of adding an Internet response option to other modes of data collection, the testing strategy should include cognitive tests of the online questionnaire, as well as comprehensive tests that would permit the assessment of the initial quality targets to confirm their achievability, the review of the usability and accessibility of the online questionnaire, the impact of the added online response option on other modes of response, and the extent of load and stress the systems infrastructure is able to carry.

D.221. Based on the test results, it may be necessary to revise budgets, timetables, or self-response targets themselves if testing has shown them to be unachievable. Rehearsals should, therefore, be undertaken late enough in the planning stage to be able to assess the final census design and yet early enough to allow any necessary changes to be implemented.

D.222. Putting in place a comprehensive integrated testing strategy is paramount in order to obtain the desired outcome and minimize the risks associated with adding the Internet response option. The testing plan should or could include the following components.

10.1.1. Cognitive/qualitative testing

D.223. Cognitive testing can take the form of focus groups or one-on-one interviews with respondents with the objective of:

- Assessing the impact of the communication strategy and respondent behaviour when they receive their invitation and reminder letters or questionnaires
- Obtaining feedback from respondents on their overall impressions of, and reactions to, the proposed online application
- Testing of the user-friendliness of the online questionnaire
- Assessing the cognitive processes of respondents when filling out the online form, for example, the use of help buttons, determining which information captures their attention first, why some questions take longer to answer than others, why some answers needed corrections, reasons for leaving questions without any responses, etc.
- Testing of the respondents' ability and willingness to answer the census questions online
- Assessing respondents' attitudes towards the confidentiality and security of the information collected online

D.224. Cognitive testing should take place before the census; however, it can also be conducted during collection in order to evaluate the communication strategy and to identify possible improvements for the next census. For example, this type of testing conducted just after the self-response phase with respondents that filled out their census questionnaires after receiving reminders can help understand why they had not responded earlier and what could have been done to motivate them to respond sooner. Similarly, cognitive testing with respondents who completed their forms with interviewers during non-response follow-up can be used to determine which factors would have encouraged and led them to self-respond, preferably by Internet.

D.225. Given the relatively small number of participants that can be involved in cognitive testing, it is very important to recruit participants who are representative of different segments of the population in the country. Depending on population diversity and the objective of a particular test, it may be preferable to conduct cognitive tests in a variety of areas across the country and in more than one language. When choosing the areas for the tests, it is important to keep in mind that residents of the capital region tend to have been exposed to governmental forms and materials more so than residents in some other parts of the country. Therefore, it may be better to conduct the tests outside of the national capital region.

D.226. As discussed earlier, adding a new collection mode to the collection strategy increases the risk of introducing bias in the results due to a mode effect. Cognitive testing helps to ensure that questions are understood properly in every collection mode and that the potential bias due to mode effect is minimized.

D.227. The following elements can be tested with cognitive testing:

LETTERS (INVITATION AND REMINDER)	• Content, what information should appear in bold, the display of text, spacing between sections and paragraphs, the location of the access code, how and where the deadline should be specified (for example, requesting a response before a specific date compared to within a certain period), the tone of the letter (especially if the census is mandatory), instructions to request a paper questionnaire (if applicable)

ENVELOPES	• Content, key messaging, the display of the text
	• Format
	  ▪ Using a self-mailer versus a regular envelope
	  ▪ Using a modern and dynamic look versus a more neutral and official look

PAPER QUESTIONNAIRE (IF APPLICABLE)	• Display and placement of the access code and the instructions to complete questionnaire online
ONLINE QUESTIONNAIRE	• Accessibility and usability of the website • Questionnaire flow • Interpretation of questions, especially sensitive questions • Edits and help functionalities • The usability of mobile devices for completing forms online
OVERALL COMMUNICATION STRATEGY	• Phases or waves (order, evolution in the tone, delay between waves etc.) • Publicity material (television, radio or newspaper ads, social media use and messaging etc.)

10.1.2. Quantitative testing

D.228. Before implementing a new collection strategy on a very large scale, quantitative testing should be done to validate the take-up rate and to help estimate the various metrics used for planning and management purposes. The real census conditions (particularly the public awareness of the census) are difficult to replicate in a test setting (when only a small sample of the country is covered), but this should not prevent the statistical agency from designing such tests. An experimental test with appropriate test panels and their associated control panels is a good way to compare the different collection/response options, especially if the objective is to replace self-response paper questionnaires with an Internet option. Since the census conditions cannot be simulated exactly during a test, control panels using the current methodology allow the comparison of current and alternate strategies under similar conditions. Also, record linkage with response from the previous census could be useful to assess impact of change in questionnaire design or collection methods.

10.1.3. Infrastructure and systems testing

D.229. As discussed earlier, the systems infrastructure for internet collection is very complex; its performance depends on the proper functioning of each of the components of the system as well as the proper communication between them. It is very important to plan and implement an integrated testing strategy involving all the key systems players; for example, the systems for registering responses, and

for communicating with enumerators in the field, the processes of sending the information to head office and field for monitoring etc. If a single component of the integrated systems fails, the entire systems infrastructure will be jeopardized and may stop functioning during collection.

D.230. In addition to testing the functioning of each system component and the communication between them, it is important to test the maximal load the systems can handle and to stress-test the system in coping with the different situations that may arise during census collection. This will help to determine:

- if the infrastructure is able to handle the numbers of respondents that are expected to access the online questionnaires on the deadline date?
- the backup plan should a component of the system malfunction?
- the impact on collection and monitoring activities in case of a delay, stop, or a failure in one of the system components?
- how systems issues will be communicated to all affected parties?

D.231. The implementation strategy should allow the statistical agency to test alternative approaches, but should also be focused to avoid spreading the efforts on too many scenarios. The testing schedule should allow time for making necessary changes, based on the tests results. Testing multiple components in a single test allows the testing of the interaction between components; however, in some cases, an iterative approach is more appropriate in order to make adjustments to the different systems components.

D.232. Whenever and wherever Internet collection is implemented for the first time, the motto must be: "test, re-test, and test again." Risk mitigation strategies and contingency plans should be put in place for situations that cannot be tested or cannot be tested to the full extent to what may happen during the census collection period.

10.1.4. Live testing

D.233. As mentioned earlier, testing alternative collection strategies in a real census context should also be considered. Live experiments during census operations are a good way to test components in ideal conditions, often at a small fraction of the cost of a separate test.

10.2 Evaluation strategy

D.234. In any project, it is best practice to develop the evaluation plan before the actual operation takes place. In the context of Internet data collection, this is even more important given that a key component of the evaluation will be based on the metadata obtained during the collection phase. Planning the evaluation phase in advance will ensure the requisite metadata will be collected, derived and kept after collection.

Chapter E - Considerations for use of mixed-mode data collection

1. Introduction

F.1. It has become increasingly difficult to maintain very high levels of response[29] in census data collections. As respondents continue to become increasingly hard to contact and reluctant to participate, and are more technologically capable and demanding of solutions that better suit them, statistical agencies have to find alternative approaches to the traditional census in order to improve coverage in a cost-effective manner. One way that statistical agencies have attempted to do this is through the use of administrative data as a supplement or replacement source for census data collected in the field. Another approach has been to use mixed-mode collection, effectively allowing respondents to provide information in the form which best suits them, such as through face-to-face interview (with paper or electronic questionnaire on handheld electronic devices), telephone interview, and self-enumeration through paper questionnaire or electronic means via the Internet. This section will discuss interviewer- and/or self-administered modes of data collections; it will not discuss the use of administrative registers in combination with a field work for statistical data production because this requires a completely different design and such an approach is not considered a traditional census[30].

F.2. Designing a data collection system for more than one mode of collection is known as mixed-mode design. Such a design entails striking a balance between maximizing the potentials, and minimizing the limitations, of the various modes, in order to improve the quality of the collected data. For example, use of electronic questionnaire (on handheld devices or via the Internet) allows for design elements that are not possible in a paper questionnaire. This leads the mixed-mode designer making decisions about the extent to which use is made of those elements in the electronic questionnaire given they cannot be replicated in the paper questionnaire. In practice, the process of designing a data collection system also involves a compromise between the ideal design and the costs of implementing it. As a result, decisions about modes are impacted by administrative and resource factors, including: the available budget; the time period in which the data are required; considerations about public acceptability and response burden; and, the existing infrastructure available for conducting data collection in different modes.

F.3. In the context of data collection, mixed-mode designs can be either sequential or concurrent. In concurrent mixed-mode data collection, respondents are offered, at the outset, the choice of one of two or more modes by which they can provide information. An example of a concurrent mixed-mode design is offering respondents the option of completing a paper questionnaire or providing information online via the Internet. In sequential mixed-mode data collection, all respondents are first requested to provide information in one particular mode only but then are offered other modes to increase the response rate. One common practice is to start with the least expensive mode and then progress to more expensive and more persuasive modes. For example, in a data collection operation consisting of four modes—Internet, mail, telephone, and personal visit—the first phase could utilize mailed request to respond via Internet, followed later by an option to complete a paper questionnaire and return it by mail. If no

[29] Response rates have generally been declining due to two main reasons. Firstly, non-contact rates are rising, partly because of the growing number of barriers between respondents and enumerators using traditional collection modes. For example, an increasing number of households are not present during the field enumeration period. Another example is difficulties faced by enumerators in getting access to living quarters as more and more people in urban areas are living in so-called 'gated communities' or using entry-phone systems, making it difficult for interviewers to gain access to households. The use of telephone answering machines, voice mail, caller ID systems and 'Do Not Call' registers has similarly introduced impediments to contact in telephone surveys. Secondly, refusal rates are also rising due to a growing reluctance on behalf of the public to take part in surveys, partly due to growing concerns about privacy and partly due to a trend attributed to 'survey fatigue' – either a real or imagined increase in the number of requests to participate in surveys.

[30] See United Nations Principles and Recommendations for Population and Housing Censuses, Revision 3, paragraphs 1.63-1.136.

response is received by mail or Internet, then a follow-up attempt could be made with computer-assisted telephone interviewing (CATI) when a telephone number is available. If a respondent cannot not be reached using CATI, or if the household refuses to participate, the address may be selected for computer-assisted personal interviewing (CAPI). Whichever option—concurrent or sequential—proves to be the most effective depends on the situation. In general, both options aim to improve coverage and response (both for the general population and for special groups) while completing data collection at reasonable costs. It is important to note, however, while mixed-mode data collection methods are effective in reducing non-response, there is a potential for measurement error as the modes used may cause measurement differences (bias).

F.4. Data collection modes vary in a number of their charactersitics making them more or less suitable to the needs of a particular data collection exercise. One of the most important challenges is deciding which data collection method, or mix of methods, is optimal in a given national or local situation. Times and methodologies are changing and this is no less true for data collection technology. Factors influencing the choice of collection method(s) include:

i) Population of interest. Modes vary in the extent to which they provide access to different population groups. The nature and geographical location of the population of interest may have a bearing on the collection method. Face-to-face interviews usually offer the most dependable method of accessing household members, because in theory, interviewers can visit any household in the country, however, it may be expensive to survey a remote or geographically dispersed population using this mode. In the same way, postal surveys can also provide access to the majority of households where there is the availability of comprehensive lists of addresses, but self-completion modes will not always be suitable for everybody because they depend on a minimum level of literacy. In countries where most households have telephones, interviews can also be carried out effectively using this additional mode, but the effectiveness is being reduced by the rising number of people abandoning their fixed-line telephones in favour of mobile (cellular) phones only.

ii) Administrative and resource burdens. The choice of mode is guided by the extent to which each has differential administrative and resource burdens. These include the financial costs of implementing the survey in each mode. The four principal modes of data collection can be ranked in terms of their relative costs, starting with face-to-face interviewing as the most expensive option (mainly due to expenses of recruiting, training and deploying the interviewers and other field personnel). Online, postal, and telephone interviews generally offer a more economical solution.

iii) Time taken to complete fieldwork. Telephone- and Internet-based data collections can be much quicker than a mail-based delivery/response mode or face-to-face interviews. Postal survey methods offer one of the lowest cost options, but the relatively low administrative costs are often offset by the comparatively long fieldwork periods required to ensure questionnaires are completed and returned – particularly where multiple reminders are sent out. This mode is also heavily dependent on the existence a comprehensive and high-quality address list. The Internet as a tool for data collection has revolutionised the speed with which census fieldwork can be carried out, though there may be significant initial set-up costs associated with programming, as well as with software development and server support.

iv) Response rates. The quality and reliability of census data is affected by response rates. Face-to-face interviews often achieve a better response rate than other methods.

2. Benefits of mixed-mode data collection

F.5. There is growing interest in mixed-mode data collection as a result of the recognition that the traditional methods of collecting data (such as face-to-face interview with paper questionnaire) are increasingly becoming inefficient and unsustainable. This is also due to the rising cost of conducting a

large-scale data collection operation, and in part, due to attempts to mitigate the detrimental effects of under-coverage and non-response on data quality when a single method of collection is adopted.

F.6. The main motivations for opting to use mixed-mode data collection are the opportunities it presents to improve coverage and reduce fieldwork costs. Another important factor is that it offers the possibility to compensate the weaknesses of one mode with the strengths of another mode. The fact that modes vary with respect to factors such as the cost and speed of fieldwork, their suitability for reaching different population groups means that, in principle, using a mix of modes allows the data collection manager to minimise both the costs and impacts on quality (due to coverage, non-response and measurement issues) associated with using any given single-mode approach. For example, an additional mode can help provide access to a group of respondents that would otherwise be hard or impossible to contact in the principal collection mode. Furthermore, combining modes sequentially, whereby one starts data collection with the most economical mode, and follows up non-respondents with increasingly expensive modes offers advantages with respect to both minimising overall costs and increasing participation. Mixed-mode design is often the most cost-effective and optimal method for the available time and budget.

F.7. In summary, the benefits of using mixed collection methods—which allows respondents to provide information in the particular mode suited to them—include:

- increased response rate;
- decrease in respondent burden;
- improved data quality and timeliness; and
- reduced data collection cost.

3. Implications for data quality

F.8. While the use of a mix of modes may offer solutions to problems of coverage and non-response—and may even help to reduce fieldwork costs—mixing modes of data collection has implications for the quality of the collected data, particularly for data comparability. One disadvantage of using a mixed-mode collection is that mode effects may occur. 'Mode effect' is the bias caused by the mode of the data collection. Mode effects are described as the delivery of different results as a consequence of using different means of collection. That is, differences observed in the data can be attributed to how the data have been collected rather than to real differences in the population. Mode effect varies depending on the motivations for mixing modes and the type of mixed mode system adopted.

F.9. Data quality can be affected by the choice of data collection mode. Three factors concerned with data quality and associated with mode-effect include:

3.1. Coverage

F.10. Coverage differs depending on the mode of data collection used and the proportion of population that can be reached through each specific mode. For single mode data collection, coverage is generally higher for face-to-face interviews. The level of coverage in other modes of collection—telephone interviews, self-completion online via Internet or by paper questionnaires delivered/collected via the mail—will depend upon the proportion of households in the population with fixed/mobile telephone lines, access to the Internet, and availability of lists or registers of addresses, respectively.

F.11. It is widely recognised that coverage errors occur due to many factors, including the quality of census maps or list of addresses used for enumeration. Coverage might also be affected by the mode of data collection due to the different ways they can introduce different types of coverage errors. As a result, it is important to study carefully the impact of different collection modes on census coverage when two or more modes are used. On the other hand, a respondent who fills in the questionnaire may create a different type of error in listing members of the households due to misinterpretation of census

questions or instructions. Telephone interviews may not create a significant bias as they are generally used as a follow-up for enumerating a small number of the population. In general, it is expected that the use of electronic data collection either online or with hand-held devices will increase the quality of enumeration through the possibility for clarifying if a person needs to be included or excluded from the household list.

3.2 Response rate

F.12. Response rates vary with mode of contact and mode of data collection. In this respect, face-to-face interviews are more effective at securing high levels of participation, with a generally equal cooperation rate across different population groups. Response rates tend to be lower for each of the other modes (telephone interviews and self-response via postal mail or Internet), increasing the likelihood of response bias (the tendency for certain subgroups to be more likely to respond than others). Thus, data collection modes not only vary in their effectiveness at achieving high levels of participation but also because they are more or less likely to encourage different members of the population to participate. For example, postal and Internet-based self-response tend to favour the more literate (including computer literate) members of the population.

3.3. Item non-response

F.13. Item non-response varies with mode of data collection. It is widely recognised that the use of electronic data collection will reduce significantly item non-response compared to paper-based data collection, due to the automatic control of non-response and consistency checks during questionnaire completion. Item non-response rate tends to be lower with the use of electronic data collection modes including self- response via Internet, face-to-face interview with hand-held devices and telephone interview. The use paper-based face-to-face data collection and self-completion face a higher likelihood of item non-response bias.

3.4. Measurement differences

F.14. One of the major challenges mixed-mode data collection presents is the fact that people tend to give different answers to questions (especially of a sensitive nature) depending on the mode in which they are asked. Respondents may give different responses in person to those they give when asked anonymously online. Measurement differences typically result from either the design of the questionnaire and the wording of particular questions being asked of the respondents, or – in the case of face-to-face and telephone interviewing – the competence of the interviewer. One type of mode-related measurement error is the tendency for respondents to modify the 'true' answer to certain types of questions in order to present themselves in a more favourable light (known as social desirability bias in survey literature), an effect that is more pronounced in interviewer-assisted collection than in self-administered collection. When comparing self-completion paper questionnaire versus Internet questionnaire (and face-to-face with paper questionnaire versus face-to-face with hand-held devices) there is an increased chance of mode effect. The mode effect may be more pronounced if the electronic questionnaire has more edits that help to improve the quality of response by warning the respondents of mistakes or inconsistencies that they may have made in answering the questions, or actually simplifying the task of completion.

F.15. Mode effects might be problematic if they have a significant effect on the overall quality of the collected data or if their effect on the comparability of the data is pronounced. NSIs should consider mode effects – particularly when changing the collection mode, or moving a data collection from using one mode to mixed modes.

F.16. The study of mode effect can provide useful information for questionnaire design and development of imputation rules for the various data collection modes.

4. Minimizing mode-effect

F.17. Use of mixed-modes—receiving data from respondents using more than one methodology—is an approach being considered by many NSI. Different data collection modes have varied advantages and disadvantages, and these can produce different outcomes, the result of mode effects. There is a need to fully understand the strengths and limitations of all mode options and to adopt those designs that are best suited for optimizing data quality within the administrative and resource constraints. This goal has become more challenging as census designs have become more complex.

F.18. In the application of mixed-mode data collection in the census, two choices confront the NSI: use techniques to minimise potential mode effects or simply accept that these effects will be present. Understanding the causes of mode effects on coverage, response, item non-response and measurement can provide information with which to develop methods of minimising the extent of their effect. If the NSI opts for multiple data collection modes there are certain measures it can implement to minimise potential mode effects, including:

4.1. Optimizing design

F.19. Mode effects are an important design consideration. As mentioned above, it is important to distinguish between two different situations: (a) sequential design, where there is one main data collection method, with additional data collection methods used for non-response follow-up; and, (b) concurrent design, in which the different methods are equally weighted and respondents are given an open choice.

F.20. In the sequential design, a main mode of data collection should be chosen that can best accommodate the data collection objective given the administrative and resource constraints (in the census context, this would be the mode that can be used to enumerate the clear majority of the population). This main mode should be used to its maximum potential, with the other modes used as auxiliary options only (these may be sub-optimal and not used to their fullest potential). For example, face-to-face interview through hand-held devices can be the main mode while paper-based face-to-face interview and telephone interview might be used as supplementary modes.

F.21. In the concurrent design, there is not a main versus an auxiliary mode; instead all modes are treated equally. An example could be a census where several options are offered to respondents, including options for self-enumeration with paper questionnaires or online, together with the option to provide information through enumerators. In this case, it is preferable to go beyond the 'unimode' design (where the census agency deliberately tries to present the same questions in the same order and layout across all modes in order to make them less sensitive to the effects of administration mode, with the risk of not using a mode to its fullest potential, by, for example, the minimal use of editing and validation in electronic questionnaires) and use a generalized design. In a generalized mode design, the census abandons the unimode approach of developing one instrument suitable for all modes, and places more emphasis on enhancing quality across all the modes administered in the data collection. In practice, this means trying to minimise the likelihood of measurement differences across all the modes being used, with a view to enhancing data quality overall. As noted above, whichever option (either sequential or concurrent) is best depends on the situation. In general, sequential design has less pronounced mode-effect as compared to concurrent design.

4.2. Conducting an empirical study

F.22. As noted above, understanding the causes of mode effects on coverage, response and measurement can provide information with which to develop methods of minimising them. Different types of experimental studies (such as mode comparison studies) could be conducted to facilitate such understanding and to quantify the extent of such effects, including assessing the magnitude of the mode effect, the direction of the effect (that is, whether or not one mode appears to provide

more 'accurate' data than the other) and, whether or not the effect can be explained by other factors. This kind of experimental study can be conducted with pre-tests and pilot censuses to understand mode effects on the data quality especially on item-non-response and measurement error. Such a study should aim to examine the likelihood of mode effects on each census variable and whether or not it significantly differs by each characteristics of population and housing. Findings from such experimental studies can be used to develop editing and imputation strategies in a way of decreasing mode effect on the data quality.

F.23. Where experiments are not possible, matching studies is another option to assess mode effects. For example, in a concurrent mixed-mode collection, information from respondents could be matched in two modes on important variables (such as age and education) to see if the matched groups are significantly different. Preferably, the variables on which matching takes place are measured independently of mode (using register-based data sources). However, this approach is much weaker than an experimental study with sampling. Still, it may provide some insight into potential mode effects, and some empirical data are better than none.

5. Management of mixed-mode data collection operation

F.24. Managing census data collection using multi-modes presents a significant operational challenge. In addition to the complexity of designing questionnaires that work in both interview and self-completion contexts and in both paper and electronic formats, there are many challenges related to managing the operational aspects of multi-mode data collections, including the validation and integration of data collected by different modes. The more options available to the respondent, the more complex the operation. The support of an integrated management information system is crucial to execute operational procedures. Integrated systems are required to manage all process functions related to the data collection including pre-notification, respondent communication, administration of the survey itself, logging receipt of materials, and the status of these activities at both the case level and the task level. The systems must also support various monitoring and reporting functions in aggregate or broken down by any required subgroup. A dedicated management team to monitor and control the multi-mode collection operation is needed.

F.25. Some of the functions that an integrated management information system for multi-mode data collection system must support include:

(i) Scheduling - start and stop dates for each operation;

(ii) Contact management - to provide respondents with timely notice and informational materials, managing contact attempts between modes, etc.;

(iii) Case status management - assignment of a unique case number identifier associated with each respondent household is critical for the conduct of the operation; the status of each unit or case is an important quality assurance component (so that it allows, for example, various reporting functions as well as the calculation of response rates, etc.) and aids in tracking each process/stage a questionnaire goes through during the enumeration period;

(iv) Avoiding duplication of responses - unique identifiers have to be assigned and monitored to ensure no double counting occurs during enumeration;

(v) Managing switching/transfer of a case between different data collection modes (such as Internet to paper or telephone) - cases initiated in one mode being completed in another mode; a questionnaire may not be completed in one go, particularly when the household has several members;

(vi) Response management - putting a system in place to send out reminders and to support further follow up actions in the field; this is a continuous process that needs to be monitored through, ideally, the use of dashboard reporting at the dwelling unit or household level; linking the response management database to a census address register will enable the generation of follow-up lists of non-returns by census management areas or teams;

(vii) Failed-edit follow up for cases requiring additional information;

(viii) Assignment of field staff – the ability to assign and re-assign interviewers during fieldwork and balance of workload of enumerators (in some areas response by self-enumeration via mail or Internet may be high, in others low);

(ix) Response integration - data management plans and tools (such as software used to integrate the data, format for data storage, etc.) for integrating data from all collection modes should be in place before collection starts.

Chapter F - Planning and management considerations for the adoption of electronic data collection technologies

1. Introduction

F.1. Population and housing censuses are the largest, most elaborate and costly data collection activities that any official statistical system undertakes. The complexity arises from the amount of effort required to clearly identify and properly sequence a multitude of activities, many of which are inter-related and overlapping in nature and must be conducted simultaneously. The logistical effort required, and the difficulties encountered in contacting and collecting information on the whole population within a limited period of time, adds to the complexity. The adoption of new technologies and tools (for example for mapping, data collection, transmission and processing, and operational management) significantly improve the efficiency of the operations and the quality of the outputs. However, they also bring new challenges and risks, and put to task the planning and management capabilities of census agencies. Large-scale IT systems projects in census operations introduce a high risk of failure, delay, or overspending. Thorough and rigorous planning and management processes are, therefore, needed to overcome the challenges and risks introduced by the use of IT.

F.2. Once the goals and objectives of the census have been clearly defined, careful planning is vital to ensure a satisfactory result. The aim of the planning process is to ensure not only that each phase is properly resourced and organized but also that the output of each phase is of sufficient quality for all subsequent and dependent phases. Because of the long duration of the census operation, planning should not remain static but be flexible to take into account changes that occur[31]. Planning must take into consideration several factors including: the preparation of detailed and realistic timeframes; the setting up of technical advisory committees; coordination with stakeholders; costing and budgeting; procurement and contracting out; IT systems development and/or acquisitions; designing instruments; methods of enumeration; quality assurance procedures; publicity and communication; etc. These and other general issues associated with planning out and managing census data collections are elaborated and discussed in detail in the *Principles and Recommendations for Population and Housing Censuses, Rev.3* and the *Handbook on the Management of Population and Housing Censuses, Rev. 2*.

F.3. This chapter covers a set of selected, essential and critical planning and management issues and processes to consider when planning census data collection that utilises electronic technologies (principally, electronic handheld devices and/or the Internet). Planning and management considerations specific to the use of electronic handheld devices are treated in Chapter D (*Data Collection with Handheld Electronic Devices*), while those specific to the use of the Internet are covered in Chapter E (*Data Collection with Internet*).

2. Management of investment in IT

2.1 Introduction

F.4. Investment in information technology (IT) improves organizational performance. However, if not managed effectively, IT projects can slip in schedule, become risky, costly and unproductive while contributing little to mission-related outcomes. To ultimately succeed, most organizations will need to have in place a systematic and disciplined management process to minimize risks while maximizing the returns of IT investments.

[31] Handbook on the Management of Population and Housing Censuses, Rev. 2.

F.5. Successful organizations manage IT systems projects primarily as investments, rather than expenses[32]. In such organizations, as IT investment management capabilities increase, IT projects are viewed more as mission improvement projects and less as information technology efforts. Senior managers become actively involved in ongoing IT project management and are responsible for making decisions about whether to continue, accelerate, modify, or cancel a project. They also provide an oversight of each IT project's performance and progress toward pre-defined cost and schedule expectations as well as each project's anticipated benefits and risk exposure. Relentless effort should therefore be made to ensure that IT projects and systems support the organization's overall business needs as well as meeting, for example, the specific needs of census users. As IT projects develop and investment expenditures continue, IT projects should be monitored to ensure they continue to meet mission needs at the expected levels of cost and risk. Interim actual versus expected results should be compared to assess whether any changes or modifications to the project may be needed.

F.6. Implementation is the most difficult phase of a large-scale IT systems project. The following sections highlight the kinds of activities that the census agency should pursue to ensure an effective management of its investments in IT projects.

2.2 Management structure for managing IT investments

F.7. Instituting a management structure is a key component in the management process of IT projects that are high-cost, high-risk, have significant scope and duration, or are cross-functional in nature benefiting multiple organizational units. A management group (or board)—comprised of senior managers across the census agency, including the agency's head or designee, and heads of the IT department and those of operational and supporting units such as programme and budget management—should be established to perform investment management functions. The engagement of senior managers and key organizational decision-makers can help attain organization-wide buy-in and from the various operational units affected by IT investment decisions. Depending on the scale of the IT project(s) as well as the size, structure and culture of the census agency, there may be a need to have one or more IT investment boards. When multiple boards execute the organization's IT investment governance process, the boards must be defined such that there are no overlaps or gaps in the boards' authorities and responsibilities.

F.8. The Executive management is typically responsible for creating the IT investment management board(s) and for defining their scope and resources, and specifying their membership. The operation of the board(s) should be guided by a documented IT investment management guide. The guide should define the membership, guiding policies, operations, roles, responsibilities, and authorities for the board(s). The board's work processes and decision-making processes (such as schedules, agendas, authorities, decision-making rules, etc.) should be described and documented in the guidance. The guide should also provide the management controls for ensuring that boards' decisions are carried out. Without these controls in place, decisions made by the investment board(s) might not be implemented because of conflicting priorities. To ensure adherence to management controls, the structure of the relationship between upper management and the board(s) must be documented and agreed to by both parties.

F.9. It is critical that the board members understand the organization's IT investment management policies and procedures and decision-making processes. Members should also have the experience and skills to carry the functions of the board. Where such skills are lacking, the organization should consider introducing its investment management processes to board members with little or no investment decision-making experience or relevant education in this area.

[32] GAO (1994). Executive Guide. Improving Mission Performance Through Strategic Information Management and Technology.

F.10. The investment management board performs two critical functions: (i) ensuring that IT projects and systems meet the business needs of the organization; and, (ii) providing IT investment oversight.

2.3 Meeting business needs

F.11. One of the major objectives of the IT investment management process is to ensure that IT projects and systems are aligned with the business needs of the statistical office. Strategically aligned IT projects and systems provide the highest benefits to any such organization and represent successful return on investment. To achieve such alignment, the statistical office must continually review and verify the business necessity for its IT projects and systems. Periodic identification of the business needs ensures that the correct and appropriate IT projects and systems are funded and that they directly support the organization's strategic plan. To assure IT projects meet core business needs, the statistical office should have a systematic process for identifying, classifying, and organizing its business needs and the IT projects used to support these needs. The direct and indirect business needs for each proposed and ongoing IT projects and systems should be well-documented, including in the business case for the project.

F.12. The investment management board plays a critical role in ensuring that IT projects and systems meet the business needs of the statistical office. The board periodically evaluates the alignment of its IT projects and systems with the organization's strategic goals and objectives and takes corrective actions when misalignment occurs. The investment board should assess a project's or system's outcomes and its value in comparison to predefined expectations, in preparation for determining whether or not, and how well, the IT project or system is meeting the NSI's expectations. The investment board should address whether business and user needs continue to be met in a cost-effective and risk-insured manner.

F.13. The process of identifying business needs also entails the identification of end-users and customer groups of IT projects and systems. Identifying census users or other beneficiaries early in the process will assist the team developing the IT project or system in focusing on specific and well-defined functionalities and attributes that are needed/desired by all stakeholders. The participation of census users is important at various points in the IT project's or system's life cycle. During the project's conception stage, such users should be heavily involved in developing the business case and in defining how the system will help to meet business needs. They should also be heavily involved again during user acceptance testing. During the operational and maintenance phase of the system life-cycle, users should play a major role in helping to identify and document any benefits that are realized from the system's implementation.

2.4 Oversight of investment in IT

F.14. Another important function of the investment board is to provide effective oversight over IT projects. Effective oversight entails monitoring each IT project's performance and progress against cost and schedule expectations as well as anticipated benefits and risk exposure. It is important to emphasise that such oversight needs to be exercised throughout all phases of the life-cycle of IT projects. The board should expect that each project development team will be responsible for meeting project milestones within the expected cost parameters that have been established by the project's business case and cost/benefit analysis. The board should oversee the project's performance by conducting reviews at predetermined checkpoints and/or major milestones, in order to interpret the data on project cost and schedule with respect to historic project data and stated expectations. The board should also employ early warning systems that enable it to take corrective actions at the first sign of cost, schedule, and performance slippages.

F.15. For each under-performing IT project or system, appropriate actions should be taken to correct (or even terminate if necessary) the project or system in accordance with defined criteria and the documented policies and procedures for management oversight. Using estimated and actual cost and

schedule data, the NSI should identify projects that are not meeting their cost and/or schedule performance expectations. Senior managers should ensure that there is a support and reward structure in place for identifying issues and raising them to the appropriate decision-making level and that there are no incentives for covering up significant problems. The investment board should regularly track the implementation of corrective actions for each under-performing project until the actions are completed. If the corrective actions are significant enough, an independent review should be conducted before returning to the original project plan and reinstatement of funding to ensure that all corrective actions have achieved their intended results and to determine whether additional changes or modifications are still needed.

F.16. It is essential for the NSI to have documented policies and procedures for management oversight of IT projects and systems. These policies and procedures should specify:

- the investment board's responsibilities when providing investment oversight;
- the procedural rules for the investment board's operation and for decision making;
- the threshold criteria that the investment board uses when analysing project performance (threshold is typically based on cost or schedule measures—for example, more than 10 per cent over expected cost);
- the procedures for escalating unresolved and/or significant issues; and
- the conditions under which a project would be terminated and the funds redirected to other 'successful' projects.

F.17. For the IT investment board to perform its function effectively and make the right decisions, it needs to be provided with all performance data on actual performance including cost, schedule, benefit, risks, and system functionality (both expected and actual) for each IT project. To perform oversight functions effectively, adequate resources, including people, funding, and tools, should be provided for IT project oversight. The organization should perform an assessment of the resources needed to oversee its IT projects and systems. These resources should include: managers and staff who are assigned specific responsibilities for monitoring IT projects and systems; and, tools to support board's oversight operations.

3. Institutional capacity development

3.1 Introduction

F.18. The introduction of new IT systems into the organizational setting of the national statistical office will usually necessitate the reengineering of work processes. It could also lead to redeployment of the workforce as many of the tasks workers perform are changed or modified. This creates the need to establish a plan to help guide business improvement efforts as well as to clarify roles and responsibilities at the organizational as well as project levels. Establishing clearly defined relationships and partnerships internally between line managers and IT units and professionals will also be critical to enable the organization to maximize the benefits of the new work process. Furthermore, an effective workforce planning will also be essential to identify gaps in mission-critical IT competency and skills and develop strategies for recruitment, retention, training and professional development.

3.1 Organizational restructuring

F.19. The introduction of electronic data collection and associated IT systems into the organizational setting of the national statistical office will most probably require the streamlining or redesigning of critical work processes. IT systems initiatives that are not focused on process improvement and guided by organizational objectives will not be well positioned to reap the full potential and opportunities they present. Process improvement efforts using information systems, if pursued in a coordinated manner, could realize significant satisfaction for users of the systems and/or cost savings, rather than the marginal efficiency gains normally associated with initiatives that use more traditional technology to

do the same work. New technologies that have organization-wide impact need to be integrated into existing work processes systematically. To maximize the benefits of process improvements across the entire organization and to reduce risks, the development of standards and rules for work processes, information and data flows, and use of technology are vital. Business process reengineering and innovation should be overseen by a senior management team and should begin with a high-level process analysis of the organization in order to identify major process improvement opportunities.

F.20. One critical outcome from the business process improvement analysis, in the context of adopting new technology, should be the clarification of roles and responsibilities (that is, knowing who is going to do what) at both the organization and project levels. It is important to require every IT systems project team to define line and IT management roles throughout the entire project life cycle. Establishing clearly defined customer-supplier relationships internally between line managers and IT professionals enables the organization to maximize the benefits of new management processes. In this arrangement, IT professionals will be responsible for supporting line managers as product/service providers. Line management should have control over IT system project funding and direction in line with the objectives of the census agency, and its key responsibilities should include identifying specific mission goals, the core processes required to accomplish them, key decisions that guide work processes, and the critical information needed to support decision-making. IT professionals, then, act as suppliers, working to support efforts to meet a management objective, make a critical decision, or solve a business problem.

F.21. Another critical outcome from the business process improvement analysis should be an implementation plan. Implementing a new business process is challenging and should be guided by a robust implementation plan. Such a plan is instrumental in helping NSIs coordinate and guide improvement efforts. Several steps are important for successfully implementing new organizational governance processes related to investment management and system development. Having the commitment of top management and the buy-in of key stakeholders is important in order to overcome possible challenges associated with implementing a new business process for carrying out such a well-established activity as the census.

F.22. The selection of an implementation team for initiating the new business process and the development of a detailed implementation plan that lays out a roadmap for executing the new process is also important. An effective implementation team should include key stakeholders from both business and IT components. Such a plan should build on existing strengths and should:

- specify measurable goals, objectives, and milestones;
- specify needed resources;
- assign responsibility and accountability for accomplishing tasks; and
- be approved by senior-level management.

F.23. Furthermore, measures to assess progress in meeting the objectives of the implementation efforts should be developed. The development of a formal evaluation process to determine the effectiveness of the new process in meeting the census agency's goals is important. The team should develop a formal evaluation process to determine the efficiency and effectiveness of the new process, which should also allow the agency to identify problems so that corrective actions can be developed quickly.

F.24. The implementation of the new business process might involve redeployment and training of some of the NSI's staff. When a business process is redesigned and new information systems are introduced, many of the tasks that staff perform could radically be changed or redistributed. Some positions may be eliminated or cut back, while others are created or modified. Workers may need to take on a broader range of responsibilities, rely less on direct supervision, and develop new skills. The implementation plan needs to identify the new tasks, roles, responsibilities, reporting relationships, and training needs required by the new process. The implementation plan should address training and redeployment as major challenges because generally they require substantial preparation time.

3.3 Change management

F.25. The implementation of a new business process improvement initiative faces multiple challenges including from any organization's natural tendency to resistance change. Often, the greatest challenges arise not from the management of the technical or operational aspects of change, but in managing the human dimensions of change. Widely-shared perceptions and assumptions deeply rooted in organizational culture could deem process improvement initiatives as unnecessary, unworkable, or unfair. To overcome such resistance, NSIs need to begin managing change early in the reengineering process. Unless planning and accountability for change management is given focus, the effort will not be managed well. During the implementation phase especially, mangers must be in the forefront in dealing with the social, psychological, and political resistance to changing the way work is done. Managers must also recognize that their own roles and responsibilities may need to undergo change as well.

F.26. Managers should begin building a change management plan from the very beginning of the project. The plan should present the goals and objectives of the new process (including change management tasks, implementation timetables, assignment of responsibilities) and link the new process to specific issues, questions, and challenges involved in implementation (such as work roles, relationships, performance expectations, supervisory methods, and career path). The plan should include periodic reviews for assessing and responding to the opinions, concerns and needs of staff about the perceived consequences of the new process. Implementation of the plan should educate and encourage staff to accept new ideas and adopt the new process. It should also prepare staff and managers for changes in their roles and career expectations. The change management plan should include provisions for helping employees to overcome concerns about the new ways of doing business.

F.27. Maintaining momentum while implementing the change management plan will often be difficult. In this regard, educating management and staff alike will be important. Unless all line managers and staff understand how the new process can make a difference in their performance, only marginal change will occur. Informed, committed opinion-leaders could be used as champions to create pressure for change. Organizational incentives, including the use of performance evaluation mechanisms could also seed desirable behavioural changes. Education, champions, and incentives can, together, go a long way in removing obstacles and resolving operational issues that can easily stall a work process improvement initiative.

3.4 IT skills and human capacity development

F.28. A sound approach to human capital development calls for viewing personnel as assets whose value to an organization can be enhanced by investing in them. As human capital increases, so does the performance capacity of the organization. Such an approach enables NSIs to effectively use their staff and to remain aware of and be prepared for current and future needs as an organization, ensuring that they have the knowledge, skills, and abilities needed to pursue the mission of the organization.

F.29. The implementation of IT systems-based projects, and the subsequent redesigning of work processes, cannot succeed without the necessary skills and resources for carrying out critical tasks. Effective workforce planning is therefore essential to ensure that organizations have the proper skills, abilities, and capacity for effective management. NSIs will need to perform IT skills assessments and gap analyses to identify mission-critical IT competency and skills gaps and develop organization-wide IT workforce plan and strategies to address any gaps.

F.30. NSIs will need to build sustainable organization-wide IT skills and information management capabilities (including at regional and local offices) that address organizational mission needs through an effective strategic human capital management planning. Strategic workforce planning will need to address two critical needs: aligning an organization's human capital program with its current and

emerging mission and programmatic goals; and, developing long-term strategies for acquiring, developing, and retaining staff to achieve such programmatic goals. The development of the strategic workforce plan will need to involve top management, employees, and other stakeholders in developing, communicating, and implementing the plan.

F.31. It should be noted that the upgrading of the skills and capabilities of line managers is critical for building organizational IT management capabilities. Managers need to have the competencies required to identify important information management issues, opportunities, and decisions. This would ensure that line managers have a better understanding of IT, its management and impact on the line unit's mission, goals, and problems. In the rapidly evolving world of IT, keeping up to date with technological developments is critical. Sustainable improvements in IT management are impossible without upgrading the knowledge and skills of managers and without the establishment of a strong working relationship with IT professionals in the organization. Managers involved in the acquisition and contracting, and management, of IT systems and services need to stay abreast of developments in IT. This is especially important if NSIs are relying to a significant degree on outside contractors and vendors. The chance of a breakdown between the organization and contractors is great when the NSI itself does not have competent IT professionals to assist line management in evaluating and supervising contractor performance. (Training and capacity development activities related to temporarily-employed field staff needed during the enumeration phase of the census are discussed in Chapter E, Section 7.)

F.32. While national approaches to workforce planning will vary, the following are four key practices in effective strategic workforce management and planning:

(i) Assess IT skills requirements

F.33. The first step in the development of an effective strategic workforce plan is the assessment of the competencies and skills that the NSI needs (that is, know the requirements) to effectively perform its IT operations to support its mission and goals. Competency assessment can help identify mission-critical gaps that would challenge the organization's ability to deliver IT-related initiatives, such as the IT systems that are expected to be used in data collection. Unless an organization assesses its IT requirements on an ongoing basis, it risks not identifying the requisite skills and knowledge in its IT workforce. Gaps need to be identified both in the technical and the managerial (such as, project management, budget and cost estimation, management of systems development, data analytics, etc.) spheres. For example, competency gaps in IT could involve cloud computing, engineering systems integration, requirements development, and Internet data collection, etc.

(ii) Inventory the knowledge and skills of IT, field operations and management staff

F.34. The next step is to inventory the knowledge and skills of current IT staff, field operations and management staff to identify gaps in needed capabilities. The organization will need to take steps to develop IT human capital practices based on identified critical IT occupations and select competencies.

(iii) Develop strategies and plans to fill gaps between requirements and existing staffing

F.35. Workforce strategies and plans are needed to implement measures for recruitment, retention, training and professional development to fill any gap between requirements and current staffing. The strategies should be tailored to address gaps in number, deployment, and alignment of human capital approaches for enabling and sustaining the contributions of all critical skills and competencies that will be needed to achieve current and future census-related objectives. Special attention should be given to the development of training programmes for IT staff and other subject specialists involved in census activities generally, and the importance of training programs for building capacity on IT-related tasks implemented by those responsible, in particular, for managing the data collection operation should be understood well and provided on time to enable all relevant staff to work efficiently within their responsibilities.

F.36. The NSI will need to identify a variety of approaches to satisfy current IT and management training needs, including the use of self-paced courses, online courses, on-the-job training, and the use of remote instructors, wherever such features can be applied without reducing the effectiveness of the training. The NSI could also offer special pay incentives to IT specialists.

(iv) Evaluate and report on progress in filling gaps

F.37. It is important to evaluate the progress made in improving IT skills and capacity, and use the results of these evaluations to continuously improve the organization's human capital strategies more generally. The NSI should evaluate its progress in human capital management planning, workforce development, and succession planning. To be effective, the evaluation should be conducted on the basis of the identified IT skills gaps and developed strategies to fill these gaps.

4. IT acquisition management

4.1 Introduction

F.38. Census operations utilizing data collection technologies will need to engage in large-scale IT acquisitions. They also often require an increase in services provided by contracted suppliers. However, given the size of these IT projects, if they are not managed properly, they can become risky, costly and, ultimately, unproductive. It is important that census agencies successfully acquire IT equipment and systems—that is, ensure that the equipment and systems are acquired on time and within budget, and that they deliver the expected benefits and functionality. Census agencies must have a disciplined and streamlined acquisitions process to effectively plan, procure and use IT assets to achieve the maximum return on investment.

F.39. Census projects utilizing new technology involve risk. To minimize such risk, IT acquisitions require the involvement of specialized (most usually, outsourced) acquisition professionals. The acquisition process need to be streamlined, and requirements and cost estimates need to be realistic and need to be developed with adequate input from industry, and with enough communication between a census agency's IT staff and the census program staff who will actually be using the hardware, software and services. Speeding up the acquisition timeline and awarding more successful contracts for IT will require the use of best practices, increased communication with industry, well-functioning and multi-disciplinary program teams, and appropriate project scoping.

4.2 Major procurement items

F.40. The census agency needs to identify those major IT acquisitions that are critical to implement the census project, and define the outcomes that these acquisitions will help realize. Major acquisitions requiring special management attention because of their importance (in terms of cost, schedule and performance) to the objectives of the census need to be identified as early as possible. Major acquisitions should be separately identified in the agency's budget from those requiring small investments. For such acquisitions, the census agency must have a well-documented acquisitions process.

F.41. The major procurement items that need to be understood include those technologies needed for field data collection, management and operations support.

F.42. For the purpose of developing requirements and cost estimates, specific issues need to be understood and conditions established before procurement including:

- Determine mobile devices/hardware and add-ons needed for data collection
- Establish adaptability/configurability of data collection software
- Evaluate data transmission modes for data to be collected

- Understand procedure for receiving, conducting quality assessment, and analysis of data
- Determine mechanisms for ensuring data quality, accuracy and security

F.43. The communication backbone needed to support the field operation as well as database, and security technologies, are also key to achieving a successful census.

F.44. Procurement items for consideration include:

i) Hardware for data collection/operations/management
   - Servers
   - Tablets
   - Laptops
   - Smart phones
   - Add-on support (GPS, Wi-Fi, Camera, etc.)
   - Call Centre technology needs if different

ii) Software applications for data collection/operations/management
   - Operating Systems (Android/iOS/Windows)
   - Database management systems
   - Applications for data collection
   - GIS including Mobile GIS
   - Navigation applications
   - Workforce Management
   - Operations Management
   - Time and Expense Reporting
   - Location tracking/monitoring for operational efficiency

iii) Data transmission/quality and security
   - Online data transmission
   - Offline capability
   - Closed network sharing
   - Partial web mode
   - Voice
   - Short Message Service (SMS)
   - Security (Virtual Private Network)

F.45. Security in this context needs to encapsulate the data available on mobile devices, data protections during transfer from device to the data centre and security of data at the centre. Risks are often related to access to the data by a third party, thus consideration should be given to protect and reduce this risk.

F.46. As noted in Chapter C, a total cost of ownership (TCO) analysis can help provide an understanding of full costs. However, some items may be easy to overlook. Broadband gaps need to be analyzed for example, as well as cost of services where available. Does the enumeration area have coverage by GSM, CDMA, WIFI, etc? Also, licensing fees and data plans need to be examined.

F.47. Issues of device life, ease of use, and training should impact decisions on hardware. Usability concerns include size of keyboard, screen resolution, battery life and size/weight. Security considerations need to extend to both the device as well as the applications. Integration with existing systems such as databases or customer relation management (CRM) systems should be understood. These issues are discussed in more detail in Chapter E.

F.48. Box F.1 shows, as a national example, the major procurements to secure the required equipment, devices, accessories and other related items that were necessary before the 2014 Census in Jordan.

Box F.1: Major procurement items from Jordan Census 2014

ITEM	DESCRIPTION
The Electronic Census Tender	This tender was specific to purchase the Tablet devices, Programming systems for the Census (*Electronic Questionnaire, Field Work Management, Call Center System, Data Processing System, Results Extraction & Dissemination System*), GIS licenses in addition to Systems and Data Transmission Services.
The Data Centre Tenders	1. *Infrastructure Maintenance*: Purchase of adequate air - conditioning systems, firefighting systems, UPS, Electric Generator, Monitoring System, Civil and Electrical Works. 2. *Purchase of Hardware Components*: Servers, Storage System, Network Components (Switches, Routers, Firewalls, and Load Balancers). 3. *Software Licenses*: Microsoft SharePoint, Microsoft SQL Server, Microsoft Datacenter, ArcIMS, Arc SDE, ArcGIS Runtime.
The Call Center Tenders	1. *Infrastructure Maintenance*: Electrical and Civil Work, Desks for Call Center Agents, Headsets. 2. *Call Center:* Hardware (Call Center Servers, Network Switch, Screens, Monitor System) and Software components (Call Center Software).
The Regional Offices' Preparation Tenders	Procurement of required components for the Regional Offices as follows: - Personal Computers and Laptops. - Laser Printers. - Wireless Access Points for Data Connection and Transmission. - Data Show.
The Operation Room Equipment Tender	- Personal Computers - Smart Screens to View Main Dashboards.
The Oracle Database Tender	- Oracle Database Enterprise Edition – Processor Licenses
The Multifunction & Photocopiers' Tender	- Multifunction A3 Black Printer - Production Printer A3 Black Printer - A3+ Color Printer Production Printer
The Media Awareness Campaign Tenders	1. Awareness Publications for the Enumeration Process. 2. Cartoon Movie and a Musical Tune for the Census. 3. School Competitions to Educate the students about the Census and its Importance

4.3 Defining acquisition strategy[33]

F.49. A strategy for large-scale IT acquisitions should be developed as soon as a decision is made on the use of IT for census operations. The acquisition strategy is important in order to ensure census goals are achieved within budgeted costs and established schedules. The strategy should take into consideration that the life-cycle of the acquisitions process comprises three phases: planning and budgeting; acquisition (beginning once the census agency has received funding and ending when the goods and services have been delivered and are shown to be fully operational); and, management-in-use phase (beginning after completion of the acquisition phase, continuing through operations, and culminating with asset disposition).

[33] This section is adapted from Capital Programming Guide. V 2.0. Supplement To Office Of Management And Budget Circular A–11, Part 7: Planning, Budgeting, And Acquisition Of Capital Assets. June 2006.

F.50. The acquisitions strategy should be an integral part of the census agency's strategic planning process, and should be guided by the consideration of (among other issues):

- the strategic objectives of the census project;
- the long-term missions of the census agency and its performance goals;
- the level of budgetary resources that will be available for the census project;
- the total cost of ownership - full life-cycle cost, including all direct and indirect costs for planning, procurement (purchase price and all other costs incurred to bring it to a form and location suitable for its intended use), operations and maintenance (including service contracts), training and technical support, and disposal as well as duties (when sourcing goods and services from outside country);
- linkage to the performance goals for other data collection programs, when IT acquisitions contribute to other data collection operations;
- best practices and successful business models from the public and private sectors; and
- applicable national procurement and financial laws, rules and standards.

F.51. Each census agency should develop an acquisitions plan that describes and lays out the steps to be taken in the acquisitions life-cycle. The acquisitions plan is the ultimate output of the Planning and Budgeting Phase and its development should be overseen by a senior management review process. The plan should include an analysis of the performance and functional requirements and capabilities that the procurement is required to fulfill, cost- and time-schedules, and justification for new acquisitions proposed, as well as summary of risk management measures. The acquisition plan should be realistic enough to be implemented effectively with available personnel, time and financial resources. The plan should be dynamic to reflect changes in decisions.

F.52. The acquisitions process must conform to, and be guided by, applicable national laws and procedures. Similarly, the types of contracts that a census agency (as a public or government entity) can enter into is usually determined by the applicable procurement law. Another important factor to take into consideration is the bidding procedure, which may be different depending on whether the acquisitions calls for international or just domestic bidders. In the event of the need for international acquisitions it is also important to take into consideration any applicable foreign customs, laws and regulations.

F.53. The census agency acquisitions plan may contain descriptions of the following elements (organized by phase):

4.3.1 Planning and Budgeting Phase

F.54. Elements of the planning and budgeting phase include:

i) **Management review process**. Each census agency should establish a formal process for senior management to review and approve the acquisitions plan before the plan is presented to the agency's chief executive for approval. A senior management review group/committee, acting for or with the census agency head, should be responsible for establishing clear lines of authority, responsibility, and accountability for the management of procurement. The committee should also be responsible for reviewing the agency's procurement process on a periodic basis and making decisions to achieve strategic goals and objectives within the budget limits. This committee should be composed of the senior operations executives and the chief information, financial, budget and procurement officers.

ii) Establishing c**ross-functional procurement team**. Each census project requires an integrated, cross-functional team composed of the census manager, IT manager, procurement manager and necessary technical staff from each related unit to plan and manage an acquisition through its life-cycle. The team should consist of the individuals with skills in the following areas: project management, contract oversight, cost estimating, risk management, scheduling, users, budget, technical experts, information resource management, and value management. Staff with other appropriate skill sets should also

participate. The team must: analyze and recommend alternative solutions; develop sound cost estimates; manage the acquisition if approved; and manage the assets once in use.

iii) **Functional requirements**. The procurement team should define the performance requirements to be achieved. Functional requirements should not be defined in equipment or software terms, but in terms of the mission, purpose, capability, the agency components involved, schedule and cost objectives, and operating constraints[34]. A needs-based approach allows the agency the flexibility to evaluate a variety of solutions with an open mind. The key is not to limit potential solutions by too narrowly defining requirements. When developing functional requirements, the capabilities of other assets or processes with which the function must interact are a major consideration.

iv) Conducting market research. Once a clear functional requirement has been identified, market research should be conducted to ensure that as many alternative viable solutions as possible are identified for consideration. Emphasis should be placed on solutions that are currently available (that is, do not require significant development) with little risk in cost, schedule, performance, and technical obsolescence.

v) Selecting the best option. Once the decision to acquire IT equipment and services is made, comparison of the various available options is needed to ensure the acquisition of the best product for the job. When evaluating the feasibility of various options, it is important to factor an estimate of the range of budget resources that may be available for the acquisition. Other important factors to take into account include: availability in the market; affordability; costs and benefits; sustainability; and, risks pertaining to cost, schedule and performance expectations. It is important to note that the 'best' option is not necessarily the cheapest, but the most cost-effective.

vi) Cost-benefit analysis. After sufficient market information on alternative solutions has been gathered, comparison should be made of the initial acquisition cost and the other life-cycle cost elements of the various alternatives. It is critical that the cost estimates are realistic estimates of the final costs and are adjusted to consider risk. When seeking funds during the budget process, the credibility of the costs is important. Alternative solutions that are not affordable within potential budget availability should be dropped from consideration, but documented for comparison purposes.

vii) Risk management. Risk analysis should be an integral part of the planning process and it should involve the entire life-cycle of the acquisitions process. Managing risk should be established early in the planning phase. An effective risk management plan must address the following risk areas:
schedule risk; cost risk; technical feasibility; risk of technical obsolescence; dependencies between a new project and other projects or systems; procurement and contract risk, and resources risks.

viii) Planning for contract type. Census agencies should make good use of contract types by matching the type of contract to how much is known about the requirement, and the likely accuracy of the agency's and the contractor's cost estimates. If the capability that the census agency is seeking is available in the market place, then efforts should be made to use fixed price or fixed price incentive contracts. Otherwise, if the capability sought is not readily available commercially, then resort could be made to the use of cost type contracts, which entail a risky development effort to be undertaken. For long-duration contracts that include significant development, it may be difficult to estimate the cost of performing the entire contract with sufficient accuracy to use a fixed price or structured incentive contract. As the contract progresses and the ability to estimate the cost of performance increases, the use of such contracts becomes more practical. Therefore, it may be desirable to initiate the work with a small, short-duration time and material or cost plus fixed fee contract for studies or early design, evolve to a cost plus award fee or cost plus incentive fee contract for later design and initial development, and then to a cost plus incentive fee, fixed price incentive, or fixed price contract for the initial and production units once all development work is complete. For such contracts, it also may be desirable to

[34] Capital Programming Guide. V 2.0. Supplement to Office of Management And Budget Circular A–11, Part 7: Planning, Budgeting, And Acquisition Of Capital Assets. June 2006.

negotiate an estimated cost or price in increments. The initial estimated cost or price would be for the studies or early design. As work progresses, the estimated cost or price should be renegotiated upward at appropriate points in the contract, as those costs become more predictable.

ix) Planning for competition. The acquisition strategy should include how to make the most effective use of competition in all phases of the process. In most cases, competition will yield better value at lower prices. In looking for ways to make the most effective use of competition, census agencies should pay special attention to using:
(1) performance-based contracting, where innovative solutions are sought to meet functional requirements rather than the more traditional method of detailed specifications;
(2) competitive demonstrations, where several competing vendors are allowed to demonstrate their products or prototypes in an operational environment; and
(3) tender of acquisition items which permit interoperability with others by featuring open architectures.

4.3.2 Acquisitions Phase

F.55. Elements of the acquisitions phase include:

i) Validate planning decisions. At the beginning of the Acquisition Phase, a re-examination of the requirements and market capabilities should be conducted to verify the conclusions reached in the Planning Phase as to whether a commercially available asset can be acquired or limited (or full-scale) development work is needed. The amount of development and complexity of integration are usually the greatest risk factors. Therefore, this validation will have a significant impact on what types of risk treatment and mitigation will be necessary.

ii) Manage the acquisition risk. The most important aspect of the Acquisition Phase is managing the risk continually throughout the life of the acquisition process. Census agencies should also carefully monitor the terms and conditions, including pricing, on which risk allocations are determined, to ensure that they reflect value for money. To ensure that all the elements of the risk are identified, integrated baseline reviews are required either prior to the award or as soon as possible after the award, as appropriate, and whenever a major modification to the program or a baseline change is necessary. This will help to track, manage and report risks, and develop the risk management requirements.

iii) Consider tools for contracting. Various tools permit census agencies to manage risk in the Acquisition Phase. Three such tools are:

- modular contracting (breaking large acquisitions into smaller, more manageable segments or modules);
- advisory multi-step acquisitions (which involves requesting progressively more detailed information on past performance, technical approach and pricing as the steps increase, with the final step involving short-listed offerors being invited to submit final proposals on cost, schedule and performance baselines, risk management plans for selection of the best offeror for award of the contract); and
- competitive demonstrations/prototyping (in which contractors are requested to develop prototypes of their system design concepts to facilitate information exchange on requirements and market capabilities and to mitigate the risk of full-scale or limited development; the contractor would be ready to move to full-scale production after satisfactorily completing the prototype).

All of these tools can be used in combination with each other.

iv) Select contract type and pricing mechanism. It is incumbent upon the census agency to clearly define the performance requirements and estimated costs for major acquisitions before request for proposals (RFPs) are issued. This up-front planning work allows the agency to assess the amount of risk to the contractors and select the appropriate contract type to protect both the agency and contractors from a high probability of program failure so as to achieve cost, schedule and performance goals. The

objective is to negotiate a contract type and price (or estimated cost and fee) that will result in a reasonable contractor risk and provide the contractor with the greatest incentive for efficient and economical performance. Agencies should make good use of contract type by matching the type of contract to how much risk there is in meeting the requirement. Ultimately, the risk of any census related failure, always rests with the census agency rather than the contractor. It is the agency that is legally responsible for the census.

v) Issue the tender. Tender solicitations should make the most effective use of competition. Generally, increased public exposure to agency functional and performance objectives will increase not only the quantity of the tender, but also the quality of the procurement. Publicizing the tender is important, especially when trying to expand the supplier base for major acquisitions beyond those few firms that regularly sell only to the government (sometimes so dependent on government business that a monopoly exists) to include firms with significant commercial sales.

vi) Proposal evaluation. Proposals should be evaluated based on the evaluation criteria in the tender. The reviewers should determine to what extent each proposal meets the criteria included in the tender and compare the proposals with each other based on those determinations. The reviewing team should prepare analyses and recommendations for presentation to senior management for approval. In selecting from competing alternatives, the reviewers, consistent with the tender, should consider functional and performance capabilities of the proposed solutions in relation to the mission needs and program objectives, including resources required and benefits to be derived by trade-offs, where feasible, among technical performance, acquisition costs, sustainable design principles, ownership costs, and time for development; and the competitors' relative previous performance record. They should also consider compliance with governmental standards and rules.

vii) Contract award. The reviewing team selects the successful contractor. The award decision should ensure that any higher price paid is worth the perceived benefits, and is within the planned funding level for the census project. However, if cost, schedule or performance parameters that are proposed by the contractor offering the best value to the census agency do not achieve program objectives within funding limitations, the team should discuss the funding shortfall with the management review committee. The committee will then decide if the project's revised cost-benefit ratio, in comparison with other potential projects, remains large enough, given the new information, to warrant award of the contract. If not, the reviewing team should terminate the acquisition and evaluate how and why the process failed. The cancellation of any potential contract at this stage would be a major issue, since, within the limited timeframe for planning the census, there may be very little time available to tender and negotiate a new contract, given how time-critical the census activities are.

viii) Contract management. The success or failure of the acquisitions process to achieve cost, schedule, and performance goals can significantly affect the census agency's ability to maintain budget discipline and achieve its strategic plan. Managers need visibility early on into a contract's progress to identify any problems. This allows time for contractors and the agency to implement corrective actions before significant deviation from goals results. The agency’s financial management and control systems should have activity-based costing capability to accumulate the actual costs of the project and integrate them with performance indicators.

ix) Acquisition analysis. The procurement team should receive regular status reports from the contractor on the acquisition. If the acquisition is not achieving cost, schedule or performance goals, the team should determine the reasons for the deviations and the corrective actions planned by the contractor. The corrective actions should be evaluated as to whether they are likely to be effective. If the corrective action cannot return the contract to within the goals before contract completion, it must at least ensure that the deviations will not continue and that the current estimates to complete the contract are realistic. Agencies should establish thresholds for deviation from the goals that require the senior management group review committee notification when exceeded. If it should be the case that the threshold goals will not be achieved at contract completion, the team should prepare an analysis of the estimated changes in cost, schedule, and performance goals and whether the acquisition would

remain cost-beneficial, and should continue to receive priority in comparison to other projects at the new funding levels. It is important to note that a recommendation to reduce the performance requirements will also affect the amount of cost and schedule overruns.

x) Acceptance. Acceptance is the final step in the Acquisition Phase before the acquired IT equipment and services move to the Management-in-Use Phase. The procurement team should ensure the acquired IT equipment and services meet the requirements of the contract. Often this will be accomplished through an acceptance test plan. Acceptance testing can be performed during and/or at the end of contract performance. Effective testing will determine whether or not the agency received the benefits it anticipated and the system is acceptable for use in accomplishing the agency's mission. Where appropriate, independent validation, verification, quality assurance processes, and regression testing should be included as part of testing for acceptance. Agencies should also ensure that unacceptable ratings with respect to contract requirements are effective disincentives to contractor's poor performance. When appropriate, agencies should withhold payment or fee depending on the contract's payment mechanisms. Agencies should also make it a policy to use accurate performance ratings in subsequent contract award decisions. If the agency accepts the asset with deviations from the contract requirement, these deviations should be documented, including any consideration (such as a reduction in price) received from the contractor as required by the contract. The evaluations must reflect an accurate summary of the contractor's performance in meeting the cost, schedule and performance goals from the beginning to the end of the contract.

4.4.3 Management-in-Use Phase (Post-acquisitions phase)

F.56. Elements of the management-in-use or post-acquisitions phase include:

i) Objectives during management in-use phase. The key objectives during the Management-in-Use Phase are to demonstrate that the existing investment is meeting the needs of the census agency and to identify more cost-effective methods for delivering performance and value.

ii) Operational analysis is a key tool. Operational analysis is a method of examining the ongoing performance of an operating investment and measuring that performance against an established set of cost, schedule, and performance goals. Operations is a critical area where improved effectiveness and productivity can have the greatest net measurable benefit in cost, performance, and mission accomplishment. A periodic, structured assessment of the cost, performance, and risk trends over time is essential to minimizing costs in the operational life of the asset. Beyond the typical performance measures of cost and schedule performance, an operational analysis should seek to answer more subjective questions in the specific areas of: customer satisfaction; strategic and business results; financial performance; and innovation.

iii) Operations and Maintenance. Poorly performing assets detract from mission effectiveness by utilizing resources that could be used more effectively to support other mission priorities. If not properly managed, an asset's useful life can be shortened dramatically or prolonged beyond the planned termination date at high cost and risk. Each agency should have an Operations and Maintenance (O&M) plan that outlines the procedures and responsibilities for scheduled preventive and regular or routine corrective maintenance.

iv) Post Implementation Review. The Post Implementation Review (PIR) for IT projects is a tool to evaluate the overall effectiveness of the agency's acquisition planning and management process. A PIR is usually undertaken either after a system has been in operation for a little time or immediately following investment termination. Some common elements reviewed during the PIR include: mission alignment; IT architecture including security and internal controls; performance measures; project management; customer acceptance; business process support; financial performance; return on investment; risk management; gaps or deficiencies in the process used to develop and implement the initiative; and best practices that can be applied to other IT initiatives.

v) Asset disposition. Asset disposition is the culmination of previous planning, budgeting and acquisition efforts. Agencies should have established practices and documented decision models for the disposition of assets. It is important that agencies comply with the relevant governmental laws and regulations when disposing of assets, depending upon the type of asset involved.

4.4. Critical success factors for IT acquisition[35]

F.57. Based on best practises from the private and public sectors, the following factors are identified as critical to the success of large-scale IT acquisitions:

i) Senior management support. Census agency leadership is critical for the success of major IT acquisitions. Senior managers could contribute to success in various ways, such as by procuring the necessary funding, providing necessary information at critical times, intervening when there are difficulties working with another department, defining a vision for the acquisitions plan, and ensuring that end users participate in the procurement process.

ii) Procurement staff having the necessary knowledge and skills. The knowledge and skills of the procurement staff is critical in large-scale IT acquisitions as individuals who have developed the knowledge and skills needed are more likely to perform their roles effectively and efficiently. This includes knowledge of acquisitions and procurement processes, monitoring of contracts, large-scale organizational transformation, software development concepts, and program management and technical monitoring.

iii) Active engagement of procurement team with stakeholders. Active engagement with stakeholders—individuals or groups (including, in some cases, end users) with an interest in the success of the acquisition—is a critical factor for the success of the procurement. Stakeholders engagement is valuable in identifying issues, problems and concerns as early as possible.

iv) Participation of end users and stakeholders in the development of requirements. The involvement of stakeholders—including census users—in the requirements development process is another factor that is critical to the success of the acquisitions process. When such users and stakeholders communicate their requirements throughout the procurement life cycle, the resulting system is more likely to perform as intended in order to meet, in particular, users' requirements.

v) End users' participation in testing of system functionality. The involvement of the census user in testing and validating the system components prior to formal end user acceptance for deployment is critical. Testing of functionality by end users prior to acceptance demonstrates, earlier rather than later in the program life cycle, that the functionality will fulfil its intended use. If problems are found during this testing, programs are typically positioned to make changes that are less costly and disruptive than ones made later in the life cycle would be.

vi) Experience of census agency and contractor staff. Both the agency's and contractor's personnel are an important resource, and their experience within their own organizations is a contributing factor to success. Lengthy experience ensures having consistent and adequate skilled staff resources to be available during the life-cycle of the acquisition process. In particular, having consistent and stable staff can allow teams to keep pace with their workload, make decisions, and have the necessary accountability.

[35] Adapted from United States Government Accountability Office (GAO), Information Technology: Critical Factors Underlying Successful Major Acquisitions, GAO-12-7 (Washington, D.C.: October, 2011).

vii) Prioritizing requirements. The prioritization of requirements enables the efficient and effective development of system functionality. Having prioritized requirements ensures that those functionality and quality requirements most critical to the end users are deployed before less-important requirements.

viii) Regular communication with the prime contractor. Regular communication with the prime contractor is critical to the success of the acquisitions process. This communication should be proactive and regular to ensure proper coordination and the rapid identification and resolution of problems. A positive, non-adversarial relationship with the prime contractor can help create rapport with an expectation of full and honest disclosure of problems. This ensures that requirements are clearly understood, and that risks and issues are identified and addressed earlier rather than later in the process, thereby increasing the likelihood that the delivered system will meet its intended purpose and resulting in less costly and less disruptive changes.

ix) Sufficient funding. Sufficient funding is essential to the success of large-scale IT investments. Investments that receive funding commensurate with their requirements are better positioned to ensure the availability of needed resources, and therefore, deliver the investment within established goals. Sufficient funding relies on strong and committed leadership from senior management and its ability to obtain support from government.

x) Continuous risk management. Risk management is critical to large-scale IT investments. The early identification of risks can allow the development of effective mitigation strategies. Involving census users early and often in risk management measures also helps to ensure that their requirements are evaluated as thoroughlyas possible.

xi) Identify and adopt IT acquisition best practices. The study of the experience of those agencies that have already created specialized IT acquisition teams can help to develop a model to adopt. Among the key questions to be considered will be the length of time individuals need to spend devoted solely to IT acquisition in order to add value to IT program teams, the kind of training and experiences that are most valuable, appropriate organizational structures, and successful acquisition strategies and practices.

4.5. Considerations for outsourcing

F.58. Census agencies may choose to contract out several activities relating to the census project because of staffing, financial, time, or expertise constraints. However, it should be pointed out that not all census tasks are appropriate for outsourcing or contracting out, and doing so will not necessarily bring the desired benefit of strengthening national capacities[36]. Census activities may be broadly classified as core and non-core activities. As a general rule of thumb, core activities should not be contracted out. If for some reason core activities need to be contracted out, then it is essential that the strategic control of such activities should firmly be with the census authorities at all times.

F.59. Issues associated with contracting out services in a census operation are elaborated in the *Principles and Recommendations for Population Housing Censuses, Revision 3* and the *Handbook on the Management of Population and Housing Censuses, Revision 2*. Some of the major considerations that have to be taken into account when outsourcing, as articulated in the above-mentioned publications, include:

4.4.1. Capacity to oversee outsourced operations

F.60. In the context of contracting out components of the census operation, the NSI would need to build the capacity to ensure proper outsourcing. This is of primary importance, particularly at the preparatory stages, as outsourcing requires a solid and comprehensive knowledge of contemporary

[36] Principles and Recommendations for Population Housing Censuses, Revision 3.

technologies and their advantages and disadvantages, as well as past experiences either domestically or in other countries. Consequently, the NSI would need to appoint and develop a particular unit for the purpose of ensuring adequate and efficient outsourcing well in advance of the census itself, as there would need to be extensive testing of the products and services that were contracted out. The NSI will need to have the capacity to understand the requirements and costs, and define the terms of engagement (scope of work), the deliverables and the timelines to the service providers. Given, the inevitability that any external resource provider will have additional or different objectives from those of the NSI, careful control is needed to ensure that the selected external provider delivers a cost-effective solution that meets the census office's needs.

4.4.2. Monitoring outsourced projects

F.61. It is important that outsourced projects are carefully monitored against the contract specification. A plan should be developed to monitor performance, quality and cost in order to apply any necessary preventive measures. This monitoring should include early identification of problems as census operations are time critical. In cases of problems arising with regard to critical activities, contingency plans should be in place in order to deal with any failure on the part of the suppliers.

F.62. In addition to monitoring the providers of goods and services, NSIs need to plan for continuous interface with the providers. This implies an additional step to monitoring and amounts to a necessity to work closely and on a regular basis in order to ensure the best quality of the products and services and to meet the standards and needs of the census operations.

4.4.3. Communication with contractors

F.63. Clear and open communication is a critical success factor in managing outsourced census activities. Regularly scheduled meetings between census agency and service provider staff is essential for managing external relationships and ensuring that expected contract results are achieved. Compliance with scheduled completion dates should be specified as a contract requirement, with listings of key attendees from all parties specified in the contract. The frequency of the meetings should be specified along with responsibility for recording decisions made or items agreed to.

4.4.4. Confidentiality

F.64. Confidentiality assurance is an important issue that should be considered by national statistical offices. NSIs are responsible for data confidentiality, in terms of both perception and legally. Consequently, contracting out of tasks that have the risk of a breach of confidentiality should be avoided. Protecting data confidentiality refers not just to the actual protection of personal census data, but also to protecting the perception of confidentiality among the general public and assuring internal security. It is important to ensure that bidding companies have good track record and good reputation for commitment to all ethical and legal contract clauses.

4.4.5. Quality assurance

F.65. The guarantee of quality assurance in the outsourcing environment is critical. Low-quality work could cause a significant loss of trust among the general public. To assess the quality of work, as part of the contract allocation process, potential contractors should be required to provide samples of their work (for example, software applications, design of IT systems used for similar projects, and other work), and to list referees who could be contacted to verify their claims or sites at which previous work can be inspected. The contracting process should state all the key requirements for the services sought and bidders should be measured against these.

F.66. Once the contract has been awarded, continuous monitoring of the progress of work entrusted to the selected company is necessary, and the NSI should ensure that a system for monitoring quality is built into the contract. Suppliers should be made fully aware of the quality targets at the outset of the

census programme, and the quality requirements of the outsourced components that enable the overall census quality target to be achieved. Operational quality control should apply to outsourced services in the same way as those that are carried out by the NSI.

4.4.6. Evaluation of a supplier's performance and documentation of this process

F.67. On completion of a contract the NSI should prepare an evaluation of the supplier's performance. This should be carried out promptly while the relevant facts are fresh. Points which could be covered in an evaluation include: a description of the work done; the quality of the work performed when measured against the original specifications; the quality of communication maintained during the project; the supplier's adherence to the schedule; and comments regarding the possible selection of the supplier for any future contract.

F.68. Last but not least, documentation of outsourced activities and decisions made is important for the purpose of institutional memory, as is the transfer of knowledge to NSI staff. There should be a training plan to ensure smooth transfer of know-how to the team with the aim to prepare them to implement similar projects in the future.

5. IT systems development

5.1 Introduction

F.69. The decision to invest in IT often leads to the acquisition or development of IT systems. The decision as to which approach best delivers the required solution—that is, whether to build internal systems or purchase existing commercial-off-the-shelf (COTS) solutions—should be based on rigorous market research, testing, technical reviews, analysis and consideration of such factors as strategic importance, cost and availability of time, and internal programming resources. The build versus buy decision is a critical one. Choosing incorrectly could result in an inadequate solution or a poor return on the NSI's investment. Once a clear a functional requirement has been identified, market research should be conducted to ensure that as many viable alternative solutions as possible are identified for consideration. Where acceptable commercial solutions are available, emphasis should be placed in using currently available standards-based software and commercial off-the-shelf solutions (COTS) with little risk in cost, schedule, performance, and technical obsolescence over custom development. When market capability is not sufficient to fulfill an agency's performance requirements, consideration could be given to custom development. In many cases, a hybrid approach, consisting of integrating the best COTS platforms with specific in-house solutions developed with the involvement of census experts, is the recommended approach to build the infrastructure needed to support census data collection.

5.2 Major IT components for electronic data collection (to develop/acquire)

F.70. The IT infrastructure for electronic data collection refers to the entire collection of hardware, software, networks and telecommunications platforms, data management and storage, facilities and related equipment used to develop, test, operate, monitor, manage and/or support information technology services required for the data collection operation. The IT infrastructure that supports an electronic data collection is usually based on a hybrid design, which entails an approach in which the census agency provides and manages some IT resources in-house but uses contracted services for others. A well-designed and reliable infrastructure that can handle the anticipated workload and ensures smooth work continuity is a pre-requisite for the success of the electronic data collection process. Figure F.1 presents a generic model for a high-level network topology for electronic data collection operations, showing the main components and functions, interactions, and data flows between these components.

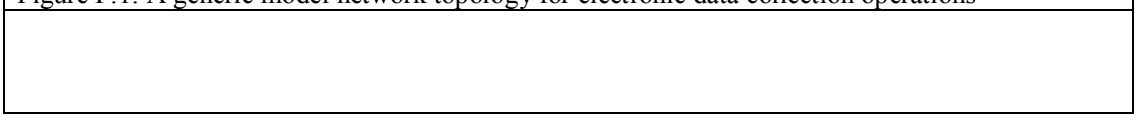
F.71. The IT infrastructure for electronic data collection may consist of the following major components:

5.2.1 Data collection application

F.72. The functional requirements, or capabilities, needed for a data collection application through the use of tablets or other handheld electronic devices, include the ability to:

- Collect response data during field operations; navigate intuitively within the instrument and allow a user to move to the next applicable question, including use of skip patterns, when specified; transition screen-to-screen on the monitor in a timely fashion; and define and display context sensitive error messages to alert users;
- Implement business logic to validate data; flexibility to support multiple types of data validation;
- Provide mechanisms for data transmission: ability to securely receive, store, and send data; ability to automate updates without user intervention; allow for wireless device connectivity; allow for the device to be used in both connected and disconnected mode; synchronize (sync) data manually and automatically;
- Ability to collect and send metadata; and log and time stamp all application events and user actions during an interview;
- Display in other languages and the ability to switch between languages at the start of, and at any time during, an interview;
- Ability to interface with other systems;
- Provide multiple mechanisms to ensure data security and confidentiality; ability to require interviewers to log in, reset and maintain passwords; ability to lock user out of the application at any point; and allow use of encryption and decryption techniques and multi-stage back-up technologies;
- Allow for GPS-enabled capabilities to enhance enumerators' productivity: display electronic maps on mobile devices; capturing of the spatial coordinates; ability to navigate to a specific geographic location; ability to notify enumerators that they are out of the expected geographic location; capability to view assignments and status as points on a map; and provide the ability to locate the device;
- Manage field work to enhance productivity and data quality: ability for enumerators to display the status and manage their case assignments on a mobile device at any time during the interview; ability to manage field staff workloads; ability to view an enumerator's work assignment; ability for enumerators to manage (track, edit, complete) their assigned cases; ability to allow appropriate staff to see the current set of alerts that need to be monitored and all of the progress and quality metrics reports used to derive the alerts being monitored; and ability to allow field managers to reassign staff, to specify the enumerator, and/or timeframe required.

Figure F.1: A generic model network topology for electronic data collection operations



5.2.2 Data transmission system

F.73. A data transmission system is needed to allow the transfer of data from remote geographical locations to centrally located data storage repositories through wireless or cellular networks. Appropriate and secure networking and telecommunications platforms are needed to effect data transmission. Census agencies usually procure data plans from telecom service providers for this purpose.

F.74. In areas with no, or poor, cellular connectivity, it would be necessary to establish data collection stations in order to supply the field team with the necessary infrastructure to accomplish their tasks, including data transfer. The expected structure of such stations consists of a computer to monitor the field work, used by the supervisor, with connectivity to the data reception service and central servers, memory sticks, battery chargers and voice over internet protocol (VOIP) phone to allow communication to a regional station/headquarters.

5.2.3. Data centre

F.75. A data centre is a physical facility that houses IT equipment used to process, communicate, and store data. Data centres are mission critical facilities for electronic data collection operations and must have the reliability to keep the data integrity, capability to work with a high loaded data base.

F.76. The IT resources needed to equip a data centre can be categorized into three groups: servers, communication gear, and storage equipment.

- **Servers** run software applications and are usually mounted in racks within the data center.
- **Communication gear** or networking gear (such as routers, switches, firewalls) manages how data is transferred in and out of the data centre and between the IT equipment.
- **Storage equipment** is where all the data is stored. Storage arrays, like servers, are also usually mounted in racks.

F.77. Such IT equipment also need two operational requirements: electricity for power and cooling for removing the heat that it generates. To maintain the security and integrity of the data collection operation, the data centre must be equipped to provide both electricity and cooling without any interruption through the provision of uninterruptible power supply (UPS) system, diesel generator, air conditioning system, fire alarm and fighting system, monitoring and security system, etc.

F.78. In terms of software, a data centre will need to have the appropriate operating systems for the servers, a database management system for data storage and application services for hosting.

F.79. The major architectural and structural components that make up a data centre are as follows:

- **Data reception.** This service is essential for permitting data transmission between field staffs' devices or respondents' devices (in the case of Internet collection) and the centralized servers processing environment. The data reception service is responsible for accepting this transmissions from the field, checking to ensure the transmissions are being made by authorised persons. It is recommended to load balance37 this service, as the reception service is a highly requested server.
- **Data aggregation.** This service has a great importance on the whole data collection process, as it is responsible for working with the collected data and checking it for its consistency and reliability as well as for data aggregation. It is recommended to separate this service from the reception, to avoid the sharing of server resources, and in order to allow data processing work to be performed inside a more safe environment.
- **Data storage.** Data management and storage is handled by database management software and storage devices include traditional storage methods, such as disk arrays, and newer network-based storage technologies such as storage area networks (SANs). SANs connect multiple storage devices on dedicated high-speed networks.

5.2.4. Disaster recovery site

[37] In computing, load balancing is the process of distributing workloads across multiple computing resources, such as computers and servers.

F.80. A disaster recovery (DR) site is a facility that an organization can use to recover and restore its technology infrastructure and operations when its primary data centre becomes unavailable. The decision about what kind of DR site an organization needs and its location requires careful planning and a balance of costs against any risks. There are two fundamental DR site options: internal and external. An organization itself sets up and maintains an internal site while an external site is one that is owned and operated by an outside provider. NSIs with large information requirements and aggressive recovery time objectives are more likely to use an internal DR site. The internal site is typically a second data centre and allows the NSI to recover and resume operations following a disaster at the primary centre.

F.81. In the context of a census operation, the disaster recovery site should perform two main functions:
- continuity of the field work if significant problems or failures occur in the main site; and
- data replication (another copy of the database) should be made at short regular intervals (such as every 15 minutes) between the main and Disaster Recovery Site.

F.82. The infrastructure for a disaster recovery site should provide back-up for each component of the main data centre site (servers, network components, connections, data lines from/to the data centre) to ensure continuous functionality and eliminate any possibility of failure that may affect field work.

5.2.5 Central Operation Control System

F.83. This system is developed and used to serve for monitoring progress and quality of data at headquarters from the first step of collection in the field. It helps in taking a clear vision of the progress of work and data quality.

F.84. Among the capabilities that a Central Operational Control System can provide are the ability to:
- define, execute, and manage business rules for operational control;
- route a workload to specified data collection modes (such as computer-assisted interview, paper, Internet, telephone interview);
- execute workflow interventions based on response data and status information on enumeration; and
- create the non-response follow-up universe of addresses on a daily basis.

F.85. The system also provides a user interface for viewing operation and case status/tracking. It could, for example, display the current status of all cases on a set of parameters (mode of collection, geographic location, number of cases per status type, current status) for a census processing period, and generate reports that enable the progress of the enumeration and performance of the enumerators to be assessed. It can facilitate a review of the data collection operation through interactive reports and dashboards, which display reports including tables, graphs and electronic maps. The system could also provide tools to perform analysis based on information and indicators generated by the monitoring system.

F.86. Such systems are usually web-based applications, and, if accessed by a large number of users, they should be hosted in a load-balanced manner. Security measures should also be taken to avoid unauthorised access.

5.2.6 Call centre

F.87. The call centre can be used to perform a variety of functions during a census operation including:
- responding to population inquiries and complaints;
- providing technical support to field-based teams (such as problems with use of tablets, data transmission, etc); and,

- reviewing and verification of data collected through other data collection methods in order to fix data problems made by the enumerator in the field (such as incomplete questionnaires, data validity of data by contacting households) and thus improve data quality.

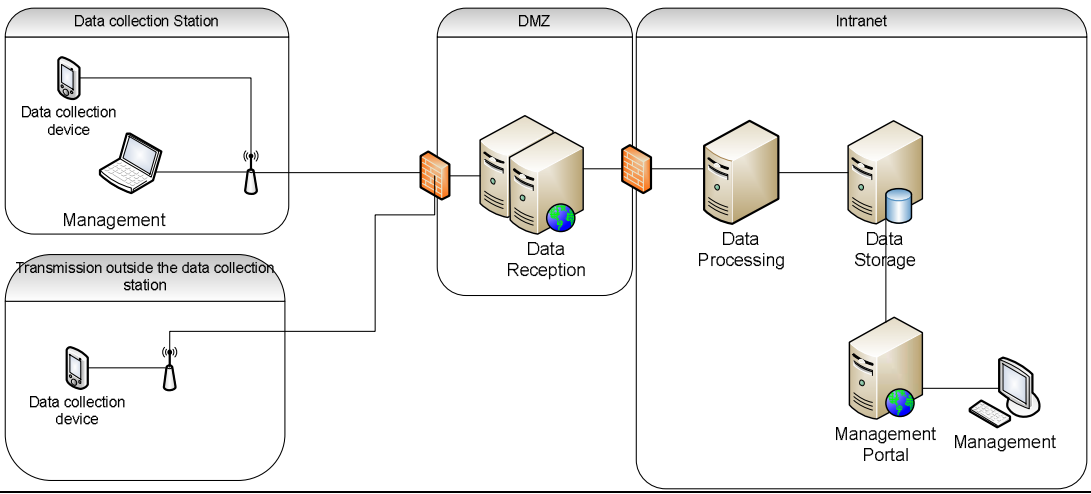
F.88. The call centre should be considered an essential and integral component of the census's IT systems. Among important functional requirements for a call centre are capability for:
- effective logging, recording and monitoring incoming and outgoing calls;
- an interface that provides simplicity and ease of use;
- routing calls for escalated enquiries and follow-up; and
- generating reports;

F.89. The deployment of an advanced technology with appropriate hardware and software can result in streamlined call handling which reduces call times and associated costs, and improves customer satisfaction. Hardware that is essential for setting up a call centre includes:
- a local area network (LAN); desktop computers for agents;
- an automatic call distributor for call routing to specific agents or terminals;
- a predictive dialler, which will automatically dial batches of numbers for outgoing calls from the centre;
- headsets selected carefully for clarity of sound, noise reduction and comfort; and
- voice solutions such as an interactive voice response (IVR) system, voice logging, voice recording and messaging systems.

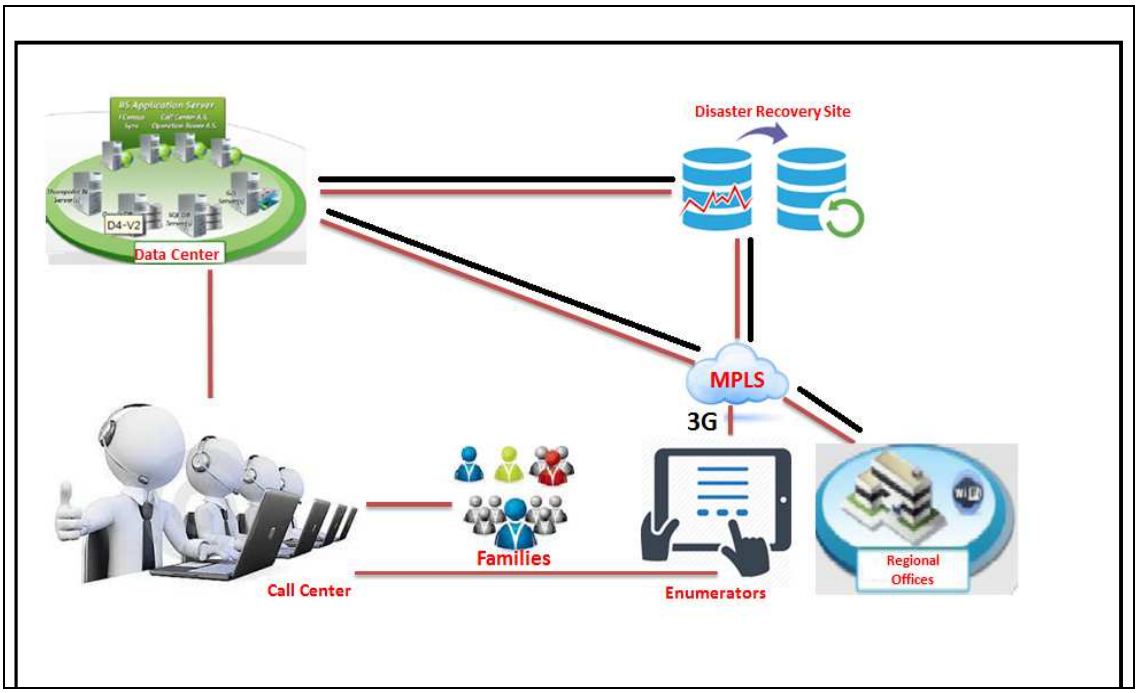
F.90. Software that enhances a call centre includes:
- customer relationship management systems;
- call centre interface;
- workforce management solutions;
- management information systems;
- voice over Internet protocol (IP) recording systems to monitor agent calls.

F.91. A software system is also needed to link and integrate the call centre system to the census database for the purpose of data quality control.

Box F.2: Brazil Census 2010 IT infrastructure for electronic data collection



Box F.3: Jordan census 2014 - network topology for the census



5.3 IT systems development methodology

F.92. System development projects need structure and organization from inception to completion in order to produce the systems on time and within budget. Following a structured process enables system development projects to be organized and have a clear path to completion. Unless such projects are well-organized and documented, even a fairly simple software project can become complicated very quickly. Many projects fail or miss deadlines and result in cost overruns for the simple reason that thorough analysis and design are not done up front and risk is not managed.

F.93. The decision to invest in IT for data collection purposes almost inevitably leads to the acquisition or development of IT systems. To manage that development, organizations often employ a system development methodology. The System Development Life Cycle (SDLC) is a conceptual model for system/software development that divides up the process into different phases, each of which has a distinct role to play in the development life cycle, and is a building block for the next phase. There are several different SDLC methodologies, each emphasizing different aspects of the life-cycle, that can be used to develop IT systems. Implementing a structured approach requires selecting a model and utilizing it throughout the development life cycle.

F.94. Among the various SDLC methodologies that can be used by an NSI to effectively develop an information system is the traditional SDLC - a linear sequential model (also known as waterfall method). The **waterfall model** begins with requirements development and continues sequentially through other phases—design, build, and test—using the output of one phase as the input to the next so as to develop a finished product at the end. This model allows the status of a development project to be easily identified and tracked based on the current phase of the project. Another SDLC method uses the prototyping model, which is often employed to develop an understanding of system requirements without actually developing a final operational system.

F.95. More complex models have been developed and successfully used to address the evolving complexity of advanced, and sometimes large, information system designs. Examples of these more complex models include the **spiral model** and the **Agile model**. The **spiral model** uses a risk-based approach to incrementally build a system by cycling through four development phases. Using this

model, each spiral, or incremental cycle, typically starts by determining the development objectives and scope for the increment. Next, alternative solutions are evaluated, and risk management techniques are employed to identify and reduce risks. Then, a product for the increment (such as a prototype) is developed. Finally, the product is evaluated to determine whether the increment's initial objectives have been met. The **Agile model** focuses on short-duration, small-scope development phases that produce segments of a functional product. This model operates with similar phases to the traditional waterfall model—requirements, design, build, and test—but uses a shorter development cycle to achieve multiple iterations in similar time frames. The Agile model produces software in small, short increments.

F.96. The expected size and complexity of the system, development schedule, and length of a system's life will affect the choice of which SDLC model to use. Careful consideration of each phase of the SDLC will greatly increase the chances of a successful project. The SDLC can be beneficial to a system development project regardless of the size or complexity of the project if the conceptual model is followed.

F.97. The NSI should have a documented SDLC guideline that should support the agency's business needs and reflect the agency's IT management capability, complexity of needs, and procurement preference. For example, some agencies maintain a development operation that builds and maintains systems while others outsource development and, potentially, maintenance as well. The former may require a more detailed guideline, while procurement-centric operations may need only objectives, service levels, and deliverables detailed.

F.98. The main elements of system development life-cycle (adapted from the traditional waterfall SDLC methodology and alternate development models) may include the following phases: initiation, system concept development, planning, requirements analysis, design, development, integration and testing, deployment/implementation, operations and maintenance, and disposition.

i) Initiation. During the initiation phase, the need for a system is expressed and the purpose of the system is documented. In addition, it is often determined whether the project will be an independent information system or a component of an already-defined system. A preliminary risk assessment is typically conducted in this phase. Once these tasks have been completed and a need has been recognized for a new or enhanced IT product or service, several processes must take place before the project is approved, to include clearly defining project goals and defining security requirements.

ii) System concept development. This phase involves a set of activities to identify and prioritize operational needs and challenges, develop alternative concepts to meet the needs, and select a preferred one as the basis for subsequent system development and implementation. The success of the subsequent development of a system can critically depend on the soundness of the foundation that is laid during the concept development stage. Communication among the key stakeholders - the research team, the software engineers, the project manager, stakeholders, and funding sponsors - is critical in this phase in order to ensure that proper requirements are obtained and documented.

iii) Project planning. The planning phase further extends the system concept, describing how the business will operate once the approved system is implemented and assessing the system's impact on business processes and the operational users/customers. To ensure that the system can deliver the products and/or services required on-time and within budget, the project resources, activities, schedules, tools, and reviews should be defined and detailed and documented in plans. The planning phase is the most critical step in completing development, acquisition, and maintenance projects. Careful planning, particularly in the early stages of a project, is necessary to coordinate activities and manage project risks effectively. The project plans refine the information gathered during the initiation phase by further identifying the specific activities and resources required to complete a project.

iv) Requirements analysis. During this phase, the IT team analyzes the requirements of the system to gain a clear understanding of what is required in terms of desirable functionality and quality

attributes. In this phase, it is essential to determine where and how the system will be used, who the users will be, and document everything for use in the (next) design phase. The requirements development activities should involve an analysis of scenarios with relevant stakeholders and end users. The team members must document even the seemingly trivial details gleaned during analysis, because these are the things that (very often) turn out to be very important for the proper execution of the software product.

v) Design. In the design phase, the analysis that was done in the previous phase is reviewed and the software engineer/IT team devises a design solution. The design must support the requirements and be as explicit as possible. Software design tends to start out relatively simple, but as all the requirements are considered, systems tend to become complex and unwieldy. It is good practice to prioritize the features based on importance and effort while putting together the design. A solid architecture and design will avoid significant reworking later on. Mainstream technology usually follows industry standards and is supported well; therefore, problems can quickly be resolved when they arise. Since the technology is innovative, bugs and other technical issues may be present, and, if so, will need to be dealt with as they are encountered. When problems arise, quick solutions may be difficult to craft because the knowledge base and support is sometimes very limited. Even minor problems in these technologies can cause a cascade of modifications that need to be implemented and which can then adversely affect the whole project schedule and ultimately jeopardize the entire project. Technical complexity increases the risk for the software project and should be avoided if possible as they can negatively impact the schedule and cost.

vi) Development/acquisition. In this phase, the system is designed, purchased, programmed, developed, or otherwise constructed. During the first part of the development/acquisition phase, the NSI should simultaneously define the system's security and functional requirements. These requirements can be expressed as technical features (such as access control), assurances (such as background checks for system developers), or operational practices (such as awareness and training). During the last part of this phase, the NSI should perform developmental testing of the technical and security features/ functions to ensure that they perform as intended prior to launching the implementation and integration phase.

vii) Integration and testing. During this phase, the system specified is assembled from the parts developed during the previous phases and methodically tested. System integration occurs when distinct software modules are linked together and are capable of functioning as a unit. When there are multiple software engineers on a project, it is vital for all the developers to code to an accepted standard. Because modules need to work together, a common protocol must be followed. System testing helps to locate problems, and potential problems, with a software system. It is essential to have people other than the software engineers testing the software. It is a good idea to develop test plans to ensure that the testers adequately test critical functionality as well as less important items. For larger software projects, reporting bugs and prioritizing remedies will be a coordinated effort between the project manager, software engineer, and testers. In smaller software projects, testing tends to be straightforward, but in large projects it is very time consuming to test every scenario, so adequate time must be allocated for testing in the schedule.

viii) Deployment/implementation. During this phase, the system is installed, and made operational in the production environment. The phase is initiated after the system has been tested and accepted by the user and project manager. Design reviews and system tests should be performed before placing the system into operation to ensure that it meets all required security specifications. The results of the design reviews and system tests should be fully documented, updated as new reviews or tests are performed, and maintained in the official NSI records. Activities in this phase include notification of implementation to end users, execution of the previously defined training plan, data entry or conversion, and post implementation review. This phase continues until the production system is operating in accordance with the defined user requirements.

ix) Operation and maintenance. During this phase, systems and products are in place and operating. Enhancements and/or modifications to the system are almost always developed and tested, and hardware and/or software is added or replaced. During this phase, the NSI should continuously monitor performance of the system to ensure that it is consistent with pre-established user and security requirements, and any required system modifications are incorporated. Information systems are typically in a constant state of evolution with upgrades to hardware, software, firmware, and possible modifications to the surrounding environment in which the system resides. Documenting information system changes and assessing the potential impact of these changes on the security of a system is an essential part of continuous monitoring, and key to avoiding a lapse in the system security accreditation.

x) Disposal. The disposal phase of the system life cycle refers to the process of preserving (if applicable) or discarding system information, hardware, and software. Activities conducted during this phase ensure the orderly termination of the system, safeguarding vital system information, and migrating data processed by the system to a new system, or preserving it in accordance with applicable records management regulations and policies. It is essential to consider legal requirements for records retention when disposing of information systems.

5.4 System design criteria[38]

F.99. Effective designs for IT systems begin with meeting functional and business requirements. An assessment of systems in term of quality attributes is essential, whether the systems are developed in-house or procured commercially, and provides a sound basis for making objective decisions about design trade-offs. These attributes are important for conducting technical reviews and comparative demonstrations, where different alternative solutions are tested in operational environments to determine the best solution. To evaluate system design, the following eight key quality attributes may be important:

i) Maintainability. This refers to the ability of the system to undergo changes with a degree of ease. Such changes could affect components, services, features, and interfaces when modifying or developing the application's functionality in order to fix errors, or to meet new business requirements. Maintainability can also affect the time it takes to restore the system to its operational status following a failure, or removal from operation for an upgrade.

ii) Portability. This refers to the level of effort required to deploy a computer system to an alternative operating system or runtime environment without loss of capability, functionality, or system dependencies.

iii) Availability/dependability. This defines the proportion of time that the system is functional and working. It can be measured as a percentage of the total system downtime over a pre-defined period. Availability is affected by system errors, infrastructure problems, malicious attacks, and system load.

iv) Integrability/interoperability. This is the ability of a system or different systems to operate successfully by communicating and exchanging information with other systems written and run by external parties. An interoperable system makes it easier (through standard protocols) to exchange and reuse information internally as well as externally.

v) Performance. This provides an indication of the responsiveness of a system to execute specific actions in a given time interval. It can be measured in terms of latency or throughput (where latency is the time taken to respond to any event, and throughput is the number of events that take place in a given amount of time).

[38] Adapted from US Census Bureau. Census Enterprise Data Collection and Processing (CEDCaP), COTS Capability Assessment & Analysis. May, 2016.

vi) Scalability/elasticity. This refers to the ability of a system to handle increases in load without impact on the performance of the system, or the ability to be readily enlarged. To scale vertically, more resources are added (such as CPU, memory, and disk to a single system). To scale horizontally, more machines are added to a farm[39] that runs the application and shares the load. Elasticity is the degree to which a system dynamically adapts to capacity, by, for example, altering the use of computing resources, to meet a varying workload.

vii) Security. This refers to the capability of a system to reduce the chance of malicious or accidental actions outside of the designed usage affecting the system, and to prevent disclosure or loss of information. Improving security can also increase the availability of the system by reducing the chances of an attack succeeding and impairing system operation. Securing a system should protect assets and prevent unauthorized access to, or modification of, information. The factors affecting system security are confidentiality, integrity, and availability. The features used to secure systems are authentication, encryption, auditing, and logging.

viii) Testability. This is the measure of how well a system or components allows the user to create test criteria and execute tests to determine if these criteria are met. Testability allows faults in a system to be isolated in a timely and effective manner, and facilitates a faster turnaround time when making any code changes.

6. Considerations for use of geospatial infromation in support of census operations

6.1 Introduction

F.100. Geography underpins most activities associated with a census enumeration. Census geography is essential to plan and manage fieldwork as well as to report results. New geospatial capabilities—as a result of technological advances in global positioning systems (GPS) and geographic information systems (GIS), and the availability of low-cost aerial and satellite imagery—have enabled national statistical institutes (NSIs) to collect more accurate and timely information about their populations. Similar advances are occurring in the areas of geographic data dissemination with all major GIS tools now making geospatial or geographical databases accessible via the Internet. NSIs that are embracing this technology are able to provide access to vast amounts of spatial information to users cheaply and quickly. This enabling technology has permitted data producers to move from a paper map base to a digital base. This has allowed maps to become dynamic snapshots of a changing geographic database rather than static objects. GIS and other geospatial tools have enabled more efficient production of both enumerator maps and thematic maps of census results. These technologies have allowed NSIs to make better maps faster and improve overall census data quality.

6.2 Geocoding and geographic databases

F.101. Geocoding is the process of assigning geographic coordinates (referring to latitude and longitude) to specific locations (such as street addresses and place names) so that they can be placed as points on a map. In the context of the census, geocoding is vital for performing such mapping tasks as:

- delineating administrative boundaries and EA boundaries;
- determining point locations of housing units and collective living quarters; and,
- locating other relevant geographic features such as roads (which can be useful for delineating enumeration areas or for providing navigational information), rivers and water bodies (which are useful for orienting census-takers) and physical landmarks (which are also useful for orienting

[39] A server farm or server cluster is a collection of computer servers usually maintained by an organization to supply server functionality far beyond the capability of a single machine.

census-takers as well as useful for use as control points for geo-referencing satellite images or aerial photographs).

F.102. Geocoding is indispensable for locating buildings and geographic features, especially in areas lacking street infrastructure or a reliable address system. Geocoding is critical for the transition into a fully GIS-based approach to census mapping. The numerous benefits of geocoding include ability to:

- generate high quality maps for use in the collection phase;
- aggregate data into new/customized units of analysis satisfying users' requirements;
- generate customizable map outputs
- reduce the work required for updating maps for future censuses; and
- facilitate the easier spatial data organization for future statistical activities (in particular when administrative divisions change).

F.103. A Global Positioning System (GPS) is a major tool for direct capture of location information and building GIS databases for census operations. Because of its ability to record latitude and longitude for any geographic areal unit, GPS technology offers many applications in census mapping activities, including the preparation and correction of enumerator maps for census activities. With a GPS, geographical positions of EA boundaries can be corrected, and the location of point features, such as buildings and housing units, can be obtained in a cost-effective way. Increasingly, countries are recording a latitude-longitude for every housing unit in the country. Coordinates can be downloaded or entered manually into a GIS or other digital mapping system, where they can be combined with other geo-referenced information.

F.104. A Geographic Information System (GIS) is a combination of computer hardware and software used to store, manipulate, analyze, and display geographic data; it is a key tool for maximizing the use of geographic data. Accurate geocoding is critical for realizing many of the benefits of GIS (Longley et at, 2011); such benefits include:

- the ability to link different items of information together through common geographic location;
- the ability to measure distances and areas and to perform more complex forms of analysis; and,
- the ability to communicate geographic information in forms that census users can readily understand.

F.105. All large operational GISs are built on geodatabases; they are arguably the most important part of the GIS (United Nations, 2009). Geodatabases form the basis for all queries, analysis and decision-making. A comprehensive census geographic database consists of a digital map of census enumeration areas and a series of base map layers that provide the context and orientation in the final enumerator maps. Base data layers might be major and minor roads, rivers, railway lines, buildings or settlements, which are stored as separate entities in a geographic database.

F.106. Once the scope of census geographic activities has been determined, the census office needs to define and document the structure of the geographic databases in more detail. The complete digital enumeration area database usually consists of such elements as features and attributes, which can be represented as follows (United Nations, 2009):

- The *spatial boundary database*, consisting of area features (polygons) that represent the census units (such as EAs and administrative/territorial/statistical divisions).
- The *geographic attributes table*, a database file linked internally to the spatial database that contains one record for each polygon. This table contains the unique identifier for each census unit and possibly some additional static variables, such as the unit's area.
- The *census data tables* containing non-spatial attributes, (that is, the census indicators for the spatial census units). Each of these files must contain the unique identifier of the census unit that provides the link to the corresponding polygon attribute table records. There will be one record for each census unit.
- Additionally, *other vector (point or area) features*, such as building/housing unit points, landmarks, roads, waterways, schools, health facilities or other buildings may be useful for orienting field staff

during the enumeration. Such features are usually recorded during preliminary field-canvassing or house-listing.

F.107. The development of the digital census database is usually based on two data sources: the conversion and integration of existing geographic data/maps that may be in hardcopy or digital form, and the collection of additional data using fieldwork with GPS receiver or digitization of satellite images, aerial photos and other raster files.

6.3 Role of geospatial information in census operations

F.108. Traditionally, the role of maps in the census process has been to support enumeration and operations management as well as to present aggregate census results in cartographic form. That role has expanded tremendously with the advent and use of GIS technologies. Today, by utilizing a modern GIS system, census agencies can realize many efficiencies as well as improvements in the quality of the data products. By utilizing GIS systems to optimize EA's, workforce assignments and field offices, there can be direct cost benefit and savings in areas such as labour and fuel for transport.

F.109. In general terms, GIS and digital mapping serve several purposes in the census process, as follows (organized by census phase).

6.3.1. Pre-enumeration

F.110. To support the full census process, during the planning stage GIS can be used to:

- create/update the geo-database;
- create/update the base maps;
- create/develop map services (that is, the ways to make maps available through the web);
- create/update EAs through;
  - the production of digital EA maps for fieldwork and operations;
  - the use of remote sensed data (images from satellite and aerial photographs); and
  - the allocation of field workers to EAs;
- validate EAs (usually at census headquarters) by using imagery where applicable and where quality data is available. Where in-office validation is not possible, field verification is required.
- conduct GIS analysis to ensure complete and balanced coverage by, for example, overlaying EA maps on a scaled national base map to ensure there are no omissions or duplications; and
- apply GIS analysis to facilitate efficient census operations by, for example, determining the most efficient placement of field staff and offices.

6.3.2 During enumeration

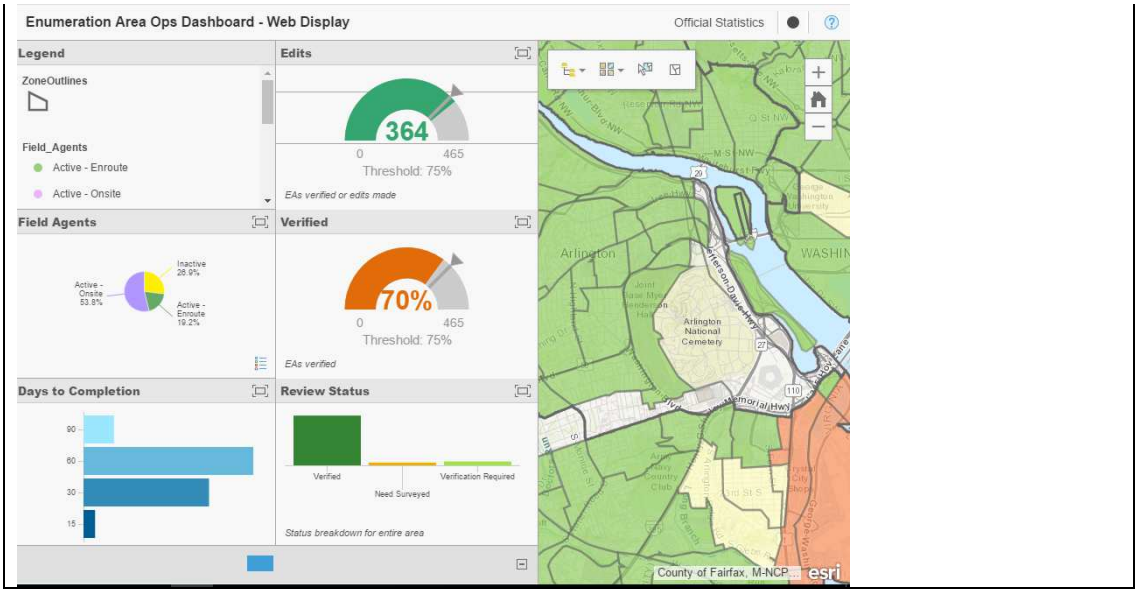
F.111. During the enumeration, GIS and mapping can help to ensure full coverage and facilitate more effective census operations by supporting logistics and the management of fieldwork, data collection and monitoring, thus giving decision makers updates on progress.

F.112. Maps of EAs provide an essential control device that guarantees coverage of the census without under- or over-counts. Moreover, digital maps of enumeration areas using high resolution satellite images along with spatial location of individual census units can help interviewers to more easily identify, and navigate their way through, their assigned geographic areas to the point of interview. Such maps can also enable supervisors to check the progress and completeness of the census data collection process, thus allowing them to strategically plan, make assignments, identify problem areas and implement remedial action quickly.

F.113. The challenges that NSOs face in monitoring enumeration in the field can be significantly improved through the utilization of GIS tools/applications that offer real-time monitoring and command and control mechanisms, ensuring seamless coordination of field operations, logistics, and

communications. GIS can also help in delivering information products needed throughout the operations processes including; maps, charts, and operational dashboards (see Figure 5.1 below for example) that provide an overview of the project status.

Figure 5.1 Environmental Systems Research Institute (ESRI) dashboard for monitoring enumeration areas



6.3.3. Post-enumeration

F.114. In the post-enumeration phase, GIS and interactive mapping capabilities make it easier to present, analyse and disseminate census results at various levels of geographical disaggregation. The cartographic presentation of census results provides a powerful medium for visualizing the results of a census. Looking at data from a spatial perspective can often add valuable context, and support the identification of patterns and the analysis of important demographic and social indicators, particularly at the small geographic area level.

F.115. Geographically referenced census data provide multiple methods for analysis. Rather than constraining a geographic analysis to national or provincial levels, data at census unit level can be re-aggregated to new units of analysis (such as climatic zones or ethnic regions). GIS facilitates this type of analysis by integrating common database operations, such as query and statistical analysis, with the unique visualization benefits that maps can provide. The data integration functions provided by GIS allows the linking of information from many different subject areas, leading to a much wider use of statistical information. Advanced visualization techniques allow the creation of increasingly sophisticated representations of census data. GIS data display functions go far beyond static two-dimensional displays and provide animation and three-dimensional modelling capabilities. The accessibility of geographical databases via the Internet can provide access to vast amounts of spatial information to users.

6.4 Planning considerations for developing a census geospatial program

F.116. Realistic and well-considered planning is needed in order to reap the benefit of GIS and other geospatial technologies for modernizing and improving census operations. Due to the long lead times needed for implementing a census, GIS programme planning needs to be initiated some years in advance. Detailed strategic, operational and managerial planning—based on a realistic assessment of time, staffing and resource constraints—is needed in order to achieve a successful outcome. However,

there will always be a trade-off between the cost of a project, the amount of time required for implementation and the quality of the final product. Because of the substantial upfront investments required in terms of, for example, hardware and software, acquisition of remote-sensed imageries, and institutional reorganization, the use of geospatial technologies in census operations needs to be carefully planned. The decision to invest in geospatial technology should be need-based and problem-driven rather than technology-driven.

F.117. Several implementation challenges face NSIs in pursuing a census geospatial programme. These consist of both institutional factors (including project management, staffing and skills, cooperation with other agencies, etc.) and technical factors (such as design issues affecting the resulting databases, selecting the appropriate hardware and software, issues associated with the use of geospatial technologies). Producing detailed geographic data at a fine enough scale for use in the enumeration will require considerable planning on the part of the NSI. Cooperation with other agencies (such as any national mapping agency) will need to be pursued to eliminate, for example, the cost of duplicative efforts. Where a national spatial data infrastructure (NSDI) exists, the common digital base (that is. the library of digital administrative boundaries, ranging from the provincial to the municipal levels) and any other geographic data should be used to the extent possible, especially if the boundaries are fully surveyed and field-corrected.

F.118. Planning is also important to realize benefits from the utilization of a modern GIS system. The benefits of moving to modern GIS systems can be categorized in two ways—improvements in efficiency and effectiveness (ESRI, 2015).

F.119. Efficiency of a modern GIS system can be realized in the amount of cost savings, productivity gains, time savings, increased accuracy, better products, and better service.

F.120. Time reduction savings can be achieved in:
- the creation of base maps and EAs;
- conducting the fieldwork;
- carrying out quality assurance (QA) and quality control (QC) checks;
- data processing; and
- publishing and disseminating the final data outputs.

F.121. Cost savings include:
- reduction in staff needed to verify EAs;
- optimizing the field force for collecting data;
- optimized efficiencies in other field expenses such as transportation costs; and
- the potential reuse of digitized base map data and maps for other non-census activities.

F.122. Improvements in accuracy can be obtained in many areas including:
- address/location by leveraging GPS onto devices
- collected data by capturing once digitally with no need for manual data entry or scanning and the use of metadata on the device; and
- utilizing real-time operations monitoring during the enumeration process.

F.123. Effectiveness of a modern GIS system can be seen in improved analytics, data sharing, and societal benefits including:
- creating foundational data layers, such as demography and administrative boundaries, shared among many users, eliminating the need for duplicative costs or efforts;
- capability to meet demand for geo-referenced small-area population data;
- capability to meet demand for disaggregated statistical data;
- ability to deliver data more rapidly;
- ability to ensure security and privacy of data as required; and
- sharing best practices,

F.124. Most census agencies use GIS for some stages of the census process. Some agencies may have a fully functional GIS unit while others may utilize GIS at another agency to aid the development and generation of census maps. Each country starts its geographic efforts from its own base of existing information, budgets, technical capabilities and available time frames (United Nations, 2009). There exists, therefore, a multiplicity of paths towards a fully digital geographic database for census data collection and dissemination purposes. The following partial list of available options, in increasing order of complexity, is dependent on budgets and time:

- production of digital maps created on the basis of existing sketch maps;
- geo-referenced enumeration area layers or spatial files, with proper coding and metadata that can be properly integrated with other digital geographic databases;
- inclusion of geographic reference layers, showing, for instance, roads, rivers, landmarks, point features and other features — these can be included as simple images from scanned maps or designed as a unit's own geographic database;
- a digital postal address registry where addresses are matched automatically or semi-automatically to digital road databases; and
- a digital database of precisely located dwelling units, created with the aid of geographic positioning systems.

F.125. The most appropriate census geographic strategy for a country will consist of a tailor-made approach that considers the NSI's needs and resources. Planning for a well-designed geospatial census programme will require consideration of various issues, including:

- conducting a needs assessment, inventorying existing geographic data and products;
- developing a collection programme to capture additional geographic data;
- building a geospatial data management system;
- identification of geographic products and services required to support enumeration operations; and
- developing capacity and skills as well as project management, including for outsourcing.

6.4.1 Needs assessment

F.126. Understanding user needs and requirements is important when developing GIS/geographic products and services. A detailed needs assessment should be conducted based on extensive consultations not only with census users but also other stakeholders that participate or otherwise have an interest in census operations. This process should include consultation on geographic content (that is, geographic structures, including administrative hierarchies or summary levels) and on geographic products that support the analysis of census data. This process should be followed by an investigation of feasible geographic options. The NSI should then reconcile user expectations with what is feasible given available resources, including data availability and time and funding constraints. As noted above, there will always be a trade-off between cost, time and the quality of the final product. Census geographic programmes require a big investment; therefore, NSIs need to decide their plans carefully before committing resources to obtaining, for example, satellite imagery and training.

F.127. Some questions to be considered in a needs assessment exercise could include:

- What type of users (such as NSI employees, field supervisors, area managers, contractor, the general public) will access the system?
- What type of device(s) will be used to access the GIS system?
- What functionality is required/allowed by the user?
- Will users work both online and offline?
- Will the same user be updating an EA as well as collecting survey data? Will they need to use multiple types of map services on the same device?
- Will users need both EA maps and census geographies?
- What GIS/mapping capabilities do field or area supervisors need?
- Will there be a need to use a street base map or an image base map or both?
- What scale/resolution is required?
- What geographic reference layers (infrastructure, natural environment) are needed?

- How will administrative data be utilized?
- Will geographic names/search be required?
- Will geocodes need to be captured, updated and utilized?

6.4.2 Inventory of existing data sources

F.128. Assessment of user requirements should be followed by the inventorying of existing geographic information and data sources. This should include the identification of maps and other geographic information (both digital and hard-copy) from previous censuses as well as from external sources such as from any mapping and cadastral agencies. A survey of existing digital and hard-copy sources will lead to the identification of available data—thus helping to avoid duplication of effort—as well as to the identification of data gaps, thus helping to provide a focus for the activities of the census geography programme. Identification of existing sources can reduce the need to collect additional data using fieldwork and/or images from aerial photography and satellite. This will save time by keeping field-checking to a minimum, and allow resources to be directed to addressing rapidly changing areas.

F.129. The NSI should seek cooperation with government agencies and other institutions for leveraging existing geographic information, including digital versions of base data, such as roads, so that time and money can be saved for other necessary census-specific activities. National mapping agencies and other government departments and entities, including transportation, health, environment and water resources units as well as the military and provincial/local governments, use geospatial technology to manage the information they collect and use for analysis and planning. Additionally, private sector companies, for example in the utilities, telecommunications and mining sectors, also use geospatial technology in managing their information needs in digital geographic form. NSIs should also leverage resources available, including expertise, through National Spatial Data Infrastructure (NSDI) institutions.

F.130. Any such data from external providers should be verified. Existing maps may be outdated, or the scale of available topographic maps may be insufficient for census purposes. For any areas for which existing materials are of insufficient quality, a strategy for field mapping or some other data-collection approach must be developed. While importing existing digital data, possible problems that may need to be addressed include: differences in definitions and coding schemes, the use of different cartographic reference systems, incompatible spatial scales, and varying accuracy standards, each of which may result in features that do not match across two sources. Addressing these problems in order to make full use of existing digital maps may require considerable processing and editing resources. During incorporation into a GIS database, in order to ensure the correct spatial relationships between features in different data-sets, information from existing sources should have comprehensive documentation. This includes geographic referencing information, including map scale; projection and geographic datum; map compilation date; compiling agency; and complete legend. In order to ensure that these census maps can be integrated with other data sources, the census-mapping organization should adhere to any existing national geographic data standards.

6.4.3 Collection of geographic data

F.131. Needs assessment and a survey of existing digital and hard-copy sources are critical in developing a strategy for additional geographic data collection. There are two data-collection approaches: using satellite images or air photos; and, using fieldwork.

F.132. *Analysis of imagery acquired by satellites or aircraft*. Digitization of point locations of buildings from paper sources (such as sketch maps) rarely provide an acceptable level of locational accuracy (US Census Bureau, 2015). For an accurate digitization of building points, an analysis of imageries from satellite or aerial photography with GIS desktop software is necessary. This should be followed up with field verification using handheld GPS technology. The combination of these two technologies can reduce the resources required for collecting data for geographic features such as

buildings, landmarks, road networks, rivers and any other information useful for delineating EAs. These techniques make it possible to capture building points rapidly and to work around the lack of an address system. However, distinguishing between living quarters and non-residential buildings, as well as registering individual housing units, still requires fieldwork. This approach is especially useful for focusing efforts on the areas most in need of updating since the previous census.

F.133. *Field GPS data collection using handheld devices*. Handheld devices (such as those described in Chapter E) enabled with GPS technology can contribute to improved accuracy of capturing point locations of geographic features and the resulting digital GIS data. Point data are relatively easy to collect and manipulate on handheld devices. However, collecting boundaries with handheld GPS devices presents difficulties when clear physical markers on the ground are absent. Manipulation of boundaries in the field adds a substantial level of complexity to both the data collection programme and the workflow for reintegrating data collected in the field back into the geographic hierarchy. Such reintegration requires an advanced workflow ensuring that the topology of the nested boundary hierarchy is preserved. Furthermore, if multiple users are editing these data simultaneously, an enterprise[40] GIS solution may need to be acquired to effectively manage the flow of data. A simpler solution for NSIs to consider is to use up-to-date high-resolution imagery for most enumeration area boundary updates (US Census Bureau, 2015).

6.4.4 Geospatial data management system[41]

F.134. For data collection operations as complex as the census, an enterprise GIS is needed to ensure data flows easily between teams and individuals (in the field and at headquarters) without compromising data quality or security. An enterprise spatial database (or geodatabase) can store and manipulate spatial data and is typically administered through a relational database management system (RDBMS). This database could be accessible within a specific working group (such as the GIS staff) or it could be available throughout the NSI and possibly via a secure Internet portal, depending on the requirements of the census.

F.135. GIS software[42] forms the basis of the processing engine and is a vital component of an operational GIS. NSIs will have to decide between either proprietary commercial off-the-shelf software (COTS) or free and open source software (FOSS) when implementing their enterprise GIS framework for the geographic listing operation. FOSS software is freely downloadable from the Internet and provides similar functionality to commercial software. FOSS implies that users can access the source code of the application, meaning that NSOs with programming expertise can tailor software to suit their specific needs. FOSS software is becoming more user-friendly, providing the capability for tailored applications for specific uses. Each option has strengths and weaknesses and NSIs should evaluate their operational goals and adopt technologies accordingly. Open source and proprietary software can be used for different components of the enterprise GIS. Many of these components are interoperable, meaning an NSI could use an open source solution for one component but a proprietary solution for another, depending on the workflow requirements.

F.136. The above solutions are typically hosted by NSIs with on-site servers or through a cloud service and require direct management by the NSI or a contracted vendor. However, there is an emerging set of alternative solutions known as GIS-as-a-Service. These solutions are a hybrid of database, server, and web map and offer varying degrees of functionality. A GIS-as-a-Service solution can potentially reduce the human and physical capital required to host geospatial data and reduce operational costs.

[40] An enterprise information system provides a technological platform that enables organizations to integrate and coordinate their business processes and to ensure information can be shared across all functional levels and management hierarchies.
[41] Adapted from U.S. Census Bureau (2015). New Technologies in Census Geographic Listing. Select Topics in International Censuses.
[42] A GIS software system comprises an integrated collection of computer programs that implement geographic storage, processing and display functions. The three key parts of any GIS software system are the user interface, the tools (functions) and the data manager. All three parts may be located on single computer, or they may be spread over multiple machines in an enterprise system configuration.

However, GIS-as-a-Service provides less control and customization than an on-site server solution and may be preferable for the dissemination phase of the census or survey lifecycle rather than the operational phase.

6.4.5 Identification of geographic products and services

F.137. When developing GIS/geographic products and services, it is important to understand the types of users and their requirements. To be best prepared for census operation, the NSI needs to identify the types of maps and map services needed in all phases. In determining the design of census geographic products, including the database, NSIs should take into consideration the available financial and human resources and other various factors, including:

- existing digital and analogue geographic products;
- technical capabilities in the statistical office and in collaborating agencies (such as geodesy authorities and mapping agencies);
- the size of the country, both population and areal extent, and also accessibility as affected by terrain and water bodies; and
- the time frame available to plan and carry out the census-mapping process.

F.138. The range of geographic outputs and products needed in census operations include (US Census Bureau, 2009):

- a set of digital area maps for enumeration and dissemination;
- geographic boundary files in a digital format for all statistical reporting units for which census indicators will be tabulated;
- listings of all statistical and administrative reporting units, including towns and villages, their variant names and geographic coordinates;
- geographic equivalency files that indicate how current reporting units relate to those used in previous censuses, or how one set of reporting units relates to another set;
- vector layers containing feature data, such as buildings, landmarks, roads, schools, hospitals and clinics, which can be used when analysing population data spatially;
- street index listings for all major urban areas;
- centroid files that provide a representative geographic point reference for each reporting unit; and
- gazetteers that provide geographic coordinates for all population settlements and other important geographic features in the country.

F.139. Geographic products used in a census operation should always include proper documentation, including coding and metadata, to make them more useful to users. Before starting any data entry and data conversion operations, the NSI should design the structure of all geographic data sets that will be produced. Good planning and documentation will avoid confusion and incompatibilities later in the process. In several countries, national geographic data committees have been formed to coordinate the development of geographic databases. Geographic data standards issued by such bodies should be followed in the production of geographic outputs for censuses.

F.140. Geographic products and services support a number of key census processes including:

- printing - in cases where census questionnaires will have an address pre-printed;
- monitoring and operational management – questionnaires could be tracked via a response management database linked to geographic information (such as addresses) to provide status information by areas (administrative and/or census management areas) and to support follow-up actions in the field, and to produce reports for field operations management;
- recruitment and allocation of field staff and payroll - field staff may be recruited to work in specific areas, while maps enable an interactive allocation of workload for field workers using the GIS technology;
- data capture operations – to orient fieldworkers and monitor their activities during the enumeration;

- census outputs - cartographic presentation of census results provides a powerful means for analysis of the results of a census.

F.141. To the extent possible, NSIs should produce new information products like map services in addition to traditional maps and data to bring about improvements in efficiency as well as effectiveness. A map service is the way maps are made available on the web. The maps are produced in a desktop application, and then published as a service to a server site. Internet or intranet users can then use the map service in web applications including desktop, online, and other client applications (such as an enumerator's tablet). A map service makes maps, features, and attribute data available inside many types of client applications. Map services represent a map that is made available to others on a server. They are designed to work in many web and intranet scenarios. A map service can serve dynamic maps and layers as well as cached maps and features. Dynamic maps are drawn at the time they are requested by a user. They are not as fast as cached maps, but they may be appropriate for highly focused intranet applications and applications that require real-time display of data. Cached map services (those that use a set of pre-created images) are the fastest way to serve maps on the web. Although users will just be viewing static pictures of maps, a cached map service can be supplemented with find, identify, and query tasks to reach the underlying data. The cache can also be updated on a regular basis if the underlying data changes.

6.4.6 Staff skills and capacity

F.142. Any new technical undertaking, such as geospatial technologies, requires a reconsideration of the NSI's technical capacity and the skills held by its GIS staff. Increased use of desktop GIS packages require considerable training in order to be used effectively, and staff should have the ability to automate GIS operations design databases for storing geospatial data, or build interactive web maps. Developing GIS capacity may entail reorganization and expanding any existing cartographic unit to a much larger and more versatile geographic core with the capability to serve all census-mapping needs (US Census Bureau, 2009).

F.143. Much of the expertise required in the traditional, manual census-mapping approach is relevant also for a digital mapping project. Rather than completely replacing existing skills, the digital mapping approach requires additional expertise in computer methods. In many countries, there may be a shortage of trained geospatial experts that can be recruited on a long-term or temporary basis for the census-mapping project. The census office must therefore evaluate training options to ensure that existing and new staff have the approriate knowledge required for successful completion of the project. Usually, staff trained in traditional geographical techniques who have some computer literacy will have little difficulty adapting to digital techniques after going through training.

F.144. Careful consideration should be given to the distribution of responsibilities among the GIS staff and to the type of expertise needed to fulfill a particular goal. Successful GIS managers will develop areas with varied skills while encouraging cross-area understanding, cooperation, and collaboration. The profile of tasks for which staff are required in a digital census-mapping project include:

- planning and project management;
- geospatial data conversion;
- map scanning and digitizing;
- cartographic design;
- field work with GPS; and
- systems administration.

F.145. Other special expertise may need to be present in the census-mapping organization depending on the census-mapping strategy that is adopted.

6.4.7 Outsourcing[43]

F.146. After assessing its GIS staff abilities, it may not be feasible for an NSI to develop the in-house skills necessary to build, integrate, and deploy a complete geographic listing system. In this case, the NSI may choose to outsource the development of such a system to a contracted external supplier. The primary goal of outsourcing should be to gain temporary access to skills that are otherwise not available within the NSI, or to augment the amount of staff available with a certain set of skills. The following guidelines should be considered if outsourcing is being considered:

- Do not cede full control of the system design and development to the contracted vendor. Ultimate responsibility for the success or failure of the geographic operation must always remain with the NSI, not the contractor. Therefore, the NSI must fully understand the technology solution being implemented and its risks.
- Make use of the institutional knowledge of GIS staff that have experience with statistical boundary update operations and address listing.
- Document the workflow for updating enumeration maps prior to the use of new geospatial technologies and use these workflows to design the address listing system with the contractor.
- Do not let technology drive the design of the geographic system.
- Take into consideration future maintenance, expandability, and staff skills when considering a particular contractor. External suppliers often specialize in either proprietary or open source systems.

6.4.8 Other important considerations[44]

F.147. There are risks associated with adopting new technologies. Existing staff members may not welcome changes to their workflows and resist the adoption of new technologies. Additionally, new technologies require investments in data security and staff training to prevent the loss of sensitive individual data.

F.148. New technology should also be tested thoroughly before deployment. As has been stressed in Chapters E and F, testing of any new technology must be built into the census project schedule and adequate time allocated to make improvements prior to implementation. If testing shows a GIS software solution will not be ready in time for the operation, an alternative plan must be available to ensure successful completion of the operation.

F.149. GIS staff and managers, and senior leadership all play critical roles and share accountability for ensuring the successful implementation of new technologies at NSIs.

7. Testing IT systems and processes

7.1. Introduction

F.150. IT systems and infrastructure play a critical role in the success of census data collected with the use of electronic data collection technologies. To assure success, the IT systems and infrastructure, both individually and when integrated, need to perform and function as intended. Complete and thorough testing is essential for providing reasonable assurance that new or modified IT systems will perform as expected. To be effective, testing should be planned and conducted in a structured manner, with

[43] Adapted from U.S. Census Bureau (2015). New Technologies in Census Geographic Listing. Select Topics in International Censuses.

processes in place to control each incremental level of testing. Testing of individual systems should be followed with testing of the integration of those systems in order to address all interrelated systems and functionality in an operational environment.

F.151. Tests are evaluative tools that use expected outcomes or quantifiable metrics to validate the operability of one or more IT systems or system components that are identified as critical in an IT plan. Tests can take several forms, including component testing (testing individual hardware or software components, or groups of related components), system testing (testing complete systems), and comprehensive testing (testing all systems and components that support an IT plan). A test should be conducted in as close to an operational environment as possible. Sufficient time and budget should be allocated for testing, especially if using such technology for the first time in a census operation. Testing should be conducted early in the preparation stage of the census life cycle so that there is sufficient time for necessary corrections and re-evaluation. Testing should be guided by a well-developed and written test plan with quality standards for each element to be tested so that all features can be assessed in a consistent manner. The consequences of not testing census IT systems and processes are too costly to ignore.

7.2. Development of plan for testing[45]

F.152. To be effective, testing should be planned and scheduled in a structured manner. Comprehensive testing that is effectively planned and scheduled can provide the basis for identifying key tasks and requirements and better ensure that a system meets the specified requirements and functions as intended in an operational environment.

F.153. Sufficient executive-level oversight and guidance is needed both in the development and implementation of a testing plan. Management oversight of system testing activities should be guided by comprehensive status information and quantitative metrics on progress in testing key IT systems and interfaces, and assessments of the overall status of testing for key operations. Specifically, key operations and systems should be judged to be ready for operation based on testing and not just merely based solely on management judgment.

F.154. The testing plan document should identify the tasks and activities that need to be performed to ensure that all aspects of the census IT system and processes are adequately tested and that the system(s) can be successfully implemented. The plan document should describe the test activities in progressive levels of detail and priority, describing the approach for the various levels of testing and testing types between systems. It should also set out the testing schedule as well as delineate roles and responsibilities of the project teams involved (including in systems development), provide guidelines for testing activities, and support necessary to carry out testing activities.

F.155. The following is a five-step plan development process that an organization may utilize to develop a testing plan:

i) Evaluate the need for a test and create a schedule

F.156. The need for a test should be evaluated by considering the NSI's overall objectives and based on factors such as:

- whether the component or system to be tested is critical to its business processes;
- the system or component to be tested is ready for testing;
- the processes and procedures for the system or component are established; and
- personnel who would test/use the system or component are trained.

[45] The content of this section was adapted from: National Institute of Standards and Technology (NIST). Guide to Test, Training, and Exercise Programs for IT Plans and Capabilities. NIST Special Publication 800-84. September 2006.

F.157. The need for a test should also be evaluated by considering any changes in the technology used and its impacts on census design. If there is already some experience in the use of a specific technology through previous censuses or other large-scale household surveys, the focus for a test would be more on improving the existing system. If there is no such previous experience, or only limited experience, on the use of a technology, the tests will be needed more extensively for the objectives of redesigning census procedures with the adoption of new technology and also building capacity for successful implementation.

F.158. Tests are usually conducted before the systems or components become operational, to ensure they do not adversely affect the security or other operational aspects of the organization. Tests should be scheduled in a structured manner to ensure that the IT plans are reasonable, effective, and complete, and that personnel know what their roles and responsibilities are in the conduct of the plans. The scheduling of tests should also consider factors such as available resources and the potential impact on the organization. It is important that when a test is being planned, that senior managers are notified and the potential impact on operations assessed to determine the best time to schedule the test.

ii) Design the test

F.159. Once the need to conduct a test has been established, a test design team should be established to design each specific test. Several factors can have a significant bearing on the design of the test, including the level of the test (component, system, or comprehensive), the organizational entities involved, and the scope of the test. These factors can affect the lead time required to develop the test, the level of complexity for the test, and the length of time the test will take. At an early stage in the design process, the personnel who will participate in the test should be identified and the senior managers for these affected areas should be contacted. The major steps in the test design process include:

(a) *Determine the scope of the test*. The scope of the test should be determined based on current system or security requirements and any potential compliance or regulatory requirements. The scope of the test is directly shaped by the type of test. Component tests are more focused and generally involve fewer individuals and organizational entities. System tests are broader in scope and include more personnel and multiple components. The test design team should include a team leader and subject matter experts for each of the areas to be tested; they should develop the content of the test cooperatively. Comprehensive tests involve much larger portions of the organization, potentially all personnel, and require more extensive coordination and planning.

(b) *Identify the objectives of the test*. The design team should define the tests that will be conducted and specify the expected results or outcomes. The test plan should consist of a series of smaller individual tests each designed to examine a part of the component, system, or group of components and systems being tested. The objectives for each test should be to measure, check, or verify whether the component, system, or group of components and systems satisfies its intended purpose and functions adequately. Where possible, the expected results or outcomes should be expressed in an objective and measurable manner, with subjective measurements being minimized. The results should be quantifiable and repeatable to the extent reasonably possible.

(c) *Determine the assessment tools*. The design team should specify the assessment tools and procedures needed to accomplish the test. The specific tools needed may vary greatly depending upon the scope of the test. Tools might range from specialized software or hardware tools (such as network sniffers[46], vulnerability scanners) to measurement and recording devices (such as stopwatches, cameras, video recorders) to checklists used to measure adherence to defined processes and procedures, and to a set of quantifiable measures used to assess the success or performance of procedures/hardware/software (such as duration of interview, volume of data

[46] A software tool that monitors, or sniffs out the data flowing over computer network links in real time. It can be a self-contained software program or a hardware device with the appropriate software or firmware.

transfer, etc.). Tools might also include items needed by the test team for logistical support (such as cell phones).

(d) *Identify the participants*. The participants in a test will vary based on the scope of the test to be performed. Participation in testing events can be thought of at two levels: the first level of participant consists of the individuals who are operating the components or systems being tested; and, the second level of participant consists of those who are not directly involved in the test, but who might be impacted by the test or related activities (such as potential users of the system/equipment to make sure efficient use of systems/software in the field).

(e) *Identify the test staff*. The design team usually designates a test director (for each type of test: systems, applications, training, etc.), who is responsible for all aspects of the test, including staffing, development, conduct, logistics, and oversight of the design team. The test director designates one or more data collectors who monitor and record the results of the test. The design team also often includes one or more individuals that are subject matter experts in the areas being tested. These individuals can help develop the test plan and identify the necessary testing tools. Because they are aware of the details of the test, these individuals should not be participants in the test; instead, they can be test observers, facilitators, data collectors, or controllers.

(f) *Coordinate the logistics*. The design team should begin to coordinate the logistical support far enough in advance to ensure the successful completion of the test. The time required for coordination also depends on the scope, and typically varies from a month in advance for component testing to several months for a comprehensive test of components and systems for a large IT plan (such as a disaster recovery plan or incident response plan). Although specific logistical elements are identified during the test design phase, it is imperative that the required list of logistical components be updated frequently, especially after the test is fully developed.

iii) Develop the test material

F.160. Once the test is designed, the design team needs to create test documentation. The magnitude of this work depends on the scope of the test. This documentation should include:

(a) a test guide explaining the objectives and scope of the test; how to plan and implement the test; who will be involved for data collection and their duties; and how to analyse and assess the data/information collected;

(b) briefing materials for different management level and stakeholders and when it is needed for public and media especially for pilot census; and

(c) an assessment report for the results of each individual test as well as an overall synopsis of the test activities. Corrective actions and recommendations are one element of this report.

iv) Conduct the test

F.161. The locations for tests will vary based on the type of test being conducted and the test's scope. For example, a small component test could be conducted in a single office, while a comprehensive test of components and systems for an IT plan should involve many different parts of the census agency in various locations (regional/local offices and offices of other stakeholders involved such as other government departments).

F.162. Safety and security are two elements that should be maintained during any test. Following the conclusion of the test, the test director and data collectors should conduct a test debrief with participants. Immediately following the test, the data collectors and participants should be asked to provide the test director with their notes or any forms completed during the course of the test and the debrief session.

v) Evaluate the test

F.163. During the evaluation phase, a member of the design team or another selected staff member should develop an evaluation report that determines how well the tested systems or components functioned. The report should document background information about the test such as the scope,

objectives, and tests and also document observations made by the test team during the test and recommendations for enhancing the IT plan that had its components or systems tested, along with associated procedures and components.

F.164. Following the preparation of the report, the it may be necessary to update the IT plan that had its components or systems tested.

7.3. Types of tests[47]

F.165. The following include types of commonly performed tests for IT systems and related procedures:

i) Development testing. This refers to tests performed in the system development environment. Development testing consists of unit level testing and integration testing, both performed in the system development environment.

(a) *Unit test* - tests individual software components as an integral and continual activity of system development. In this first phase, a unit can refer to a function, individual program or even a procedure;
(b) *Integration test* - validates software modules created from the integration of previously unit-tested software to validate proper integration.

ii) System testing. This ensures that the system performs the necessary business functions as outlined in the system requirements. It verifies that the complete system (comprising the full complement of application software running on the target hardware and systems software infrastructure) meets the specified requirements. It allows for the identification and correction of potential problems within an individual system, prior to integration with other systems. Some of the following types of tests could be performed as part of System Testing:

(a) *Usability test* – checks if the user interface is easy to use and understand. It is mainly concerned with the use of the application and its usability.
(b) *Functional test* – is the process used in software development to verify that it conforms to all requirements. It validates the functionality specified in functional requirements.
(c) *Performance test* – validates that the system can perform as designed on the existing or target infrastructure and projected workloads and user load. It also determines the existing infrastructure does not introduce any security issues under load.
(d) *Infrastructure test* - refers to testing of hardware, software, networks, data centres, facilities and related equipment used to develop, test, operate, monitor, manage and/or support information technology services within the census agency.
(e) *End-to-end test* - verifies that a defined set of interrelated systems, which collectively support an organization's core business area or function, inter-operate as intended in an operational environment. The inter-related systems include not only those owned and managed by the organization, but also the external systems with which they interface.
(f) Other tests include: *Interface (Pair-wise Internal and External) test* - focusing on the functionality of the interfaces between systems; and, *Application Regression test* - used to validate that already existing functionality is working as designed and new code has had no negative impact on it.

iii) Acceptance testing. This is performed by the system users and project test teams to solicit feedback and approval from users. It enables end users to evaluate real-world scenarios to test the system before it is deployed in the production environment. This testing is essential to determine if the system correctly implements business processes and increases end user acceptance of new or modified system.

[47] The content in this section is adapted from: US Census Bureau. 2020 Census. Test and Evaluation Management Plan. Version 2.0. December 22, 2016.

iv) Integration testing. This verifies that systems, when combined, work together as intended. Effective integration testing ensures that external interfaces work correctly, and that the integrated systems meet specified requirements. Integration testing focuses on executing tests across system boundaries, validating the physical and logical interfaces between systems, hardware products, software products, and external interfaces. The primary objective is to ensure that the system under development evolves as an homogeneous system as opposed to a collection of incompatible hardware and software products. This requires that the system be integrated and tested in a logical, incremental fashion as the development phase of the program progresses. Types of testing conducted as part of integration testing include:

(a) End-to-end test – designed to assure that the system flows are systematically exercised to make sure that the systems have been integrated successfully and, ultimately, that the business process need has been met;

(b) Performance test (Load, Volume, and Stress) – performance measurements are executed under production-like conditions and at certain times during the system operations;

(c) Exception test – focuses on the exception scenarios for system behaviours and handling of exception scenarios across business process scenarios;

(d) Infrastructure test (Continuous operation, Backup and Recovery) – ensures continuity of operations remains in place through failures such as network, hardware, and power related issues;

(e) Interface test – focuses on the functionality of the interfaces between systems;

(f) Regression test – consists of test cases which ensure the system functions as expected after major releases.

v) Security (controls) testing – security controls testing focuses on validating that security requirements have been satisfied.

vi) System readiness test – is a system-wide test to exercise the end-to-end census test solution to check that the system can process data through multiple response channels and can successfully communicate and transfer data between external interfaces. Types of testing conducted as part of system readiness test include:

(a) Infrastructure test – ensures continuity of operations remains in place through failures such as network hardware, and power related issues;

(b) Interface test – focuses on the functionality of the interfaces between project systems;

(c) End-to-end test – designed to assure that the system flows, or threads, are systematically exercised to make sure that the systems have been integrated successfully and, ultimately, that the business process need has been met;

(d) Performance test – performance measurements are executed under production-like conditions and at certain times during the system operations.

vii) Performance and scalability test - assesses whether or not systems perform as needed based on the target infrastructure and projected workloads.

viii) Operational readiness test - confirms that the system is functioning correctly in the production environment. It is the final check that needed resources (people, systems, processes, and facilities) have been acquired and developed. Types of testing conducted include:

(a) End-to-end test – exercises the business processes for each operation and tests data inputs and outputs from start until the end of delivery. The test exercises all operational aspects of the systems to ensure that they can fully operate during production;

(b) Interface test – confirms the functional operation of and data transfer accuracy between the system interfaces executed identified in an environment similar to production;

(c) Business process validation – ensures and confirms that the process flow for each task, identified in the business processes models, is executed and meets the business requirements. Testing of these tasks will ensure that all operational documentation, processes, and materials, used in production. This testing focuses on the demonstration of business processes used in production; however, with a functional focus.

8. Information and system security

8.1 Introduction

F.166. Information security protects any organization's IT supported resources and assets. Such protection ensures the integrity, confidentiality and availability of the NSI's data and systems. In this context, 'integrity' means that data have not been altered or destroyed in an unauthorized manner, 'confidentiality' means that information is not made available or disclosed to unauthorized individuals, entities, or processes, and 'availability' means that data will be accessible or usable upon demand by an authorized entity.

F.167. Key activities for managing information security risks include:

- **Risk assessment**—identifying security threats and vulnerabilities to information assets and operational capabilities, ranking risk exposures, and identifying cost-effective controls;
- **Risk mitigation measures (controls)**—implementing the controls necessary to deal with identified risks to information systems, physical facilities, and networks, in order to protect them;
- **Awareness and training**—promoting awareness of security risks and educating users about security policies and procedures, as well as providing security training to staff;
- **Evaluation**—monitoring the effectiveness of risk mitigation measures (controls) and awareness and training activities through periodic evaluation; and
- **Central management**—coordinating security activities through a centralized group.

F.168. These activities are each discussed in the following paragraphs.

8.2 Risk assessment

F.169. The use of a risk management process is an important component of an effective information security program. The principal objective of any organization's risk management process is to protect the organization and its ability to perform its mission, not just its information assets. Because risk cannot be eliminated entirely, the risk management process allows information security program managers to balance the operational and economic costs of protective measures and achieve gains in mission capability. Risk management consists of three inter-related processes, namely: risk assessment, risk mitigation, and evaluation and assessment. By employing best practices and procedures in risk management, an NSI can provide information security protections commensurate with the risk and magnitude of the harm resulting from unauthorized access, use, disclosure, disruption, modification, or destruction of information and information systems.

F.170. Conducting risk assessment on all major applications is critical for identifying and managing threats, vulnerabilities, and risks to a given environment. The depth of the risk assessment performed can vary greatly and is determined by the criticality and sensitivity of the system, as applied to confidentiality, integrity, and availability. To carry out a successful risk assessment exercise, a six-step process[48] need to be followed.

8.2.1. Step 1 – System characterization

F.171. Characterizing an information system establishes the scope of the risk assessment effort, delineates the operational authorization boundaries, and provides information relating to hardware,

[48] National Institute of Standards and Technology (NIST). Information Security Handbook: A Guide for Managers. NIST Special Publication 800-100. October 2006.

software, system connectivity, and responsible division or support personnel. This step begins with the identification of the information system boundaries, resources, and information items. When characterizing the system, the mission criticality and sensitivity should be described in sufficient terms to form a basis for the scope of the risk assessment. As a minimum, the system characterization should describe the following individual system components: hardware; software (such as, for example, Oracle, Apache web server, Microsoft Internet Information Server, etc.); external interfaces to other systems; data; and, people. In addition to the component descriptions, the system characterization should describe other factors with the potential to affect the security of the system, such as:

- System functional requirements;
- Organizational security policy and architecture;
- System network topology;
- Information flows throughout the system;
- Management, operational, and technical security controls implemented or planned to be implemented for the system; and
- Physical and environmental security mechanisms.

F.172. The accuracy of the results from this step is essential for obtaining the best view of the risk profile of the system undergoing assessment, since this step provides the basis for the remaining steps. Inaccuracy at this point will propagate and lead to a cascade of analytical errors as the process progresses.

8.2.2. Step 2 – Threat identification

F.173. Threat identification consists of identifying threat sources with the potential to exploit weaknesses in the system. This step should culminate in the development of a 'threat statement' or a comprehensive listing of potential threat sources. The threat statement must be tailored to the NSI and its processing environment, which is accomplished by performing a threat evaluation, using the system characterization as the basis, for the potential to cause harm to the system.

F.174. There are common threat sources that typically apply, regardless of the system, that should be evaluated. These common threats can be categorized into three areas:

(i) natural threats (such as floods, earthquakes, tornadoes, landslides, avalanches, electrical storms);
(ii) human threats (intentional or unintentional); and
(iii) environmental threats (such as electrical power failure).

F.175. In general, information on natural threats should be readily available, as known threats have been identified by many government and private sector organizations. Intrusion detection tools also are becoming more prevalent, and government and industry organizations continually collect data on security events, thereby improving the ability to realistically assess threats.

8.2.3. Step 3 – Vulnerability identification

F.176. Vulnerability is defined[49] as "a flaw or weakness in system security procedures, design, implementation, or internal controls that could be exercised (accidentally triggered or intentionally exploited) and result in a security breach or a violation of the system's security policy." Vulnerabilities can be identified using a combination of a number of techniques and sources. Reviews of such sources as previous risk assessments, audit reports, vulnerability lists, and security advisories can be used to begin the process of vulnerability identification. System security testing, using methods such as automated vulnerability scanning tools; security, test, and evaluation (ST&E); and penetration testing can be used to augment the vulnerability source reviews and identify vulnerabilities that may not have been previously identified in other sources.

[49] National Institute of Standards and Technology (NIST). Guide for Conducting Risk Assessments. Special Publication 800-30 Revision 1. September 2012.

F.177. In addition, developing a security requirements checklist based on the security requirements specified for the system during the conceptual, design, and implementation phases of the SDLC can be used to provide a 360-degree inspection of the system. The results of the checklist can be used as input for evaluating compliance and noncompliance, which in turn identifies system, process, and procedural weaknesses that represent potential vulnerabilities.

8.2.4. Step 4 – Risk analysis

F.178. The risk analysis is a determination (or estimation) of risk to the system - an analysis that requires the consideration of closely interwoven factors, such as the security controls in place for the system under review, the likelihood that those controls will be either insufficient or ineffective protection of the system, and the impact of that failure. In other words, it is not possible to estimate the level of risk posed by the successful exploitation of a given vulnerability without considering the efficacy of the security controls that have been, or are to be, implemented to mitigate or eliminate the potential for such an exploitation; nor the threat's motivation, opportunity, and capabilities, which contribute to the likelihood of a successful attack; nor the impact to the system and organization should successful exploitation of a vulnerability occur. The following four steps—control analysis, likelihood determination, impact analysis, and risk determination—are, in a practical sense, performed simultaneously or nearly simultaneously because they are so tightly linked to each other.

i) Control analysis. As previously discussed, the analysis of controls in place to protect the system can be accomplished using a checklist or questionnaire, which is based on the security requirements for the system. This analysis can be used to strengthen the determination of the likelihood that a specific threat might successfully exploit a particular vulnerability.

ii) Likelihood determination. Likelihood determination considers a threat source's motivation and capability to exploit a vulnerability, the nature of the vulnerability, the existence of security controls, and the effectiveness of mitigating security controls. Likelihood ratings are described in the qualitative terms of high, moderate, and low, and are used to describe how likely is a successful exploitation of a vulnerability by a given threat. For example, if a threat is highly motivated and sufficiently capable, and controls implemented to protect the vulnerability are ineffective, then it is highly likely that any attack would be successful. In this scenario, the appropriate likelihood rating would be high. The likelihood ratings of moderate and low are similarly defined to successively lesser degrees.

iii) Impact analysis. The third factor used in determining the level of risk to a system is impact. A proper overall impact analysis considers the following factors: impact to the systems, data, and the organization's mission. Additionally, this analysis should also consider the criticality and sensitivity of the system and its data. While impact can be described using either a quantitative or qualitative approach, in the context of IT systems and data, impact is generally described in qualitative terms. As with the ratings used to describe likelihood, impact levels are described using the terms of high, moderate, and low.

iv) Risk determination. Once the ratings for likelihood and impact have been determined through appropriate analyses, the level of risk to the system and the organization can be derived by multiplying the ratings assigned for threat likelihood (probability) and threat impact. Because the determination of risk ratings for impact and threat likelihood is largely subjective, it is best to assign each rating a numeric value for ease of calculation. The rationale for this justification can be explained in terms of the probability assigned for each threat likelihood level and a value assigned for each impact level.

8.2.5. Step 5 – Control recommendations

F.179. The goal of the control recommendations is to reduce the level of risk to the information system and its data to a level the NSI deems acceptable. These recommendations are essential input for the risk mitigation process, during which the recommended procedural and technical security controls are

evaluated, prioritized, and implemented. This step is designed to help agencies identify and select controls appropriate to the organization's operations and mission that could mitigate or eliminate the risks identified in the preceding steps. The following factors should be considered in recommending controls and alternative solutions to minimize or eliminate identified risks:

- Effectiveness of recommended options (for example, system compatibility);
- Legislation and regulation;
- Organizational policy;
- Operational impact; and
- Safety and reliability.

8.2.6. Step 6 – Results documentation

F.180. The risk assessment report is the mechanism used to formally report the results of all risk assessment activities. The intended function of such a report is to describe and document the risk posture of the system while it is operating in its stated environment (as described in the system characterization) and to provide NSI managers with sufficient information so that they can make sound, risk-based decisions, such as resources that must be allocated to the risk mitigation phase. Lastly, the agency should ensure that the results of the risk assessment are appropriately reflected in the system's Plan of Action and Milestones (POA&M) and System Security Plan. As a minimum, the risk assessment report should describe the following:

- Scope of the assessment based on the system characterization;
- Methodology used to conduct the risk assessment;
- Individual observations resulting from conducting the risk assessment; and
- Estimation of the overall risk posture of the system.

8.3 Risk mitigation

F.181. The second phase of the risk management process is risk mitigation. Because it is impractical, if not impossible, to eliminate all risk from an IT system, risk mitigation strives to prioritize, evaluate, and implement the appropriate risk-reducing controls recommended from the risk assessment process. System and organizational managers may use several options to reduce the risk to a system. These options are risk assumption; risk avoidance; risk limitation; risk planning, research, and acknowledgement; and risk transference. Working from each risk identified and analyzed in the first process—risk assessment—managers must then decide whether the risk is acceptable or unacceptable and, subsequently, whether or not to implement additional controls to mitigate unacceptable risks.

F.182. Because it is impracticable to eliminate all risk, it is important to note that even after the controls have been selected and implemented, some degree of residual risk will remain. The remaining residual risk should be analyzed to ensure that it is at an acceptable level. If the residual risk has not been reduced to an acceptable level, the risk management cycle must be repeated to identify a way of lowering the residual risk to an acceptable level.

F.183. The types of control that can be implemented can generally be grouped into one of the three categories: controls for information system security, for physical security of the agency's facilities, and for network access.

8.4 Awareness and training

F.184. Security awareness and training is a critical component for ensuring information security. Security awareness and training programs are critical for disseminating security information that the workforce, including managers, need to do their jobs. It is important for the census agency to have a policy for general security training for all employees and contractors and for more specialized security training tailored to certain job descriptions. It should also have a program in place for identifying employees who need specialized security training. These programs will ensure that personnel at all

levels within the NSI understand their information security responsibilities to properly use and protect the information and resources entrusted to them. Agencies that continually train their workforce in organizational security policy and role-based security responsibilities will have a higher rate of success in protecting information. Requirements for the security awareness and training program should be documented in the agency-level policy and should include: definition of security roles and responsibilities; development of program strategy and implementation plan; and, maintenance of the security awareness and training program.

F.185. An awareness program should include a variety of tools and should not only communicate information security policies and procedures that need to be followed, but also provide the foundation for any sanctions and disciplinary actions imposed for any non-compliance. A large part of an awareness effort is communication with users of the IT systems within the NSI, managers, executives, system owners, and others. A communications plan is needed to identify stakeholders, types of information that is to be disseminated, channels for disseminating information, and the frequency of information exchanges.

F.186. Information security training should strive to produce relevant and needed security knowledge and skills within the workforce. Training supports competency development and helps personnel understand and learn how to perform their security role. Role-based training is important in providing security courses that are tailored to the specific needs of each staff identified as having significant responsibilities for information security. Where possible and necessary, it is also important to integrate training and certification for all critical security skills and competencies.

F.187. Several institutions, including vendors, provide training programs to support the information security needs of the public and private sectors. Certification can help link training with an assessment mechanism to validate knowledge and skills, resulting in the 'certification' of a pre-defined level of competence.

8.5. Evaluation

F.188. Evaluation and assessment is the final phase in the risk management process. Because systems are upgraded and expanded, components are improved, and architectures are constantly evolving, the evaluation of IT environments must be continuous and ongoing. It is important to use a database to track the status of systems' certification and accreditation and to track any deficiencies (including network and system control weaknesses). The security control evaluation and assessment provides input needed to finalize the risk assessment. The results should be used to provide the responsible manager with the essential information needed to make a credible, risk-based decision on whether or not to authorize the operation of the information system.

F.189. Ideally, the risk assessment activities would be conducted at the same time the system is being certified and accredited. The reuse of assessment data will not only save valuable resources, but also provide the most up-to-date risk information for the authorizing official. Many of the risk management activities are conducted during a snapshot in time—a static representation of a dynamic environment. All the changes that occur to systems during normal, daily operations have the potential to adversely affect the security of the system in some fashion, and it is the goal of the risk management evaluation and assessment process to ensure that the system continues to operate in a safe and secure manner. This goal can be partially reached by implementing a strong configuration management program. In addition, to monitoring the security of an information system on a continuous basis, agencies should track findings from the security control assessment to ensure they are addressed appropriately and do not continue to pose or introduce new risks to the system.

8.6. Central management

F.190. It is important to have a central management for coordinating security activities and for developing and maintaining information security policies and procedures. This office should be responsible for ensuring that IT security procedures, standards, and guidance are implemented, and ensure that security policies are enforced. This office should also coordinate efforts with offices responsible for physical and personnel security.

8.7. Security activities within the SDLC

F.191. Security activities must be integrated into the system development life cycle (SDLC) to ensure proper identification, design, integration, and maintenance of applicable security controls throughout an information system's life cycle. The risk management process should not be treated primarily as a technical function carried out by the information security experts who operate and manage the information security system, but as an essential management function of the NSI that is integrated into the system development life cycle (SDLC). To be most effective, information security must be integrated into the SDLC from system inception. From inception forward, agencies should consider the possible threats, vulnerabilities, and risks to the system so that they can better prepare it to operate in its intended environment, securely and effectively, and within a select risk threshold, as deemed acceptable by an agency senior official during the security certification and accreditation process.

F.192. Early integration of security in the SDLC enables agencies to maximize return on investment in their security programs, through:

- Early identification and mitigation of security vulnerabilities and misconfigurations, resulting in lower cost of security control implementation and vulnerability mitigation;
- Awareness of potential engineering challenges caused by mandatory security controls;
- Identification of shared security services and reuse of security strategies and tools to reduce development cost and schedule while improving security posture through proven methods and techniques; and
- Facilitation of informed executive decision making through comprehensive risk management in a timely manner.

9. Contingency planning

9.1. Introduction

F.193. Information systems[50] used in the collection of population and housing census data may be vulnerable to a wide variety of disruptions. These disruptions could range from minor incidents causing short-term disruptions (e.g., short-term power outage, disk drive failure) to severe ones that affect operations for an extended period (e.g., equipment destruction, disaster events such as fires). While much of the vulnerability to disruptions could be minimized or eliminated through efficient management, operational, or technical controls, it is not possible to completely eliminate all risks, because in many cases, critical resources (such as electric power or telecommunications) may reside outside the census organization's control, and the organization may be unable to ensure their continuous availability.

[50] An information system is a discrete set of information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information. Information system components include, but are not limited to, servers, workstations, network components, operating systems, and applications. Network components can include, for example, such devices as firewalls, sensors (local or remote), switches, routers, wireless access points, and network appliances. Servers can include, for example, database servers, authentication servers, electronic mail and Web servers, proxy servers, domain name servers, and network time servers. Information system components are either purchased commercially off-the-shelf or are custom-developed.

F.194. A contingency plan is an alternative plan which will be used if a foreseen risk event occurs in any phase of the census operation. This plan should identify what the potential risks are, what action should be taken and who will take this action. Potential risks have to be determined while designing census operations and these must be tested to ensure the right action. It should be noted that a contingency plan should be developed for all possible risks - low and high probability risks – and especially must take into account the factors that may affect deadlines and quality targets.

F.195. Contingency planning is crucial for providing effective and efficient solutions to mitigate the risk of system and service unavailability. Contingency planning refers to interim measures to recover information system services after a disruption. Because information system resources are essential to a census organization's success, it is critical that identified services provided by these systems are able to operate effectively without excessive interruption. Contingency planning supports this requirement by establishing a coordinated strategy involving plans, procedures, and technical measures that can enable the recovery of information systems, operations, and data after a disruption. Through contingency planning census organizations can work toward building a resilient infrastructure, minimizing the impact of any disruption on mission essential functions.

F.196. Interim measures, as part of an information system contingency planning, that could be taken to restore disrupted services generally include one or more of the following:

(i) Restoring information systems using alternate equipment;

(ii) Performing some or all of the affected business processes using alternate processing (manual) means (typically acceptable for only short-term disruptions);

(iii) Recovering information systems operations at an alternate location (typically acceptable for only long–term disruptions or those physically impacting the facility).

F.197. Information system contingency planning consists of a broad range of activities designed to sustain and recover critical system services following an emergency event. Information system contingency planning is just one of among a suite of plans a census organization would need to use to properly prepare response, recovery, and continuity activities for disruptions affecting the organization's information systems, business processes, personnel, and facilities. As a result, there is an inherent interrelationship between information system contingency planning and other types[51] of security and emergency management-related contingency plans and organizational resiliency. Information system contingency planning should therefore fit into a census organization's larger risk management, security, emergency preparedness, and organizational continuity and resiliency plans. Because of this relationship, there must be coordination between each plan during development and updates to ensure that recovery strategies and supporting resources neither negate each other nor duplicate efforts.

9.2. Contingency plan development[52]

F.198. Plan development represents the core activity in information system contingency planning. The contingency plan should contain detailed roles, responsibilities, teams, and procedures associated with restoring an information system following a disruption. The plan should document technical capabilities designed to support contingency operations as per the specific requirements of the census operation.

F.199. Contingency plans for census operations should make a special effort to secure and manage large volumes of electronic information or data that are transferred from field to the headquarters during the field enumeration. The impact of data loss or corruption from hardware failure, human error,

[51] Other types of emergency preparedness-related plans include: Business Continuity Plan; Continuity of Operations Plan; Crisis Communications Plan; Critical Infrastructure Protection Plan; Cyber Incident Response Plan; Disaster Recovery Plan; Information System Contingency Plan; Occupant Emergency Plan; etc.

[52] National Institute of Standards and Technology (NIST). Contingency Planning Guide for Federal Information Systems. NIST Special Publication 800-34 Rev. 1. May 2010.

hacking or malware will create a significant problem that must be solved in a short time, without jeopardizing the integrity of the census.

F.200. The plan should contain three main components that govern the specific actions to be taken following a system disruption:

(i) the **Activation/Notification** phase which describes the initial actions to be taken once a system disruption or outage has been detected or appears to be imminent. This phase includes activities to notify recovery personnel, conduct an outage assessment, and activate the plan;

(ii) the **Recovery** phase which details the suggested course of action for recovery teams to restore system capabilities, repair damage, and resume operational capabilities at an alternate site or using contingency capabilities. Depending on the recovery strategies defined in the plan, these functions could include temporary manual processing, recovery and operation at an alternate system, or relocation and recovery at an alternate site; and,

(iii) the **Reconstitution** phase, the third and final phase of contingency planning implementation, describes the activities to test and validate system capability and functionality and outlines actions that can be taken to return the system to normal operating condition and prepare the system against future outages.

F.201. The plan should be prepared in a clear, concise, and easy way to implement in an emergency, providing quick and clear directions in the event that personnel unfamiliar with the plan or the systems are called on to perform recovery operations. Where possible, checklists and step-by-step procedures should be used.

F.202. The plan should be accompanied by supporting information that provide essential background or contextual information that makes the contingency plan easier to understand, implement, and maintain. The supporting information should aid in making decisions on how to use the plan, and in providing information on where associated plans and information outside the scope of the plan may be found.

F.203. The supporting information should provide details about the information system, including the following elements:

(i) System description — a general description of the information system addressed by the contingency plan. The description should include the information system architecture, location(s), other important technical considerations, input/output (I/O) diagram and system architecture diagram, and security devices (e.g., firewalls, internal and external connections).

(ii) Overview of three phases for information system recovery: **Activation and Notification**, **Recovery**, and **Reconstitution**.

(iii) Roles and responsibilities — a description of the overall structure of contingency teams, including the hierarchy and coordination mechanisms and requirements among the teams, along with an overview of team member roles and responsibilities in a contingency situation.

F.204. Contingency plans must be developed for each information system used in the census operation to meet the needs of critical system operations in the event of a disruption. Effective contingency planning should begin with the development of a contingency planning policy based on statutory and regulatory requirements.

F.205. The following is a seven-step contingency planning process that an organization may utilize to develop and maintain a viable contingency planning program for their information systems.

(i) **Develop contingency planning policy statement.** A formal policy provides the authority and guidance necessary to develop an effective contingency plan. The contingency planning policy statement should define the organization's overall contingency objectives and establish the organizational framework and responsibilities for system contingency planning. To be effective and to ensure that personnel fully understand the organization's contingency planning requirements, the contingency plan must be based on a clearly defined policy.

(ii) **Conduct business impact analysis.** Business impact analysis (BIA) is a systematic process to determine and evaluate the potential effects of an interruption to critical business operations as a result of a disaster, accident or emergency. Results from business impact analysis can help prioritize contingency planning measures to support information systems and components critical to supporting the organization's mission/business processes.

(iii) **Identify preventive controls.** Based on outage impacts identified in the business impact analysis, identify measures to be taken to reduce the effects of system disruptions and increase system availability.

(iv) **Create contingency strategies.** Contingency strategies should be designed to ensure that the system may be recovered quickly and effectively following a disruption. These should cover the full range of backup, recovery, contingency planning, testing, and ongoing maintenance.

(v) **Develop an information system contingency plan.** The contingency plan should contain detailed guidance and procedures for restoring a damaged system unique to the system's security impact level and recovery requirements.

(vi) **Ensure plan testing, training, and exercises.** Testing validates recovery capabilities, whereas training prepares recovery personnel for plan activation and exercising the plan identifies planning gaps; combined, the activities improve plan effectiveness and overall organization preparedness.

(vii) **Ensure plan maintenance.** To be effective, the plan must be maintained in a ready state that accurately reflects system requirements, procedures, organizational structure, and policies. The plan should be a living document that is updated regularly to remain current with system enhancements and organizational changes.

9.3. Technical considerations for common types of information systems[53]

F.206. This section highlights specific considerations associated with contingency planning for two commonly used types of information systems: client/server systems and telecommunication (LAN and WAN) systems. It also discusses common considerations when planning contingency capabilities. Given the broad range of information system designs and configurations, as well as the rapid development and obsolescence of products and capabilities, the scope of the discussion is not intended to be comprehensive. Rather, the section describes technology practices to enhance an organization's information system contingency planning capabilities.

9.3.1 Common considerations

F.207. When developing solutions for technical contingency plans—consisting of preventive and recovery measures—there are several areas that should be considered regardless of the platform or type of system. Common considerations include the following:

(i) Use of information gathered from business impact analysis process — the business impact analysis process is the first source for determining contingency planning strategies. Its results determine how critical the system is to the supported mission/business processes, what impact the loss of the system could have on the organization, and can help determine the type and frequency of backup, the need for redundancy or mirroring of data, and the type of alternate site needed to meet system recovery objectives;

(ii) Development of data security, integrity, and backup policies and procedures — maintaining the integrity (through regular backups of data on all systems) and security (through encryption applied to both the primary data storage device and on backup media) of system data and software is a key component in contingency planning;

(iii) Protection of equipment and system resources — making hardware and software resilient to environmental and component-level failures that would otherwise cause system disruptions based on risk-informed decisions;

[53] The content of this section was adapted from: National Institute of Standards and Technology (NIST). Contingency Planning Guide for Federal Information Systems. NIST Special Publication 800-34 Rev. 1. May 2010.

(iv) Adherence and compliance with security controls — establishing and adhering to information system security, integrity, and contingency policies for contingency planning purposes helps protect an information system against threats that can disrupt operations;
(v) Development of primary and alternate sites with appropriately sized and configured power management systems and environmental controls; and
(vi) Use of high availability (HA)[54] processes to minimize downtime by building redundancy and resiliency into the architecture.

9.3.2 Client/server systems[55]

F.208. Contingency considerations for client/server systems should emphasize data availability, confidentiality, and integrity at both the server system level and the client level. To address these requirements, regular and frequent backups of data should be stored offsite. Specifically, the system manager should consider each of the following practices for client/server systems:

(i) **Store backups offsite or at an alternate site.** Backup media should be stored offsite or at an alternate site in a secure, environmentally controlled facility.
(ii) **Standardize hardware, software, and peripherals.** System recovery is faster if hardware, software, and peripherals are standardized throughout the organization. Additionally, critical hardware components that need to be recovered immediately in the event of a disaster should be compatible with off-the-shelf computer components. This compatibility will avoid delays in ordering custom-built equipment from a vendor.
(iii) **Document system configurations and vendor information.** Well-documented system configurations ease recovery. Similarly, vendor names and emergency contact information for vendors that supply essential hardware, software, and other components should be listed in the contingency plan so that replacement components may be purchased quickly.
(iv) **Coordinate with security policies and system security controls.** Client/server contingency solutions should be coordinated with security policies and system security controls. In choosing the appropriate technical contingency solution, similar security controls and security-related activities (e.g., risk assessment, vulnerability scanning) applied in the production system should be implemented in the contingency solution to ensure that executing the system contingency solution does not compromise or disclose sensitive data during a system disruption or emergency.
(v) **Use results from the business impact analysis.** Impacts and priorities of associated information systems discovered through the business impact analysis should be reviewed to determine related requirements.
(vi) **Minimize the amount of data stored on a client computer.** Critical user data (e.g. enumerators and supervisors) should be stored on central servers that are backed up as part of an organization's enterprise backup strategy, rather than on the client computer hard drive.
(vii) **Automate backup of data.** Client/server systems should have software installed that automatically schedules data backups to a central data backup location. Data for backup should be stored at a common directory name to ease in automated backup and to make sure that only pertinent data is backed up. If the client system backup process is not automated from the network, users should be encouraged to back up data on a regular basis. Automated backup schedulers should be set up for stand-alone desktops and portable devices whenever possible.
(viii) **Provide guidance on saving data on client computers.** Instructing users to save data to a particular folder on the computer eases the IT department's client support requirements. If a

[54] High availability (HA) is a process where redundancy and failover processes are built into a system to maximize its uptime and availability. The concept of HA is to achieve an uptime of 99.999 percent or higher, which equates to just a few minutes per year of downtime. Several vendors offer HA products and services designed to minimize downtime by building redundancy and resiliency into the architecture.
[55] Client/server systems can have processing and data at both the server and client workstation levels. Client workstations are normally desktop computers or portable electronic devices (e.g., smart phones, tablets, laptops) connected to servers as clients. Servers support file sharing and storage, data processing, central application hosting (such as email or a central database), printing, access control, user authentication, remote access connectivity, and other shared system services. Local users log into the server through networked client machines to access resources that the server provides.

machine must be rebuilt, the technician will know which folders to copy and preserve during recovery.

(ix) **Store backup information at an alternate site.** If users back up data on a stand-alone system rather than saving data to the network, a means should be provided for storing the media at an alternate site. Software licenses and original system software, vendor service level agreements (SLAs) and contracts, and other important documents relevant to the stand-alone should be stored with the backup media. The storage facility should be located far enough away from the original site to reduce the likelihood that both sites would be affected by the same contingency event.

F.209. Contingency considerations for servers in a client/server system rely extensively on LAN and WAN connectivity to communicate with their clients. Because of this, server components must consider system contingency measures similar to those for LANs and WANs, including:

(i) **Standardize hardware, software, and peripherals.** System recovery may be expedited if hardware, software, and peripherals are standardized throughout the client/server system. Recovery costs may be reduced because standard configurations may be designated and resources may be shared. Standardized components also reduce system maintenance across the organization.

(ii) **Document systems configurations and vendors.** Document the server architecture and the configurations of its various components. In addition, the contingency plan should identify vendors and model specifications to facilitate rapid equipment replacement after a disruption.

(iii) **Coordinate with security policies and security controls.** Server contingency solution(s) should be coordinated with network security policies where similar security controls and security-related activities (e.g., risk assessment, vulnerability scanning) in the production environment should be implemented in the contingency solution(s) to ensure that, during a system disruption, executing the technical contingency solution(s) does not compromise or disclose sensitive data. Security of data within a client/server system is key as most systems are multi-tenancy, having multiple users and applications residing on the same system, with different security requirements and controls.

(iv) **Coordinate contingency solutions with cyber incident response procedures.** Because many application servers use Web services to provide an image of the organization to the public, the organization's public image could be damaged if the application server were defaced or taken down by a cyber-attack. To reduce the consequences of such an attack, contingency solutions should be coordinated closely with cyber incident response procedures designed to limit the impacts of a cyber-attack.

(v) **Use results from the business impact analysis.** Impacts and priorities discovered through the business impact analysis of associated LANs and/or WANs should be reviewed to determine recovery requirements and priorities.

9.3.3 Telecommunications systems[56]

F.210. When developing the telecommunications recovery strategy, the considerations that were provided in Section 9.3.2 regarding client/server systems are applicable. In addition, the following practices should be considered:

(i) **Telecommunications documentation.** Physical and logical telecommunications diagrams should be up to date. The physical diagram should display the physical layout of the facility that houses the LAN and/or WAN, and cable jack numbers should be documented on the physical diagram. Diagrams should also identify network- connecting devices, IP addresses, Domain Name System

[56] There are two primary classes of telecommunications systems: LANs and WANs. Wireless connectivity, prevalent for use with portable devices, can be used in either LAN or WAN environments. A LAN is located within an office or campus environment. It can be as small as two PCs attached to a single network switch, or it may support hundreds of users and multiple servers. LANs can be developed using any of several topologies. Each connection on a LAN is considered a node. A WAN is a data communications network that consists of connecting two or more systems that are dispersed over a wide geographical area. Communications links, usually provided by a public carrier, provide the connection to enable one system to interact with other systems. WANs can connect LANs together, connect to mainframe systems, and connect client computers to servers. WANs provide much of the communications requirements of geographically dispersed environments.

(DNS) names, and types of communications links and vendors. The logical diagram should present the telecommunications infrastructure and its nodes. Network discovery software can provide an accurate picture of the telecommunications environment. Both diagrams help recovery personnel to identify where problems have occurred and to restore telecommunications services more quickly.

(ii) **System configuration and vendor information documentation.** Document configurations of network connective devices that facilitate telecommunication (e.g., circuits, switches, bridges, and hubs) to ease recovery. Vendors and their contact information should be documented in the contingency plan to provide for prompt hardware and software repair or replacement. The plan also should document the communications providers, including proof of concept (POC) and contractual or service level agreement (SLA) information.

(iii) **Coordinate with security policies and security controls.** Telecommunications contingency solution(s) should be coordinated with network security policies to protect against threats that could disrupt the network. Therefore, in choosing the appropriate technical telecommunications contingency solution(s), similar security controls and security-related activities (e.g., risk assessment, vulnerability scanning) in the production systems should be implemented in the contingency solution(s) to ensure that, during a network disruption, executing the technical contingency solution(s) does not compromise or disclose sensitive data.

(iv) **Use results from the business impact analysis.** Impacts and priorities discovered through the business impact analysis of associated systems should be reviewed to determine telecommunications recovery priorities.

10. Evaluation of investment in IT

10.1. Introduction

F.211. Once the census project has been fully implemented, an evaluation on the IT investment management should be conducted. This evaluation completes the IT investment management process and helps in validating actual investment results. The purpose of the evaluation is twofold: (i) to compare the actual results, costs and benefits of recently implemented IT investments against estimates and expectations that were set for them in order to assess performance; and (ii) to identify lessons learned geared towards improving future IT investment decision and implementation processes. Lessons that are learned during the evaluation phase are critical for improving how the organization selects, manages, and uses its IT resources.

F.212. When conducting this type of evaluation, statistical organizations should measure a census project's actual results not only against the costs, benefits, schedules and risks (CBSR) presented in the business case, but also against the organizational objectives that are associated with the project. Evaluation should also be conducted for IT investment projects that were terminated before completion, to readily identify potential management and process improvements.

F.213. There is no consensus regarding the timing of such an evaluation. If the evaluation is conducted too soon after implementation, it may fail to capture the full benefits of the new IT system. In contrast, if the evaluation is conducted too late, institutional knowledge about the IT investment could be lost. However, this guideline should be adjusted depending upon the nature of the project and the organization's expectations for when the benefits that are documented in the project plans should be realized.

10.2. Focus areas of evaluation

F.214. Essential areas[57] of performance that should be evaluated as part of an evaluation of impact of investment in IT include:

(i) Achieving the strategic needs of the organization

F.215. This area of evaluation involves the evaluation of the aggregate impact of IT investments on the whole organization, and not just individual operational customers/units within the organisation. This evaluation provides insights into impacts made by the organization's IT investments. This area focuses on ways to measure how IT supports the accomplishment of organizational strategies. The strategic perspective recognizes that in successful organizations, all components, including IT, must align with organizational goals and directions. When evaluating the impact of IT in terms of strategic needs, the following questions should be considered:

- How well integrated are IT strategies with business needs?
- How well is the overall portfolio of IT investments being managed?
- Is IT spending in line with expectations?
- Is the organization consistently producing cost-effective results?
- Is the organization maximizing the business value and cost effectiveness of IT?

(ii) Satisfying the needs of customers (operational customers/units within organization)

F.216. This area of evaluation measure the quality and cost effectiveness of IT products and services. When evaluating the impact of IT on customer satisfaction, the following questions should be considered:

- How well are business unit and IT staff integrated into IT systems development and acquisition projects? (This assesses extent of customer partnership and involvement in IT-related activities.)
- Are customers satisfied with the IT products and services being delivered?
- Are IT resources being used to support major business process improvement efforts requiring information management strategies? If so, are the IT projects delivering the expected share of process improvement?

(iii) Fulfilling IT internal business performance

F.217. This focus area aims to evaluate the operational effectiveness and efficiency of the IT organization itself. The ability of the IT shop to deliver quality products and services could have a direct impact on decisions to outsource IT functions. When evaluating internal IT business functions, the following questions should be considered:

- Are quality products delivered within general industry standards?
- Are quality products being delivered using accepted methods and tools?
- Is our infrastructure providing reliable support for business needs?
- Is the enterprise architecture being maintained and sustained?

(iv) Accomplishing IT innovation and learning

F.218. This area of evaluation is concerned with IT workforce competency and development as well as the use the new systems, the extent to which advanced technology was used, employee satisfaction or retention, and the methodological expertise of the IT development team. This area recognizes that without the right people with the right skills using the right methodologies, IT performance will surely suffer. Assessments in this area should be guided by answers to the following questions:

- Does the organization have the right skills and qualified staff to ensure quality results?

[57] The four focus areas of evaluation are adapted from: United States General Accounting Office (GAO). Executive Guide: Measuring Performance and Demonstrating Results of Information Technology Investments. Exposure Draft. GAO/AIMD-97-163. September 1997.

- Is the organization tracking the development of new technology important to its business/mission needs?
- Is the organization using recognized approaches and methods for building and managing IT projects?
- Is the organization providing its staff the proper tools, training, and incentives to perform their tasks?

F.219. By assessing IT performance across the four major goal areas (strategic, customer satisfaction, internal business performance, and IT innovation and learning), the evaluation will be constrained to take into account the context of the whole statistical organization. This limits the possibility of overemphasizing one area of measurement at the expense of others. In addition, measuring IT performance from different perspectives helps strengthen the analysis of both the tangible and the intangible benefits that are attributable to technology.

F.220. It should be noted that the areas of evaluation presented above do not represent the full universe of what an organization might evaluate. Also, in practice, the goal and objective of evaluation may require focus areas more specific than those presented above.

10.3. Process requirements for evaluation

F.221. To ensure consistent evaluation, it is important for the statistical organization to have a documented methodology for conducting evaluations. Evaluations should be required to ensure that completed IT projects are reviewed in a timely manner. The organization should also have policies or procedures that document how information from an evaluation is to be relayed back to decision-makers for improving decision and implementation processes.

F.222. An organization will have difficulty performing an effective evaluation unless it has established policies and procedures to assess the benefits and performance of its IT investments. Policies and procedures governing an effective evaluation should spell out: who conducts and participates in the evaluation; when it is appropriate to conduct an evaluation; what information is presented in an evaluation; and, how conclusions, lessons learned, and recommended management action steps are to be disseminated to managers and others.

F.223. The evaluation should generally cover: the IT investment expectations; actual investment results (e.g., end-user satisfaction, technical capability, mission and program impact, unanticipated benefits); cost and schedule deviations, such as additional “hidden” costs related to investments that have been made to enable the primary investment; environmental changes that affected the investment; a review of the assumptions that were made during the decision-making period; expected next steps for the investment; general conclusions and lessons learned; and recommendations to mangers.

F.224. It is important to ensure that adequate resources, including people, funding, and tools, have are provided for conducting evaluations. These resources typically involve: assigning a team to prepare and conduct the evaluation; assigning one team member responsibility for leading the evaluation; and, tools to support the evaluation, such as investment planning and scheduling programs, and risk and benefit assessment methods and tools. In most cases, the project team should actively assist the evaluation team in conducting the evaluation.

10.4. Information requirements for evaluation

F.225. A central input to the process of evaluation is the variety of data and information including historical records of the project. The key information and data required can generally be categorized into those that assist in: i) measuring actual vs. projected performance; and, ii) documenting the "track record" of the project and its process.

(i) Information requirements for measurements of actual vs. projected performance

F.226. One of the purposes the evaluation is to assess whether a project's actual results as compared to estimates in terms of cost, schedule, performance, and mission improvement outcomes. An attempt should also be made to determine the causes of major differences between planned and end results. And the evaluation should be used to help identify any inappropriate systems development and project management practices. Some of the key information to help answer questions related to measurements of actual vs. projected performance include information on:

- projected versus actual cost, benefit, and risk;
- cost, benefit, and risk information that was used for initial project justification;
- updates made to costs, benefits, or risks;
- verification/validation of cost data, some contained in financial management/accounting databases;
- performance expectations and actual outcomes;
- qualitative and quantitative measures of project benefits;
- assessments of customer satisfaction (end-users, business or program unit sponsor, etc.);
- assessments of technical capability (e.g., conformance to recognized systems development methodology, architecture compliance, contractor performance and oversight).

(ii) Information requirements for documenting the track record of the project and its processes

F.227. The organization should be maintaining documentation of all decisions, changes, actions, and results that occurred throughout the project's life cycle, as well as other relevant project information, such as the business case and updated cost/benefit analyses. The organization should also be tracking recommendations (for both improving the project and refining the overall investment management process) that arose out of previous evaluations. This "track record" will be invaluable for helping the organization refine and improve its processes as more and more information is collected and aggregated. Some of the key information to help in tracking the project and its processes include qualitative information, such as the perspectives and insights of project participants and end users. These may serve to validate or raise questions about the existing IT investment management processes used by the organization. Qualitative data can include: surveys and interviews of end users, customers, project management, project staff, contractors, and developers; project management and staff interviews; and, interviews with senior decision makers involved in IT investment oversight.

10.5. Decisions from evaluation

F.228. One of the major outcomes of the evaluation phase is the number of key decisions made based on the results of the evaluation. These include an assessment of how well the project met its intended objectives; a determination of what changes or modifications will need to made for future projects; and, an identification of ways to modify or improve the overall IT investment management process to better maximize results and minimize risks. In addition, the organization may assess the overall performance of its IT investments in improving mission performance. To make these decisions, managers must gauge the degree to which past decisions have influenced the outcome of IT projects, understand why these decisions had the effect that they did, and determine how changing the processes for making decisions could create a better outcome for current IT projects and future IT proposals.

F.229. The results and recommendations that arise out of the evaluations, combined with other project information, are a critical input for senior decision makers to use to assess the project's impact on mission performance. They are also important in terms of developing plans for continued support and operation of IT projects, especially those that will be repurposed for use in other data collection activities. IT systems that will be used for other data collection activities may require hardware upgrades, system software changes, and ongoing user training. Resources may need to be allocated for the operation, maintenance and disposition of such systems.

F.230. An organization's IT investment management process will usually evolve and change over time as the organization learns more and more about what has been successful and what still needs to be improved. Based on lessons learned extracted out of the evaluation, recommendations could be developed to improve the IT investment process. Additional recommendations could include improving the development of the business case and refining project cost, risk, benefit criteria.

10.6. Documentation

F.231. All of the information and documents produced in the evaluation phase should be collected and maintained along with other relevant project information. Lessons learned and recommendations for improving the IT investment process developed during the evaluation should be documented and then distributed to all stakeholders. Documentation of all decisions, changes, actions, and results that occurred throughout the project's life cycle should be maintained. Developing a library of project information helps to establish an organizational memory in which both successes and failures can be used for learning and improving management and implementation processes.

Annex 1. Suggested Topics to Include in Electronic Questionnaire Specifications

Topic	Specifications to Include	Benefit
Question or variable names	Specify the name of the variable for the output data file. Use question number or question names that describe the intent of the question.	Fosters consistency within and across instruments and provides data file documentation.
Universe/skip patterns	Indicate who should be answering the question.	Eliminates programmer guesswork; facilitates testing.
Preloads	Specify input source (such as what outside data source and variable names) and where preloads are used (for example, as fills, to drive routing).	Expedites programming and provides documentation for user.
Prefilled responses and wording variation	Specify "who" gets each version of the question and the preload variables or responses that drive the variants and fills.	Eliminates programmer guesswork; facilitates testing.
Routing instructions for "don't know" and "refused" responses	Indicate where these are allowable responses; indicate routing for each, or specify general rule that these responses always follow the "no" response unless otherwise specified.	Prepares instrument to handle the unexpected or less expected responses; prevents inappropriate questions from being asked in error.
Format requirements	Specify input format for dates, numbers, etc.	Allows program to capture data in the desired format.
Consistency checks	For each question, specify any consistency or data completeness check that is required; indicate the specific variables or responses that are involved in the check.	Identifies key items in the interview that require editing; allows interviewers to resolve problems with the respondent during the interview.
Scripted probes	Specify the exact wording to be used to resolve detected errors; provide means to continue the interview when no resolution is possible.	Assists the interviewer and respondent in resolving consistency problems detected during the interview.
Range checks	Specify the allowable range for open-ended numeric fields.	Checks for acceptable responses.
Looping requirements	Indicate the number of times the program should loop through a series of questions (such as the number of times the same set of questions are repeated for different household members).	Addresses data completeness needs by allowing adequate space in the data file.
Field widths for open-ended text responses	Specify the character limit for each field.	Ensures that sufficient space is allowed for data that require coding during or after the interview; reduces truncation.
Interviewer instructions	Specify to indicate they should not be read to the respondent.	Reduces the need for hard copy reference materials.
Programmer instructions	Describe how rosters, tables, and other features are envisioned.	Promotes open lines of communication with programmer.
Date and time stamps	Indicate when the interview date and time is to be captured (such as at the start or at the end) and where timing data is needed (for each section, for a particular question block, etc.).	Captures interview data for analysis and timing data to identify sections that may need to be shortened in length.
Automated data transmission and back up	Specify if there should be automated data transmission and/or back up. If so, indicate when or how often the data transmission or back up should occur.	Reduces the risk of data loss.

Source: US Census Bureau: New Technologies in Census Data Collection. Part 2: Developing an Electronic Questionnaire.

Annex 2. A Sample of Questionnaire Features to Be Tested, Possible Problems, and Testing Approaches to Detect Them

Questionnaire Features	Possible Problems	Testing Approach
Screen appearance	Inconsistent screen design and formatting The question is not immediately identifiable on the screen Poor visual design (cluttered, poor use of screen space, etc.)	Q-by-Q testing
Preloaded sample data and sample administration	Incorrect data formats Incorrect data order or appearance	Q-by-Q testing Testing by task Pretesting
Question wording	Inaccurately worded questions Missed words Spelling errors	Q-by-Q testing Testing by task Pretesting
Response ranges and formats	Formats do not match specifications Missing response options Inappropriate formats	Q-by-Q testing Testing by task Data testing
Missing values	Refusal, don't know, not applicable; other response options not used consistently or not at all	Q-by-Q testing Testing by task Data testing
Skip patterns—unconditional, conditional, missing values	Not all response options branch correctly Skips to wrong question	Testing by task Data testing Scenario testing Simulation
Calculations and fills	Division by zero Missing values Incorrect formulas Insufficient space reserved for fill variables	Q-by-Q testing Testing by task Pretesting
Randomization	Biased processes	Testing by task Data testing Simulation
Function keys and instructions for the interviewer	Not accessible Inaccurately worded Incorrect placement of the instructions Difficult to find on the screen	Testing by task
Rosters	Incorrect branching Insufficient calls to a roster	Q-by-Q testing Testing by task Scenario testing Pretesting
Attempt tracking and other case management features	Insufficient variables to track visit attempts Inappropriate visit slots	Testing by task Pretesting
Screening questions	Inaccuracies in determining eligibility	Q-by-Q testing Scenario testing Data testing
Termination questions	Insufficient termination codes	Q-by-Q testing
System issues	Abnormal terminations Corrupt output files	Scenario testing Testing by task
Data transmission issues	Cannot transmit data Corrupt output files	Testing by task Data testing
Data storage issues	Corrupt output files Insecure data storage environment	Testing by task Data testing
Data output issues	Mislabeled variable names Digits cut off Incorrect coding Corrupt output files	Testing by task Data testing

Logistics issues	Internet connection not available or too slow for data transmission at some locations Not able to charge mobile device at some locations	Testing by task Pretesting
Equipment issues (Testing equipment functionality and usability under various environmental conditions)	Battery runs out too quickly Memory cannot hold enough cases Screen freezes Sun glare on the screen GPS functionality and accuracy	Testing by task Pretesting
Other usability issues	The device is difficult to hold with one hand The text on the screen is too small Too many questions per screen	Testing by task Pretesting

Source: US Census Bureau: New Technologies in Census Data Collection. Part 2: Developing an Electronic Questionnaire.