

Malawi population and housing census technological trajectory: Unpacking 2018 experience

Mercy Kanyuka, Jameson Ndawala, Isaac Chirwa, Medson Makwemba, Richard A.P. Phiri*,
Chisomo Singano and Grevazio Kapaswiche
National Statistical Office, Zomba, Malawi

Abstract. Globally, with increase in need for evidence for relevant and effective responses in this century, holistic stocktaking and documentation of subjects has been heightened. In the same vein, Malawi has successfully conducted censuses from 1966 to 2018. Unlike other censuses, the latest round adopted use of Satellite imagery for mapping, Computer Assisted Personal Interviewing (CAPI) technology for data capturing and wireless and on-line data transmission to significantly reduce processing time and improve reliability and timeliness of census results.

However, in the face of CAPI and built-in data quality control features, data processing is irreplaceable and key since censuses are never perfect and errors do occur. Further, whilst incorporation of technology demonstrates benefits and merits, the approach comes with some logistical, financial and technical implications.

It is also evident that Knowledge sharing between National Statistical Offices (NSOs) is worthwhile, and incorporation of technological innovations has advantages irrespective of significant costs. Finally, being optimistic, positive minded and pro-active is key to implementation of a successful census.

Keywords: Population and Housing Census (PHC), household, CAPI, PAPI, satellite imagery, ArcGIS, mapping, base maps, enumeration area, Virtual Private Network (VPN), GIT lab, CSEntry, Network Access Storage (NAS), Network File System (NFS) CSPro, batch edit, synchronization, specification document, control centre Supervisor

1. Census undertaking in Malawi

Census undertaking dates back to as early as 3800 BC by the Babylonians that focused on counting all persons and livestock within a pre-defined area (Population Reference Bureau, 2019). Globally, with increase in the need for evidence for relevant and effective responses to situations, the holistic stocktaking and documentation of subjects of interest has been heightened and embraced in this century as discussed by Davoudi [4] and Cronin and Sadan [3].

In the same vein Malawi successfully conducted the first comprehensive Population and Housing Census

(PHC) in 1966 and it was followed by other rounds in 1977, 1987, 1998 and 2008. Unlike the 2008 PHC, the previous censuses utilized paper-based tools, processes and products. With this approach, enumeration and data processing proved to be time consuming and costly as it required manual conversion of the questionnaire responses into compatible data files for analysis. Further, data back-up was a challenge resulting in more reliance on the used paper questionnaires.

In 2008, paper questionnaires were used for data collection and heavy-duty questionnaire scanners were employed for data capturing and initial data processing which equally was labor intensive, time-consuming and had a substantial financial implication emanating from engagement of data-entry clerks, editors and reviewers for not less than 3 months on-site. Additionally, just like manual processing, this approach was

*Corresponding author: Richard A.P. Phiri, National Statistical Office, Chimbiya Road, Po Box 333, Zomba, Malawi. Tel.: +265 1 524 377; E-mail: richardakphiri@gmail.com.

prone to human errors which affected data quality. In particular, it did not have automated data consistency and accuracy checks in the field and during data processing resulting in traceable incidences of missing responses, wrong entries and omitted cases. Further, in terms of geo-referencing and mapping, all these censuses utilized a clear backdrop. This negatively affected map interpretation and enumeration as the field personnel struggled to relate to features on the ground and to identify pre-defined boundaries of enumeration areas, more especially imaginary ones.

2. Approach for the 2018 PHC

Census trajectories in many countries including Malawi have not been easy to sail through due to massiveness and complexity of the entire process. To navigate through such a challenging and multifaceted course requires grounded methodology and an informed and effective implementation plan.

In the face of the previous experiences, lessons drawn and financial implications, NSO started preparations for the 2018 PHC in the year 2015. Firstly, a census strategic plan aimed to implement a cost-effectiveness methodology, safeguard data quality and ensure timely release and dissemination of printed and electronic census products was developed. It opted for adoption of innovative strategies and incorporation of technology in some of the census activities to significantly reduce processing time and improve reliability and timeliness of census results [2].

For the latest census, NSO decided to embrace use of Satellite imagery for mapping, Computer Assisted Personal Interviewing (CAPI) technology for data capturing and wireless and on-line data transmission. To support the adoption of these technologies, NSO conducted a situation analysis on the technical capacity of the office, resources and budget implication, equipment required and geography and research boundaries. Results of the analysis highlighted the need for additional staffing, procurement of equipment, increase of office space, provision of storage rooms and security, installation of electrical power back-up system and need to update maps.

In respect of the foregoing, Mapping Strategy was developed and approved by the Secretary to the Treasury (ST) for Malawi Government. The document detailed the structural framework of the proposed mapping methodology, highlighted activities and expected timelines, stakeholders and a total budget of

US\$3,263,779 for implementation. During the 2015/2016 fiscal year, the Ministry of Finance (committed approximately US\$550,000) and other stake holders mobilized resources for the initial phases of the census. The resources covered procurement of computers, servers, ArcGIS mapping software, field work and initial payment for 6000 satellite imagery from Regional Centre for Mapping of Resources for Development (RCMRD). As per objective of the mapping exercise, NSO set a condition that satellite images were to be latest. For urban areas, they were to be captured within 1 year and a maximum of 3 years in rural areas whilst being of a prescribed 0.5 meters resolution.

Additional resources were earmarked for the collaborative implementation of the mapping component. Malawi Government through NSO roped in Department of Surveys under Ministry of Lands, Ministry of Local Government and Rural Department, US Census Bureau and RCMRD. RCMRD were to provide on-site and remote technical support for mapping processes. RCMRD is an inter-governmental organization established to develop capacity and provide technical support in the use of space technology and has 20 Contracting Member States in the Eastern and Southern Africa Regions, including Malawi; and US Census Bureau, as the name suggests, is an official statistics agency of the United States of America.

3. Census mapping

Relative to 2008 PHC mapping, boundary shifts had taken place hence mapping updates were very necessary. Precisely, some Group Village Headmen had been elevated to the status of Sub Traditional Authority or Traditional Authority which in turn affected their jurisdiction areas. City boundaries had been shifted, land area for wards in cities had increased and rural areas had been dented due to urbanization and other drivers. A comprehensive mapping exercise had to be undertaken to reflect current boundaries and ultimately, create a geographic frame with distinct boundaries that could allow a complete count of persons, households and structures; avoid duplication of data and facilitate disaggregation of data at any geographic and administrative level. Additionally, the mapping component would feed into facilitation of timeliness, universality and simultaneity of census processes and activities at the smallest feasible level.

Effective updating of administrative boundary layers, enumeration area' boundary layers and map at-

tributes and corresponding shape files necessitated capacity building of the mapping team. In this regard, NSO identified the Regional Centre for Mapping of Resources for Development (RCMRD), ESRI-South Africa, other experts and avenues to build capacity of the team in all aspects of mapping. For knowledge and skills in interacting with maps (in terms of symbology, visualization, and finding/ identifying/selecting features), working with tabular data and performing spatial analysis, the team went to ESRI South Africa for short term trainings. As part of the RCMD contract for census technical support, the NSO team underwent a number of short-term trainings on-site (NSO Headquarters) as well as at RCMD base in Nairobi, Kenya. The trainings focused on creating, displaying and evaluating data for analysis, designing map layouts and automating the mapping process. To complement this aspect, US Census Bureau offered and deployed GIS experts to organize and facilitate working sessions on mapping. Further, NSO capitalized on international meetings and interactions with experts from other Statistical Offices to equip the GIS team with other required skills.

In line with the highlighted trainings and also recognizing the technological innovations and advances, detailed assessment on the technology and equipment that would contribute to efficiency of the mapping processes was proposed and undertaken. Census study tours were prioritized as they provide professional insight through knowledge sharing [5]. The team travelled to Kingdom of Eswatini, formerly Swaziland for a hands-on access and live demonstration of the processes and systems used. From the visit, details of specific electronic devices and other equipment that could ably handle the Malawi census mapping and other functionalities were documented. Missions to Egypt and Ethiopia were also planned as the former had just conducted a full CAPI census in the year of 2017 whilst the latter was at an advanced stage of census preparation. Unfortunately, the rest of the study tours did not materialize mainly due to logistical challenges and other technicalities. Additionally, consultations with experts from US Census Bureau, other technical experts on census and specialists within Malawi were arranged and took place.

Based on these consultations and situation analysis, NSO procured forty high performance HP desktop computers, 20 Laptops, 1 HP Proliant DL60 Gen 9 server, 200 handheld global positioning devices and 2 plotters for map printing. The server was for central storage and controlled access to satellite images by

the computers for processing satellite imagery, updating 2008 PHC Enumeration Area (EA) maps, and developing dwelling structure frame using ArcGIS software. The computers were also for converting map products into formats compatible with tablets for field work phase (EA boundary identification and data collection). Additionally, Garmin GPSMAP78 global positioning gadgets were procured for geo-referencing of features of interest and field validation.

By design, field and office processes of mapping were run concurrently to allow field verification and updating of map features and revision of the maps. The in-office aspect focused on the 2008 mapping processes and products. It concentrated on EAs that were flagged as being so vast, had poor terrain, reportedly the numbers of households were above the threshold (150 in rural areas and 250 in urban areas), boundaries were problematic (had imaginary boundaries, erroneously missed features and other references, etc.) and other highlighted issues. Further, as part of the office component, boundary layers of 2008 base maps were overlaid on the satellite imagery to aid identification and marking of structures, potential households, physical features and where necessary update attribute tables. This phase also led into development of frame of dwelling structures using dotting approach (BBBB, 2008). Finally, using ArcGIS software and respective satellite imagery the team adopted mapping propositions and produced latest maps.

For the other part of the mapping phase, the teams were deployed for field verification and validation of the updated administrative and EA maps printed using heavy-duty plotters. To ensure local recognition/ownership of the process and more significantly the administrative boundary changes, local authorities or representatives were involved. The mappers reported to the head of District Police Station, District Commissioner and other key stakeholders for debriefing on the work and the list of gazetted TA's from the Ministry of Local Government.

The field teams physically checked features on the printed administrative and EA map. They randomly checked sizes of segments highlighted on the maps and where necessary they proposed new boundaries and recommended structures and other features to be marked on the maps. This phase allowed the teams to calibrate the handheld GPS receivers with ground reference points on the satellite imagery to minimize errors. For areas not yet updated, the teams capitalized on their presence in the district or neighboring district to collect information for updating the 2008 base map layers (roads, hospital, etc.).

4. Use of CAPI in the census

Prior to 2018 Population and Housing Census, NSO decided to migrate and adopt Computer Assisted Personal Interview technology (CAPI) over Pencil and Paper Interviewing (PAPI) system. The decision was driven by the need to improve efficiency in terms of timeliness and data quality; ease data capturing; minimize human errors [8]; ease data processing and transferring; and enhance availability of geo-referenced data. By its nature CAPI facilitates real time logic checks, skip patterns, and validations which makes data collection more efficient and achieves high data quality (World Bank Group, 2019). In Malawi this technology has been used in a number of surveys including Malawi Demographic Health Survey, Feed the Future Survey, Malawi Communications Regulatory Authority (MACRA) Survey and Integrated and Household surveys (IHS).

A consultative approach was used to identify a software for the structural framework of the proposed CAPI system for the census. In-house assessment was conducted and CSPro was preferred as no major issues have been experienced; on-site and remote technical support was assured; and it has no financial implication as it can be downloaded free of charge and requires no user licenses. Initially, CSPro version 7.0 was used in the programming of the CAPI system, however with the complex set-up for 2018 PHC application new versions (7.1, 7.2 Beta and 7.2) were adopted along the way.

4.1. CAPI application development

In light of the size and complexity of the census CAPI application, NSO engaged US Census Bureau for full-package technical support. Unlike custom package, the full package provided exhaustive support for the entire census process through 2 to 3 weeks in-country missions by experts in fields of interest. For CAPI development, US Bureau experts jointly with NSO team initially reviewed previous census questionnaires. The process focused on questionnaire modules, reliability and cost-effectiveness of questions. It was also grounded on harmonizing the questionnaire with internationally recognized guidelines for census and research (in particular, Principles and Recommendations for 2020 Round of Population and Housing Censuses, standard disability module and questions by Washington group on Disability, etc.)

Following review there was a need to ensure that the content and the corresponding technical requirements of the questionnaire will be effectively addressed. As hinted by Brancato et al. [1], questionnaire specification document was developed to inform this aspect of CAPI development. The spreadsheet-based document was designed to provide question numbers, question labels, question texts, variable names and universes (the targeted respondents) for each question. It also clarified response formats, responses and routing or skip instructions for each question. Further, it provided pre and post field checks and error messages to be displayed if an error/inconsistency is captured. Furthermore, it specified interviewer instructions (what should the interviewer do [observe, probe, etc.]) and question pre-fills and fill instruction wherever necessary. The specification document strived to ensure that all the mandatory questions in CAPI were tackled and responded to. One such approach was to provide instructions for resolving tricky situations instead of leaving the field blank.

The actual migration from paper questionnaire to Computer-Assisted Personal Interviewing application is notably iterative and cumulative nature. The process relies on gradual substantiation of the census questionnaire specifications document using CSPro software (initially 7.0 then later versions of 7.1, 7.2 Beta, and 7.3). In a cyclic manner the technical team tested the CSPro syntax, modified it, re-tested, modified and eventually finalized the procedure for the particular question.

To ease CAPI navigation and coordinate work in the field, the NSO team incorporated several menus. Practically, the menus allowed setting of the system and restricted access to either Supervisor or Enumerator mode. The Supervisors mode allowed the user to set the census area, manage field personnel (add interviewers, manage staff details) and assign work to the enumerators. This mode also initiated Bluetooth data synchronization with enumerators of interest (2-way pull and push), review collected data, conduct random re-interviews and transmit data to the central office online using a virtual private network (VPN). In particular, the use of VPN was for high level data security during transmission.

As for the enumerator mode, the system only allowed household enumeration, capturing of geographic information (automatically in the background) and details of structures and group quarters. This mode also facilitated 2-way data synchronization with supervisor through Bluetooth and backing-up data on both field

supervisors and enumerator tablets at every synchronization.

Prior to finalization of the CAPI system, NSO arranged 7 independent pre-tests of the application and the resultant revised version of the application was Piloted in September 2017. Equally, observations were made, revisions followed and were pre-tested 3 times to inform the final version of the CAPI application for deployment in tablets and utilization during the main enumeration phase.

To expedite the development process, ease coordination and allow remote technical support in terms of coding for the CAPI application, Source tree and GIT Lab software applications were used. By design, these powerful repositories eased access and interaction with files of interest, both on-line and off-line. The Source tree system allowed multiple accredited users to visualize the CAPI code/syntax, download and ultimately modify the current files whilst keeping track of what was proposed or revised initially in the repository files. As expected the system allowed the developers of the CAPI application to be more productive as they could either accept or discard changes to the code for whatever reason, from bugs in the system to CAPI syntax redundancy. However, in spite of the benefits, the approach at times poses some challenges as coding conflicts could be fatal thereby derailing CAPI development process entirely.

4.2. Equipment and technology for CAPI Census

Considering technological innovations and advances, NSO did an assessment on the technology and equipment that will support for a full CAPI census. For data collection NSO settled for a user-friendly handheld Lenovo Tab 4 tablet. The Android 7.0 (Nougat) enabled device uses GSM / HSPA / LTE network technology, 8.0 inches display and resolution of 800 x 1280 pixels. With an internal memory of 16/32 GB and 2 GB RAM, Nano-SIM, Bluetooth and GPS features, the tablets allowed smooth running of the census application, data synchronization between tablets and over mobile line internet connection and also capturing of geo-coordinates of households and structures.

Since approximately 20,000 Lenovo tablets were to be provisioned for enumeration, charging stations, each with 60 charging ports, were sourced. With this development, all tablets were charged in time thereby allowing them to be turned on, have time and date set up, GPS activated, Bluetooth renamed, CSEntry application downloaded and installed, and census application and maps uploaded.

Further, electrical power outages/challenges were inevitable in the rural areas of Malawi and sometimes even the urban areas during load-shedding hours. In readiness, 24000mAh/88Wh foldable convenient and fast charging power banks with 4 solar panels were procured. The team specified the add-on feature of built-in LED light considering that census processes in some instances take place at night. Notably, the high capacity power banks utilized tri-recharging technology. The power banks could also be recharged using hydro-electrical power through wall outlets/socket as well as DC power output port in the vehicles. The third option proved to be handy as every Control Centre Supervisor was assigned a vehicle throughout the census period.

To support transferring and storage of data from the field at the central office, additional equipment was budgeted for and procured. One of such equipment is the high-performance Intel® Quad-core 2.4 GHz Network Access Storage (NAS) with a maximum reading and writing capacity of 449 MB/s and 396 MB/s, respectively. The specific model is Disk Station DS2415 + RAM: 6 GB, 20 terabytes (TB) storage size, 6 GB DDR3 RAM and was using Network File System (NFS) file sharing protocol. The NAS device provided backup and storage for census data on the network. The computer device was added to the 2018 PHC network structure to provide the varied access to the census data by designated multiple users. It functioned as a file-level computer data storage server with more than one storage drive conveniently arranged to facilitate file saving on the network. As hinted by Levine (1998), configuration of NAS is simple, quickens data access and eases administration of the data sharing on the network.

Three (3) HP Proliant DL60 Gen 9 rack mounted servers were also proposed and procured. As per requirement to handle large data files, the servers provided RAM of 32 GB, 1 Processor, 6 cores, Hyper threading enabled CPU and 3TB HDD. The team structured the network in such a way that one server was CSWeb server, the second one handled back-up and at the same time dashboard server, whilst the third was remote/off-site back-up server.

5. Data management

Adoption of CAPI technology for data collection has often led to the thinking that we can do away with data processing. Indeed, in an ideal scenario, data pro-

cessing should be by-passable and arguably data analysis can follow completion of the enumeration phase and/or data concatenation of unique data files. This inclination is obviously attributable to misconception that the use of CAPI technology sufficiently enhances technical implementation of the census in terms of distribution and management of work. Further, with the built-in checks and skips/routing capabilities, CAPI application completely effect data flow consistency checks and logical harmonization of responses of an individual case/respondent in real time.

On the contrary and in the face of CAPI and built-in data quality control features, data processing is irreplaceable and key. As hinted by Kordos [6], censuses are never perfect and coverage and/or content errors and other technical irregularities end up on the data files. For Malawi, the main issues included assignment of wrong ID parameters to assigned enumeration area' case, partial or incomplete data files attributable to erroneous launch of data entry application (e.g. calling household questionnaire application instead of census structures capturing application, etc.), enumeration of households beyond the EA boundaries, inappropriate tablet sharing/transferring among enumerators, missing data files from unsuccessful data synchronization, data structuring, etc.

5.1. Data quality assessment and editing

Without loss of generality the foregoing necessitated a detailed assessment of the 2018 Population and Housing Census data files. As per underlying objectives the assessment focused on frequency distributions for each variable on one hand and the frequency distribution relative to other variables as well as logic flow of the responses on the other hand. This approach accorded and allowed NSO to understand the type of errors and also quantify the extent of discrepancies that existed in the data file of interest. Further, the utilization of data distributions informed and determined algorithms to be effected to repair the broken data using a CSPro (version 7.1) batch editing tool. The tool was opted for as it effectively flags out problematic cases, inconsistent and/or invalid responses, and eventually correct the noted discrepancy in such a way that it can be replicated. Further and as expected, NSO strived not to change valid data or modify data distributions as imputations were only to be called in to repair data that has been already/adequately classified as invalid.

To substantiate transparency and accountability, edit files were designed in such a way that information on

the inconsistency/invalid response and the imputations performed were clearly described. The CSPro edit programs produced "Edit Reports" and "Frequency Distributions" which were reviewed by programmers and subject matter specialists both prior and post edit. This approach allowed grounded review of anomalies, flaws in the edit program and framework as well as assessed the impact of the imputations.

NSO with technical support from US Census Bureau developed EDIT100 and EDIT200 that comprised of a series of CSPro edit algorithms targeting specific aspects and structure of the census tool. Precisely EDIT 100 focused on records containing insufficient data for data analysis. It removed questionnaires with no populations records and also introduced the `URBAN_RURAL` recode variable based on the geocodes recorded for the case. EDIT 200 looked at the household questionnaire entirely and it focused on the pattern of the valid responses for each question/variable. In particular, the 200 Edit program checked for consistency of responses in the data file and impute using multi-layer hot decks. Hot decks were also adopted for imputations of missing data/omissions.

An additional EDIT 300 was also developed and it dwelled on duplicate cases. Initially it checked and flagged cases with duplicate IDs then match the responses in the census modules of the duplicate cases. The duplications mostly came about as some enumerators assisted their fellows in completing EAs, a situation which demanded more than one enumerator login into the same EA. If the contents were different, the batch edit machinery assigned a different and appropriate case ID to the assumed duplicate file otherwise it deleted one.

6. Census field operation

The initial field plan was that five enumerators would be assigned 1 field supervisor and 40 field supervisors (FS) would work under 1 Control Centre Supervisor (CCS) who would report to the census district supervisor/manager who in turn reported to the Census Zone manager. The technical census implementation, in terms of data transfer, was also devised to follow the same structure only that from the Control Centre Supervisor the data would go straight to NSO Headquarters. With the logistical challenges that led to failure to procure additional 5000 tablets in time, NSO changed the data transfer plan. Though field supervisors were maintained, their direct role in data transfer

was scrapped off such that CCS synchronized data directly with 40 interviewers.

Despite the technical dent on data transfer, data collection and supervision structure of the 2018 PHC remained intact. Every Control center supervisors (CCS) recruited 8 field supervisors (FS) to assist in manning the 40 enumerators (5 enumerators each). They acted as link for ensuring smooth collection of data, located boundaries of each enumeration area, verified and certified completion of the assigned workload. The FSs also safe-guarded well-being and safety of enumerators. To ensure all front-line staff were updated regularly with relevant information, the FS regularly held briefing meeting with CCS and formed part of their respective census district WhatsApp groups.

Since the field supervisors were already trained on CAPI and supervisory roles, they were allowed to log-in on the interviewer's tablet. This accorded them an opportunity to review the structures and households enumerated, re-interview random households in the EA, troubleshoot problems and ensure that data backing-up was taking place.

7. Census results dissemination

The census results were as per protocol presented to the public through various reports. This phase involved hiring of private printing companies who designed and printed several copies of the successive reports, which were then stored at the NSO Headquarters in readiness for launch and distribution. The preliminary report was first released and launched on 10th January 2019, which was then followed by the main report released and launched on 30th May 2019. Additional reports on specific areas in the form of thematic reports, district monographs, and constituency reports are underway and will in the same spirit be released to the public with special interest to policy makers when completed. The released reports have been shared with government sectors, academia institutions as well as other interested parties and stakeholders at large.

NSO with help from UNFPA, has plans to further disseminate data for the 2018 PHC. It has planned to conduct district dissemination of reports and infographics, and disseminate corporate products (media briefs, data wheels, fliers and posters), and also develop data localization platform. Conceptually, the platform will be a mobile phone application that will allow users to query the database for information at different levels including enumeration area level.

8. Challenges experienced

The use of advanced technology and incorporation of innovative systems is increasingly transforming the way censuses and surveys are conducted (Castano, 2018). Despite the strengths and merits underscored by the endless success stories, the technological migrations bring along some hiccups on the census trajectory as described below.

Firstly, Malawi has 28 districts which were demarcated into 40 census districts, 485 control centers and 18,772 Enumeration Areas (EA) for purposes of censuses and surveys. By design, this required approximately 20,000 tablets as one control center supervisor manned and synchronized data with 40 front line personnel each tasked with enumeration of an EA. This implementation plan obviously had a financial implication in addition to creating a logistical challenge in terms of sourcing, distributing and provisioning as well as ensuring security for such a huge number of tablets. Similar cost challenges were faced in procuring the satellite imagery and mapping equipment; heavy-duty plotters, scanners, GIS software(s) and other IT infrastructure. Therefore, a thorough cost-benefit analysis and risk enquiry for embarking on the technology is required in the planning of a census project.

Secondly, the pilot census informed NSO that from the onset of census implementation, back-up supply of electric energy will be required by field personnel as quite a substantial part of the country has not been connected to the electric grid. Further, intermittent electric power interruption was persistent in many parts of the country. To counter power shortages in remote areas with little or no access to electricity, the budget of 2018 MPHC had to be revised upwards to allow procurement and distribution of 2000 milliamps (mA) electric power banks and solar chargers.

Further, CAPI census also faced data transfer challenges. On one hand, data transfer from an enumerator to a control Center Supervisor was over Bluetooth connection deliberately opted to counter poor internet connectivity in very remote areas. This required physical presence of a CCS for every data synchronization which proved to be tedious and costly since one CCS was tasked with synchronizing data from 40 enumerators. On the other hand, on-line data transfer posed a high risk of data confidentiality breach resulting from unauthorized data interception as well as malicious access to the data bank. In view of this, network systems were strengthened and upgraded as demonstrated by opting for virtual private network for data synchroniza-

tion with data center at the Head office which came at a substantial cost. Additionally, 3 servers safeguarded with passwords and an encryption mechanism were added to the data network.

9. Lessons learnt and recommendations

Census undertaking of 2018 has accorded NSO an opportunity to draw a number of lessons. Firstly, knowledge sharing within the African region in the spirit of South to South Cooperation is worthwhile. NSO greatly benefited from experiences and skills from countries that have pioneered incorporation of CAPI technology and use of satellite imagery during Population and Housing Censuses. In reciprocating the deed, NSO-Malawi has explicitly opened up to study tours and provision of remote and on-site support on CAPI development, Mapping and other areas of interest to other countries.

Incorporation of technological innovations in censuses comes with notable advantages on one hand and significant costs on the other hand. For instance, migration from paper questionnaire to CAPI technology contributed to over 30 percent of the overall budget whilst mapping component on the framework of satellite imagery utilized over 50 percent of the 1.5-billion-kwacha (US\$2.3 million) budget. Fortunately, the cost of the Malawi census was greatly subsidized through bi-lateral agreements in which DFID procured 15,000 tablets and UNFPA-Malawi coordinated loaning of the devices and other gadgets under the umbrella of south-to-south cooperation. Following enumeration, data processing and cleaning, the tablets were forwarded in July 2019 to Zambia for their 2020 Population and Housing Census.

With regard to funding and late disbursement of resources, being optimistic, positive minded and proactive is key. Major activities of the Malawi census were characterized by funding issues up to as late as 2 months before enumeration when the donor community through UNFPA-Malawi filled the 20 percent gap. However, irrespective of that situation, NSO implemented all the activities whose resources were already secured and conducted preparatory work for the activities that had resource gaps. This approach arguably contributed to the success story of implementing a full CAPI census.

10. Conclusion

The 2018 Malawi Population and Housing Census has been a success story. The 2018 PHC has been ap-

preciated for smooth running and completion of implementation. Particularly, the overall timeliness of the census results has been far more effective. The preliminary report was released within 4 months after the data collection and the main report was released within 4 months after the preliminary report. With the speed and quality of the census results, the cost implication of using the CAPI system was worthwhile. Although the census incorporated extra costs in usage of tablets, there was an overall cost minimization compared to the 2008 PHC. According to the 2018 MPHC results, the total population enumerated was 17.5 million people against a total budget of US\$19.8 million representing a high cost efficiency of US\$1.1 per capita against US\$1.4 in 2008 and US\$1.74 average per capita for most censuses in Southern Africa.

Acknowledgments

Despite the efforts made by authors in this project, this paper would not have been possible without the generous support and help of some individuals. We therefore would like to extend our sincere thanks.

Firstly, we are highly indebted to Mr Lusungu Chisesa for his guidance and constant review on the technical aspect of data synchronization, data back-up and equipment specifications as well as for providing information for other areas of interest.

We would like to express our heartfelt gratitude towards Mr Kingsley Manda for his support on the census mapping component. Further, we would like to acknowledge support, kind co-operation and encouragement from all members of staff of Demography Division of the National Statistical Office.

My thanks and appreciations also go to US Census Bureau, Regional Centre for Mapping of Resources for Development (RCMRD) and other stakeholder for making the 2018 Population and Housing Census project a reality.

References

- [1] Brancato G, Macchia S, Singore M, Simeoni G. Handbook of recommended practices for questionnaire development and testing in the European Statistical System, 1st ed. unstats, 2006.
- [2] Castano J. The increasing use of technology in the census of agriculture. Presented at the 16th Conference of IAOS, FAO, Paris, France, 2018.
- [3] Cronin GP, Sadan M. Use of evidence in policy making in South Africa: An exploratory study of attitudes of senior government officials. *African Evaluation Journal*. 2015; 3: 10.

- [4] Davoudi S. Evidence-Based Planning. *disP – The Planning Review*, 2012.
- [5] DeMello MA. The impact of study tours in developing global-mindedness among PK-12 educators in Southeastern Massachusetts. Northeastern University, Boston, Massachusetts, 2011.
- [6] Kordos J. The Challenges of the Population Census round of 2020. *Statistics in Transition*. 2017; 18: 115-138.
- [7] Population Reference Bureau, Moments in Global Census History, <https://www.prb.org/milestones-global-census-history/>: Retrieved on 30/09/19, 2019.
- [8] Sainsbury R, Ditch J, Hutton S, Computer Assisted Personal Interviewing. Department of Sociology – University of Surrey, Research Update, 1993.
- [9] The World Bank Group, Computer-Assisted Personal Interviews (CAPI), [https://dimewiki.worldbank.org/wiki/Computer-Assisted_Personal_Interviews_\(CAPI\)](https://dimewiki.worldbank.org/wiki/Computer-Assisted_Personal_Interviews_(CAPI)), Retrieved on 30/09/19, 2019.
- [10] UNFPA-IDWG; Census, UNFPA STRATEGY FOR THE 2020 CENSUS ROUND 1UNFPA Strategy for the 2020 Round of Population & Housing Censuses, 2017.