Wiadomości Statystyczne. The Polish Statistician, 2023, *68*(6), 47–66 https://doi.org/10.59139/ws.2023.06.3
Spisy powszechne – problemy i wyzwania / Issues and challenges in census taking
Zgłoszony/submitted: 4.11.2022, poprawiony/revised: 27.05.2023, zaakceptowany/accepted: 31.05.2023

Use of new technologies and evidence-based decisions: key factors in the strategy for the 2020 Population and Housing Census in Mexico in the context of the COVID-19 pandemic

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Abstract. The development of population and housing censuses implies a challenge regarding the necessary resources, logistics, and operations for National Statistical Offices (NSOs). At the global level, this challenge was more significant in the 2020 census round due to the COVID-19 health contingency. This led Mexico's National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía – INEGI) to analyze possible scenarios in the face of the pandemic and rethink some activities in order to adapt to the contingency. As a result of these measures, the 2020 Population and Housing Census in Mexico turned out a success.

The aim of the paper is to share INEGI's solutions implemented before, during, and after the COVID-19 contingency, which favored the development and conclusion of the census in Mexico and which other countries might find useful. Among the key elements of the Mexican census strategy was the incorporation of technologies for data collection, e.g. migrating from paper questionnaires to the use of mobile computing devices (MCDs), which reduced the time of capture and processing of information. In addition, a brief analysis of the behavior of past pandemics facilitated the decision-making. The main lessons learned from the Mexican experience include: the importance of maintaining the generation of official statistics in crisis contexts, the need for NSOs to have a robust risk management system that contemplates all types of scenarios and allows them to act in any contingency, and the need to implement innovative data collection methods and extend the use of Information and Communication Technologies (ICT).

Keywords: 2020 Population and Housing Census, COVID-19, strategy, mobile computing devices

JEL: J19, O33, D81

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Wykorzystanie nowych technologii i decyzje oparte na dowodach: kluczowe elementy strategii prowadzenia Spisu Powszechnego Ludności i Mieszkań 2020 w Meksyku w kontekście pandemii COVID-19

Streszczenie. Z prowadzeniem spisów powszechnych ludności i mieszkań wiąże się wiele wyzwań, z którymi muszą się mierzyć urzędy statystyczne, zarówno w zakresie logistyki, jak i niezbędnych zasobów i środków. Runda spisów 2020 okazała się szczególnym wyzwaniem z powodu wybuchu pandemii COVID-19. W tej sytuacji meksykański Narodowy Instytut Statystyki i Geografii (Instituto Nacional de Estadística y Geografía – INEGI) przeanalizował różne scenariusze działań i dostosował procedury spisowe do warunków pandemicznych. To pozwoliło na sprawne przeprowadzenie w Meksyku Powszechnego Spisu Ludności i Mieszkań w 2020 r.

Celem artykułu jest przedstawienie rozwiązań wypracowanych przez INEGI i wdrożonych w okresie poprzedzającym pandemię, w jej trakcie oraz po jej ustaniu, dzięki którym badanie zostało z powodzeniem zrealizowane i które mogą okazać się przydatne dla innych krajów. Jednym z kluczowych elementów przyjętej strategii było zastosowanie nowoczesnych technologii gromadzenia danych i rezygnacja z kwestionariuszy papierowych na rzecz mobilnych urządzeń liczących (ang. *mobile computing devices*), co skróciło czas uzyskiwania i przetwarzania informacji. Ponadto analiza przebiegu wcześniejszych pandemii ułatwiła podejmowanie decyzji. Doświadczenia wyniesione ze spisu w Meksyku wskazują m.in. na wielką wagę ciągłości opracowywania oficjalnych statystyk nawet w sytuacjach kryzysowych, potrzebę posiadania przez urząd statystyczny stabilnego systemu zarządzania ryzykiem, który uwzględnia wiele scenariuszy i pozwala działać w każdej sytuacji, oraz konieczność wdrażania innowacyjnych metod gromadzenia danych i szerszego wykorzystania technologii informacyjno-komunikacyjnych.

Słowa kluczowe: Spis Powszechny Ludności i Mieszkań 2020, COVID-19, strategia, mobilne urządzenia liczące

1. Introduction

At the international level, 53 countries participated in the United Nations (UN) 2020 census round; in many countries, this round of national censuses coincided with the onset of the pandemic due to COVID-19 and, due to health restrictions, only eight countries managed to conduct their census, including Mexico, which was also among the first to publish the census results.

Evidence-based decision-making was crucial for the National Statistical Office (NSO) of Mexico to continue and conclude the census activities planned for 2020. The analysis of statistical and historical information from pandemics such as SARS-CoV-1 was key to estimating the COVID-19 behavior, influencing the decision that the census activities could continue.

Conducting a census in Mexico generally implies a challenge because the entire national territory has to be traveled through and almost 44 million dwellings visited, in addition to mobilizing approximately 200,000 people, including interviewers, supervisors, and operational personnel.

The completion of the 2020 Census was successful due to the incorporation of current technological advances to perform various census processes, specifically, the use of mobile computing devices (MCDs) for the integration of digital applications in the various census processes such as streamlining the data collection and the incorporation of the essential validation criteria simultaneously with the collection of information. For this, it was necessary to develop different applications linked to the census operation and staff training. For the management of the devices and the preservation of the security of information, computer communication systems were structured.

The backup mechanism was paper-based in places where MCDs could not be used. Additionally, two complementary methods of collecting information were established: self-enumeration (through the NSO web page) and telephone-assisted interviewing. The series of efforts and decisions made within the NSO allowed the preliminary results of the 2020 Census to be published on 25th January 2021.

The objective of this article is to share the experiences and strategies implemented before, during, and after the COVID-19 contingency, which favored the development and conclusion of the census, despite adverse circumstances.

2. Pandemic: measures taken and guidelines

In Mexico, carrying out a census represents a significant challenge because the survey has to cover 2 million square kilometers of the national territory, and, as mentioned before, almost 44 million dwellings have to be visited as well as approximately 200,000 people (interviewers, supervisors, and operational personnel) have to be mobilized. This means a considerable human, financial, technological, and material investment (Instituto Nacional de Estadística y Geografía [INEGI], 2021b). In most countries, censuses are carried out every 10 years. In Mexico, they are carried out in years ending in zero, and the most recent census coincided with the start of the COVID-19 pandemic (INEGI, 2021a).

The key element of the strategy for the 2020 Census in Mexico, realized through the National Institute of Statistics and Geography (INEGI), was evidence-based decision-making. Statistical and historical information from previous pandemics (such as the 1918 influenza (H1N1) and the SARS-CoV-1 outbreak in 2003) was analyzed, as shown in Figures 1 and 2.

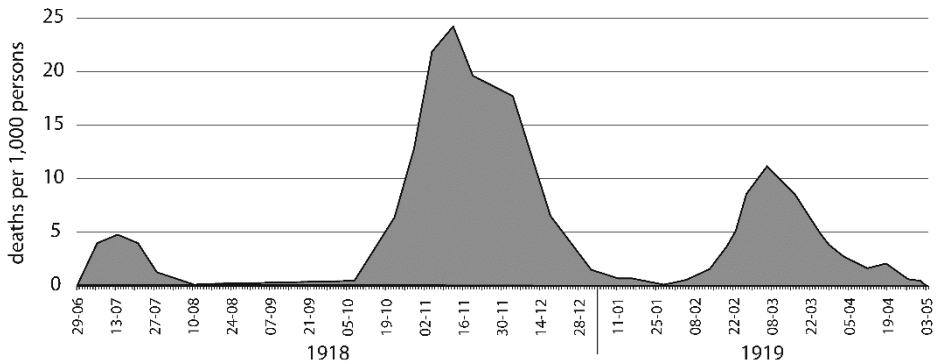
In addition, the knowledge about the 1889–1890 flu pandemic was utilized, even though month by month data on that pandemic's behavior was not available. It was important for the decision-making, however, to remember it occurred and for how long. This was the first pandemic in a fully interconnected world.

The H1N1 virus, during 1918–1920, affected mainly young adults between 20 and 40 years of age; there were about 500 million people infected, and at least 50 million died (Taubenberger & Morens, 2006). The statistical and historical analysis of the H1N1 pandemic shows that the first wave (from March to May 1918) was not very deadly, the second wave (from September to December 1918) was more violent and deadly, the third wave (from February to March 1919) was less outspread than the previous two waves, and the fourth wave (from January to April 1920) had less impact than the preceding ones. The SARS-CoV-1 pandemic showed, on the other hand, how quickly an infection spreads in an interconnected world. However, despite the speed of contagions, just over 8,000 people became ill, and approximately 1,000 died (World Health Organization [WHO], 2003).

Information from previous pandemics was useful for determining that their stages take place according to a wave pattern; that is, infections and deaths do not occur with the same frequency and intensity every day, but there are blocks in which these phenomena increase or decrease. Furthermore, it was possible to identify that the peaks of infections and deaths do not occur during the first days or weeks of the virus outbreak (Vielma Orozco, 2022b). The brief analysis of the existing data of past pandemics, which was conducted in less than a week, helped to estimate the pattern that this new pandemic would have. After this analysis, it was determined that the activities of the 2020 Census could continue as planned. One of the most important reasons why it was possible to collect information was that the census coincided with the early stage of the contingency (named Phase 1 by the health authorities), where infections were still relatively rare and there were no strict measures to follow.

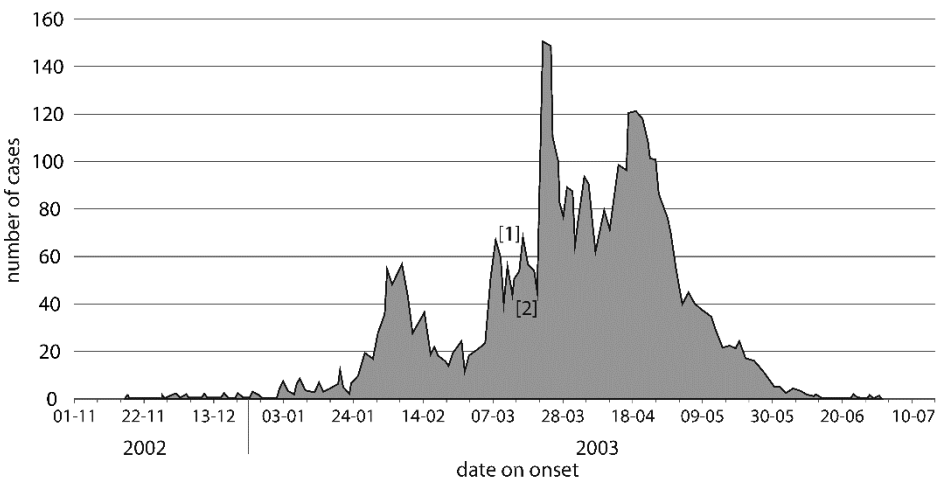
Here it is very important to highlight that it was not the depth of the data analysis, but rather the identification of existing information related to previous pandemics, which allowed the best decisions to be taken in less than a week, and additionally the knowledge that postponing the census for six months or a year would take us to the most critical moment of the pandemic, as it happened to most NSOs in other countries. Also, we anticipated that if we postponed the census, a year later (most of the pandemics analyzed lasted for two years, plus slight additional recurrences), due to the effects of the pandemic, financial and human resources would be limited, as in fact happened during 2021 and 2022, mainly due to the considerable limitation of the economic activity and the purchase of supplies to eradicate the pandemic (vaccines and intensive medical care).

Figure 1. Three pandemic waves: influenza and pneumonia mortality combined weekly, United Kingdom



Source: adapted from Taubenberger and Morens (2006).

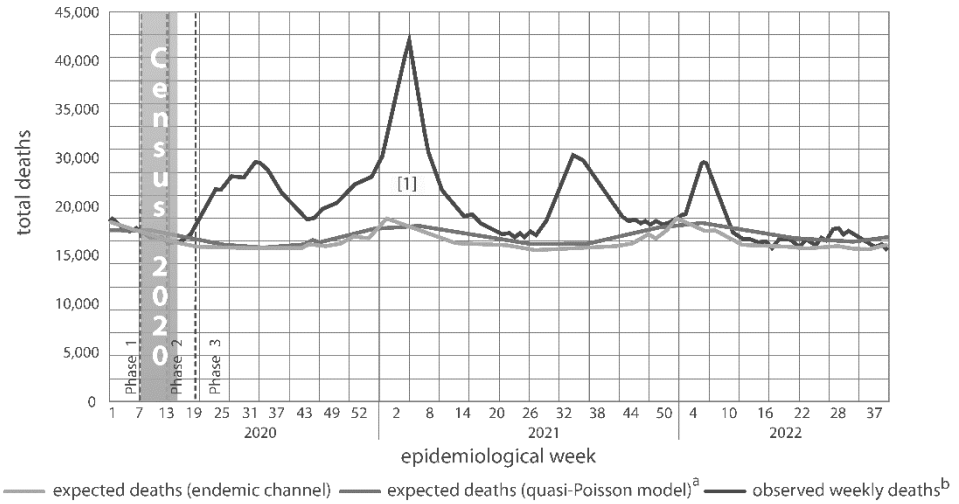
Figure 2. Probable SARS cases by week of onset worldwide



Note. n = 5,910. [1] WHO issues global alert: 12th March. [2] WHO issues first travel advisory: 15th March.
Source: adapted from the WHO (2003).

As can be seen in Figure 3, the decision taken by the INEGI regarding the 2020 Census proved to be the right one, since practically at the end of the enumeration in the field, the government indicated the entry to Phase 2 of the pandemic, referring to the beginning of the community transmission of the virus, and weeks later to Phase 3, an epidemiological stage where the virus had already reached thousands of people in various localities (Gobierno de México, 2020a).

Figure 3. COVID-19 effect. Excess mortality in Mexico, 2020–2022

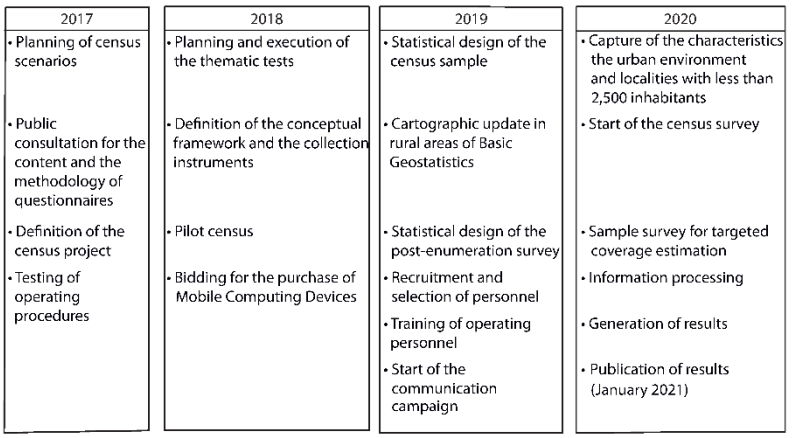


a Generalized linear model with the generalized estimating equations (GEE) method was fitted to estimate the expected value of the number of weekly deaths by state, age group, and sex during 2015–2019.
b Preliminary information.
Note. The filled box on the graph indicates the 2020 Census survey period, shown in the context of the weeks and phases of the pandemic. [1] Compared to the "expected deaths" line, the "observed weekly deaths" line establishes the excess mortality during the COVID-19 pandemic.
Source: INEGI (2023).

It should be noted that, at the international level, 53 countries made up the 2020 census round of the United Nations (UN). Still, due to health restrictions, only eight states managed to carry out their censuses, including Mexico, which was also one of the first to publish its results (INEGI, 2021a).

The complexity that characterizes censuses requires several years of planning, and in the case of the 2020 Census in Mexico, the preparations began three years prior to the survey, as seen in Figure 4. In 2017, a public consultation was held to define the theme and methodology of the questionnaires. Then, in 2018 and 2019, different preparation activities were carried out, such as the pilot test, personnel recruitment, and the start of the communication campaign.

Figure 4. Development of the 2020 Census activities



Source: author's work.

Data collection, their processing, and the generation and publication of the results were scheduled for 2020. In these stages, the planning and technification of the census favored the process's speed, even in the context of the pandemic (INEGI, 2021b).

The global spread of the SARS-CoV-2 virus occurred rapidly during the first months of 2020: the first confirmed death from the virus was reported on 11th January in Wuhan, China (El Mundo, 2020). On 22th January, the Mexican Ministry of Health issued an epidemiological alert in response to the new coronavirus (Comisión Nacional de Vigilancia Epidemiológica, 2020).

During February, the INEGI surveyed the characteristics of the urban environment and localities with less than 2,500 inhabitants, and it was not until the 27th of that month that the first case of COVID-19 infection in Mexico was reported (Guzmán Aguilar, 2021).

The enumeration of inhabitants was carried out from 2nd to 27th March, and relevant events related to the health contingency continued to occur during that period. On 11th March, the WHO declared the COVID-19 pandemic (Organización Panamericana de la Salud, 2020). On 18th March, the first death due to the new virus was registered in Mexico (Secretaría de Salud, 2020a). As of this date, the INEGI allocated resources for acquiring face masks, antibacterial gel, and liquid soap for the staff use. The enumeration of dwellings continued, and on 20th March, additional measures were requested from the INEGI personnel with fieldwork, such as the prohibition of entering homes, avoiding any physical contact between personnel, maintaining a minimum distance of 1.5 meters between people, the confinement of

personnel suspected of contagion, and the prohibition of fieldwork by personnel belonging to groups at risk,[1] all the above to protect interviewers and informants (INEGI, 2021a).

On 23rd March, social distancing began, and the first mobility restrictions were made official; basic prevention measures were issued, non-essential activities were suspended, and mass events were rescheduled (Gobierno de México, 2020b). As of this date, the INEGI employees began to work from home, except for the census and survey personnel, who had to comply with the measures of using masks, healthy distance, and the use of antibacterial gel for the last days of the data collection.

The census operations took place in the atmosphere of expectation, mainly due to different reactions of the informants to the field staff. Around the third week of the survey, an increase in the level of aversion and refusal to answer the interview in dwellings was observed among the population, which just coincided with the number of the confirmed positive COVID-19 cases starting to multiply (INEGI, 2021a). There were even media occurrences where public figures and officials requested the suspension of the 2020 Census activities. This situation negatively influenced some sectors of the population (El Dictamen, 2020). In isolated cases, events of aggression towards the census personnel were reported.

It should be noted that from the beginning of the enumeration, invitation letters were distributed so that inhabitants could answer remotely, accessing the 2020 Census online platform or by telephone; this was an option both if the respondents wished so and when it had not been possible to collect the information after three visits to the dwelling. During the field operation, 800,000 letters were delivered, and another 800,000 were sent by mail (INEGI, 2021a).

On 30th March, the General Health Council of Mexico published the "Agreement declaring the epidemic of disease caused by the SARS-CoV-2 virus as a sanitary emergency due to force majeure" in the Official Gazette of the Federation (Secretaría de Gobernación, 2020a). The following day, the Ministry of Health declared a sanitary emergency with 6,620 positive cases, with which non-essential activities were suspended, including the census and surveys in the national territory (Secretaría de Gobernación, 2020b); as a result, the INEGI officially announced the suspension of the face-to-face data collection.

The enumeration phase had been completed several days earlier, but the verification phase had yet to be finished. The post-enumeration survey had to be carried out; the former was postponed, and the latter was cancelled. By that time, the number of infected INEGI personnel had been minimal; however, a follow-up

[1] People with comorbidities associated with COVID-19, such as: diabetes, hypertension, and obesity, as well as elderly and pregnant women.

identification was created for all the personnel to prevent and mitigate the spread of COVID-19.

On 1st June, the reopening of activities began following the criteria of the Epidemiological Risk[2] (Secretaría de Salud, 2020b). As a result, on 15th June the Institute was able to resume activities in 16 states with orange status in the stoplight, following the "Guide for the mitigation and prevention of COVID-19", elaborated by INEGI (2020a).

On 17th July, the Ministry of Health published the "Agreement by which all censuses and surveys to be carried out in the national territory are resumed" in the Official Gazette of the Federation (Secretaría de Gobernación, 2020c), and at the same time, thanks to the collaboration between this federal agency and the INEGI, "General guidelines for the mitigation and prevention of COVID-19 in the generation of statistical and geographic information" was published (INEGI, 2020b), in which the minimum performance criteria were defined to resume field activities.

3. Mobile computing devices

For most of the 20th century and the beginning of the 21st century, using paper questionnaires was the usual way of conducting population and housing censuses. This traditional method involves several processes during the collection phase, including printing, distributing copies to various application sites, filling by hand during collection, and returning to the regional centers. All the above results in an extensive collection of printed documents that need to be captured manually in computers, which implies a significant amount of human and technological resources, in addition to the work hours required for this task.

On the other hand, during the second decade of the 21th century, the miniaturization of computer components reached such an extreme that it is now possible to have in the palm of one's hand a device that can match the technological performance of a basic computer, as is the case of tablets and cell phones.

Given the above, the INEGI proposed incorporating current technological advances to carry out various tasks of the 2020 Census, specifically using MCD for integrating digital applications in different processes. In addition to speeding up data collection, these devices made it possible to incorporate essential validation criteria simultaneously with data collection, such as question passes and the review of

[2] The Epidemiological Risk is an indicator that measures the level of epidemiological risk of COVID-19 in the states and municipalities of the Mexican Republic. It comprises information on hospital occupancy, SARS-CoV-2 positivity, the trend of hospitalized cases, and the trend of the COVID-19 syndrome. The stoplight classification is: red (maximum risk), orange (high risk), yellow (medium risk), and green (low risk).

congruence between related variables and valid values, which reduced the omission of data and improved the quality of information.

An institutional projection estimated that using the traditional method for the 2020 Population and Housing Census in Mexico would mean processing 35 million paper questionnaires (Vielma, 2022a). Furthermore, a comparative scenario analysis determined that the collection of the information on paper would generate a cost of over 1.5 billion Mexican pesos, while data collection by means of MCDs would cost only 300 million Mexican pesos (without the purchase of the devices); therefore, the remaining 1.2 billion Mexican pesos could be used for the purchase of the devices (INEGI, 2020c).

Considering that the 2020 Census would require slightly over 185,000 devices, it was estimated that in order to keep the cost of the survey carried out by means of MCDs at the same level as the cost of the traditional census (on paper), each device should cost slightly less than USD 346 (at the exchange rate in pesos at that date). However, if devices were acquired at a lower price, this would generate savings.

The actual cost per unit was less than USD 94, to which professional services, materials, and furniture expenses had to be added. At the end of the comparison, the estimated cost of the survey with MCDs, compared to the paper-based scenario, showed a saving of almost 60%; it should be noted that this only reflects the difference in the direct cost of capturing the information using paper or mobile devices (INEGI, 2020c).

After deciding to implement MCDs for the 2020 Census, several minimum characteristics of the devices were determined. Some of them had to have: an adequate processor and memory, an Android 6.0 or higher operating system, a screen with good resolution and brightness to be used outdoors, 32 GB internal storage to house the operating system, information capture applications, cartography, training material, satellite images, and the collected data; a battery that would guarantee operation for a full day of work; connectivity through the Universal Mobile Telecommunications System (UMTS or 3G network), as it is the most widespread in the country; and GPS to support the location of the personnel in the field (INEGI, 2019). Another important detail was that it could be operated just with one hand for more comfort for the interviewers.

Tests and field exercises were conducted before the purchase of the devices. Therefore, in 2017, the Operational Strategy Test was performed with various digital devices meeting the above mentioned requirements, in selected areas of Baja California, Hidalgo, Tabasco, and Yucatan (INEGI, 2021d). Five types of tablets of different brands, models, sizes, capacities, and operating systems were analyzed. More specifically, what was tested was their viability of use in the interviews, the

performance of the device and applications in different climates, its connectivity, ability to send information from the survey field, and data backup.

With the results of the above-mentioned test, the MCD characteristics were selected, and a limited number of units were purchased to be used during 2018 in the 2020 Population and Housing Census pilot test, thus subjecting them to an exercise in actual operating conditions. At the same time, various requirements for the bidding and purchase of the equipment were analyzed. In addition, in 2019, the selected MCD was combined with the established operating procedures and the selected technological and communications tools to make the final adjustments to the IT (Information Technology) infrastructure.

In the rules of the public bidding process for the purchase, it was established that the devices should be new, not remanufactured or discontinued, and have warranty coverage of at least one year. It was also stipulated that suppliers should participate in technical performance and endurance testing of the device, be responsible for transportation and delivery, and install customized software upon delivery.

Finally, it was stipulated that upon the delivery of the total number of devices, a sample of them would be reviewed. The shipment would be regarded undelivered if more than 1.5% of this sample did not meet the expected performance standard and characteristics. The procurement process lasted almost a year, and towards the end of 2019, a visit was made to the manufacturing plant.

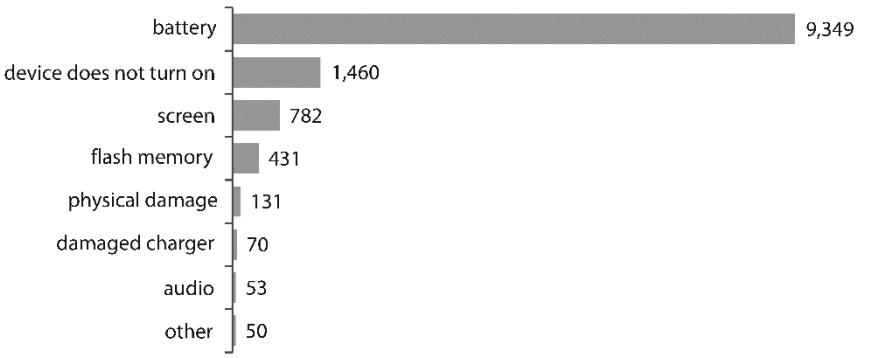
The MCD selected in the bidding process to be used by the INEGI in the 2020 Census had the following technical parameters:

- an MT6580 quad-core processor;
- Android 9.0 operating system;
- a 5.99 inch (15.21 cm) and 1440 by 720 pixels IPS display;
- brightness above 400 nits;
- capacity of 2 GB of RAM and 32 GB of internal storage;
- a 3,900 mAh battery that allows more than 8 hours of continuous use;
- connectivity with USB memory via OTG cable.

The inventory of the 185,824 devices was carried out at the Institute's central offices, and during the process, defective devices were identified and returned to the supplier for replacement. Once the inventory was completed, the devices were distributed to 34 local offices in the states of the country; this task was mainly carried out by vehicles and personnel of the Institute, taking various precautions for the safety of transportation.

As for warranties, they were attended directly by the supplier in each of the 34 local offices, with a maximum resolution time of 24 hours. In 2020, 6.6% of the equipment failed in some way. There were 12,326 failures, mostly related to the battery, as shown in Figure 5.

Figure 5. Main failures of MCDs



Note. *n* = 12,326 failures during 2020, occurring in 6.6% of the MCDs used in the census.
Source: author's work.

4. Technology and developed applications

It should be noted that the technology used in the 2020 Census (and applied to such a task for the first time) was not limited to the incorporation of MCDs to the survey process. The devices were the most visible, but without the efficient software, no digital hardware would be helpful. Therefore, to carry out the census, different applications related to the census operation and staff training had to be developed within the INEGI. Likewise, computer communication systems were structured to manage the devices and preserve the security of information.

This way, the following applications were created and installed in the MCD: Kiosko INEGI, which limited the usability of the device to census-related functions; Census Administrator, which had tools for capturing information; Census Cartographic Module (Spanish acronym MCC) that was used to update cartographic records; and the application for the training of operational figures (Spanish acronym CAAP).

As mentioned before, the Kiosko INEGI restricted the functions of the MCDs only to applications developed for the 2020 Census (INEGI, 2020c). With user credentials and an enablement pattern from the MCD, the device started the application for the interviewer or supervisor of interviewers. Due to the restrictions, the main features/functions available on the device were: device battery indicator, brightness level, making calls between operating figures, enabling or disabling the Wi-Fi, 3G and location.

Likewise, the camera was used to read the QR codes of the labels, invitations for self-enumeration, and printed questionnaires. Due to security policies, the

installation and uninstallation of applications, factory reset, notifications, access to settings, USB debugging, and connection to any PC were disabled.

The work area access module was in the Census Administrator, which is the beginning of data registration for urban blocks and dwellings, necessary to carry out census interviews. The GPS provided the location of the supervisor and interviewer's work areas while visualizing and managing workloads. It also helped transfer cartographic information from the supervisor and interviewer and provided the tracking module which controlled the progress of the survey in their work areas.

Likewise, the Census Administrator was the computer tool that allowed the application of the questionnaires during direct interviews (INEGI, 2020c). This included: the Basic Questionnaire and the Expanded Questionnaire for private inhabited dwellings, the Urban Environment Questionnaire, the Locality Questionnaire, and the Capture Module for the registration of each property (List of Properties).

The MCC made it possible to register cartographic updates detected during the surveillance in urban and rural areas, which contributed to the comprehensive census coverage and reliability of information during the survey. In addition, this application made it possible to create and delete urban blocks (areas), change the names of objects and even locations, and modify block fronts.

A total of 6,624 cartographic packages in GEOJSON format, one for each area manager, were generated and installed in the devices of the interviewer and supervisor. The information layers contained: urban and rural blocks, specific localities, road axes, block fronts, and satellite images. Due to a large size of files, there were minor setbacks in loading and visualization of the cartographic layers derived from the number of polygons that make up an area (especially in rural areas).

On the other hand, the CAAP training module was a software application designed for training the operational staff. It integrated the learning contents in infographics of the installed tools, the device care, standard solutions to problems, audio and video on each learning topic, maintenance of accessories and USB data backup devices, and self-evaluation.

Using the CAAP for personnel preparation was beneficial, as it allowed the trainee to have autonomous learning while receiving immediate feedback and evaluation of their verification activities, as well as being able to follow up on their performance. It also allowed the trainee to review audiovisual content at any time or place and to exercise the use of the device's systems.

The information captured in the MCDs was then sent in two ways: via the Internet (the Interviewer transferred the information collected to his/her Supervisor who integrated it into the central database through the OPERA platform), and

through mobile data. A prepaid SIM (Subscriber Identity Module) card was installed in each MCD. With this, the interview data were sent at the time of completion. If there was no mobile data service, the data were saved for sending later when the device detected a signal.

For the 2020 Census, the OPERA platform was used, which showed which devices were enrolled, and in addition their incidences (INEGI, 2020c). OPERA is an institutional multi-operational technological platform that provides services through modules or computer tools to meet the needs of the INEGI's census projects at almost all stages. This system has been developed on the basis of a modular design, allowing high scalability and integration with the requirements of different institutional projects.

It is composed of the following main modules: the operational monitoring of the main tasks; logistical monitoring to control the provision of material resources to field personnel; monitoring contingencies and operational incidents to support their prevention and ensure their registration; IT support and management of the MCD; recruitment and selection of personnel; data integration (to transfer the information captured to the central database); and remote distribution of digital and operational materials.

Together, the modules provided tools for executing and supporting the operational personnel's activities. They also informed managers and directors of the situation and aspects that arose throughout the project, enabling them to make decisions that would contribute to improving the quality of data collection.

5. Data collection

For most of the 33.6 million interviews in the 2020 Population and Housing Census, the information was collected through digital questionnaires that were viewed and uploaded through the MCDs (CAMI[3] method). The devices streamlined the conduct of face-to-face interviews and made it easier to automate the follow-up and monitoring tasks (INEGI, 2021c).

A small percentage of the data collection was done traditionally, on paper, mostly in high-risk (e.g. crime-ridden) areas, or when there was a technical failure with the device (mainly due to problems with the battery, screen or ignition). This way, paper-based collection functioned as a backup mechanism. Each questionnaire had a unique quick response code (QR), which made them unrepeatable and controlled their distribution among the personnel responsible for the data collection. On the

[3] Computer-assisted mobile interviewing, sometimes just known as computer-assisted personal interviewing (CAPI).

whole, around 700,000 questionnaires were filled out on paper and captured manually (INEGI, 2021d).

Additionally, two complementary methods were defined. The first was self-enumeration, in which the informant provided data on the dwelling and its residents through the INEGI web page, on the basis of the invitation letter delivered to them by the interviewer (CAWI[4] method). The second method was an assisted interview by telephone (CATI[5] method), in which the informant called the number indicated in the invitation letter to provide data on the dwelling and its inhabitants. Due to the COVID-19 health contingency, it was necessary to use the mailing of self-enumeration invitations to complete another small percentage of interviews.

Furthermore, the application used in the MDC, CAWI and CATI to capture information was used on mobile devices such as netbooks to collect information from the population living in collective housing (nursing homes, prisons, shelters, etc.).

At the end of the 2020 Census, 97.7% of the data on dwellings and persons were captured on digital devices, 2% on paper, and 0.3% via the web or telephone. A total of 43,903,443 dwellings were visited, of which 35,233,462 (80.3%) were inhabited, and 8,669,981 (19.7%) were uninhabited or intended for temporary use. Of the total number of inhabited dwellings, private and collective, 95.5% coverage was achieved (INEGI, 2021c).

Thanks to the above-mentioned efforts and decisions, it was possible to publish the basic results of the 2020 Population and Housing Census in Mexico on 25th January 2021. According to them, there were 126,014,024 inhabitants in Mexico, of whom 64,540,634 were women (51.2%), and 61,473,390 men (48.8%). The information was also generated for each state and municipality in the country, disaggregated at the urban block and locality level, providing the main socio-demographic characteristics of the population, such as age and place of residence.

This information was an essential input for the country's decision-makers in the distribution of vaccines against COVID-19, as it made it possible to geographically locate and prioritize vulnerable populations (Vielma Orozco, 2022b).

[4] Computer-assisted web interviewing.
[5] Computer-assisted telephone interviewing.

6. Main differences between the PAPI and CAMI (supported by CAWI and CATI) method for the 2010 and 2020 censuses

In this section, we present a brief comparison of the information on the IT technologies and field strategies used in the 2010 and 2020 Mexican censuses (Table).

Table. Comparison of strategies between the 2010 and 2020 censuses

Strategy stage	2010 Census	2020 Census
Input development	The content of both the didactic materials and the census questionnaires was developed.	
	All census material was printed (manuals, questionnaires, cartography).	All census material was developed on a digital platform (manuals, questionnaires, cartography) that was then stored on mobile computing devices (MCDs).
Selection and hiring	The selection and hiring process of all personnel was carried out on a digital platform.	The selection and hiring process of all personnel was carried out on a digital platform. For 2020, there was a greater integration of the selection modules.
Interviewer training	The training was carried out in classrooms, led by a tutor who explained the thematic contents. Trainees received their printed material, which was abundant (it was not possible to guarantee that they would read all the material). After the training, they were evaluated.	The training was organized on MCDs using CAAP, with audio, image and reading content, for greater attention from the interviewers. The interviewers listened to the content through headphones and read the information which appeared in the MCD. At the end of each section, they were evaluated on the same device. The role of the tutor was only advisory for the correct use of the device.
Cartographic update	The cartographic update was carried out on paper maps and took weeks to capture and validate.	The cartographic update was carried out on the MCD and any adjustment was identified and applied in real time.
Interview methodology	Face-to-face interview with paper-and-pencil (PAPI).	Face-to-face computer-assisted interview (CAMI), with the support of the CAWI and CATI methods.
Information capture platform	A data information capture platform was developed for paper questionnaires, once they were used and sent to the local offices. The information questionnaires arrived in the INEGI central offices three to four weeks after.	A data information capture platform was developed for the questionnaires applied through the MCDs. Once these were used, they were sent in real time to the computer servers of the INEGI central offices.
Monitoring of the census operation in the field	The follow-up of the census operation in the field took a week to know the progress of the first day. The leaders of the central offices took a week to make decisions.	The follow-up of the census operation in the field took five hours to know the progress of the first day. Every day at 7:00 a.m., the leaders of the central offices reviewed the specific progress throughout the national territory and sent instructions at the beginning of the day of operations to the coordinator in different country localities.

Table. Comparison of strategies between the 2010 and 2020 censuses (cont.)

Strategy stage	2010 Census	2020 Census
Geographical identification of the dwellings	Through a paper map.	Through a coordinate emitted by the MCD GPS. The label of the dwellings had a QR code that associated the number with the preloaded cartography of the MCD.
Information validation	The information was first registered and then validated, which typically took two to three weeks. In many cases, it was difficult to return to the field to correct some faulty information.	The MCD identified basic inconsistencies in real time, which made it possible to consult the interviewee about what was detected at that precise moment.
Data security	As the information was captured in paper questionnaires, anyone could access what a household had answered.	As the information was captured on an MCD, nobody could access the information, once the information was sent in real time.
Safety of the interviewing staff	Staff whereabouts were known once they returned to their local offices (in rural areas this could take days).	The MCD sent the geolocation signals of the location of the interviewing staff.
Data production time	After the census data collection, the effective time of processing the data took 9 months.	After the census data collection, the effective time of processing the data took 6 months.

Source: author's work.

The benefits of using MCDs instead of paper questionnaires included a reduction in the operating cost by approximately 47 million dollars, or 60%, compared to the previous census. But the greatest benefit was the improved timeliness of data, as well as its better quality.

7. Conclusions

The activity connected to the 2020 Housing and Population Census in Mexico began long before the COVID-19 pandemic, so when the SARS-CoV-2 alert was issued, the census work was already well underway.

It is essential to highlight that the analysis of the behavior of previous pandemics facilitated evidence-based decision-making, since it was foreseen that the pandemic would not last months but years; it was also possible to observe that, in its first days, infections and deaths from COVID-19 would be few and that as the weeks pass, the situation would become more serious.

Therefore, it was decided that the field collection of the 2020 Census data would continue, as it is an indispensable socio-demographic statistical activity. The organization of the census-related activities over a relatively long period, the digitalization of the interview process, and the review of historical information from

the past pandemics constituted the determining factors to the fact that most of the census stages were carried out on time and only some final activities were rescheduled.

Likewise, using applications and systems through MCDs made the capture of information more straightforward and agile, generating savings in human and material resources, time, and money simultaneously. If MCDs had not been used, data processing would have taken months, and the information from the paper questionnaires would have required putting many people inside a confined space for its capture, which, in the context of the COVID-19 pandemic, is unthinkable. Therefore, the opportunity to present relevant data for the health emergency would have been lost.

Also, we learned some important lessons following the COVID-19 pandemic, so other institutions and statistical offices can use this information to make decisions in the face of eventualities.

The first piece of useful knowledge drawn from the Mexican census experience is the great importance of providing continuity in the generation of official statistics, since the usual indicators, as well as the indicators derived from the current situation, are an essential input to the decision-making in critical circumstances. The second "lesson" is the significance of maintaining adequate communication to build a relationship of trust between the national statistical office, the population, and government authorities, to be ready for emerging changes in activities. The third valuable experience points to the vital importance of having robust risk management that considers all types of scenarios, even those that seem unlikely, to aid decision-making, have various strategies and define specific courses of action. The fourth "lesson" is realizing the need to implement innovative or uncommon information-gathering methods in developing countries, such as telephone-based information gathering and self-enumeration.

The fifth piece of knowledge gathered from the 2020 Census in Mexico is the necessity to further increase the use of Information and Communication Technologies (ICT) to perform tasks related to collecting and processing information in a more agile and efficient way, which will lead to savings in economic and human resources. And the sixth and final "lesson" learned from our census is that it is necessary to strengthen inter-agency collaboration through officials with a high level of general and managerial knowledge of events that may impact mass statistical programs, who know both the activities of their organization and those of others, and who know other subjects (in this case health and history) to analyze the behavior of pandemics. If we draw appropriate conclusions from the 2020 Census in Mexico, we will be able to prepare better for making effective decisions in the future difficult situations.

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