Report to the World Bank

Assessing the Opportunities and Challenges in the Transition to Computer-Based Survey Data Collection: The Role of Key Software System Features

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Narayan Sastry, William Axinn, Julie de Jong,
Dirgha Ghimire, and Emily Treleaven

Survey Research Center

University of Michigan

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1. Introduction

This report examines the opportunities and challenges associated with the adoption of computer-assisted interviewing (CAI) technology for data collection in household surveys in the Indian context, following a recent large-scale test of CAI in the southern Indian state of Tamil Nadu. The issues identified are highly relevant to the Government of Tamil Nadu's (GOTN) ongoing work to convert state survey data collection operations to CAI. These issues are also more generally informative to the shift from paper-based questionnaire instruments to CAI technology for state governments throughout India. The Survey Research Center (SRC) at the University of Michigan has worked closely with a Tamil Nadu state government agency—the Department of Economics and Statistics—that is at the center of this shift to CAI. Based on this experience, and our background running major CAI surveys in the U.S., Nepal, China, and elsewhere, this report provides some broader context about CAI, key features to consider in the selection of CAI software platforms, issues in the management of CAI operations, and related topics. This report was prepared by SRC independently of GOTN, but in service of the GOTN's work to expand CAI data collection.

2. Background: Key Issues in Adopting Computer-Assisted Interviewing Software

Improving the social and economic well-being of a population requires up-to-date, population-representative information about current circumstances and needs. This information is typically collected in cross-sectional surveys, which are often domain-specific and offer a "snapshot" of the current situation among individuals and households. Repeated cross-sectional surveys provide multiple "snapshots" across time, which can be valuable for monitoring change at the population level. Data can also be collected through panel (longitudinal) surveys of individuals and households, which provide a "movie/film image" by following the same individuals or household over time. Panel data provide a crucial tool for understanding the dynamics of poverty and well-being, the effects of government programs over time, and life course and intergenerational outcomes. Introducing and maintaining panel surveys can help government and other service providers to better design, plan, and implement welfare schemes and programs targeted at improving well-being among individuals and households.

Both cross-sectional and panel surveys require rigorous study designs and data collection processes in order to obtain high quality data. Paper questionnaire instruments are historically the most common method for collecting household and individual level data in interviewer-administered face-to-face surveys. However, paper instruments require data entry and processing that is slow and inefficient, and paper instruments increase the risk of interviewer error. The use of paper instruments necessitates the physical transportation of completed interviews as well as data entry and cleaning that lead to significant delays in making results available to policymakers and the public. Paper-based data collection is also subject to the risk of physical destruction or loss. Furthermore, the addition of a data entry step and the separation of data entry feedback from the interviewing process introduces significant quality control limitations—not only do data entry errors occur, but it is generally impossible to resolve errors or inconsistencies with respondents if data entry is conducted separately in a different location at a later time. In contrast, CAI via laptop, tablet, or other handheld electronic device provides significant improvements in the speed of data entry and delivery, identifying and resolving data entry errors and inconsistent reports by respondents, and capturing additional information about the interview (such as audio recordings) or circumstances of the interview (such as geographic coordinates based on the Global Positioning System). These advantages grow as the length and complexity of questionnaire instruments increase.

Achieving high quality survey data requires understanding and minimizing the potential sources of error that can occur both when interviewers are attempting to contact respondents, as well as when the interviewer is administering the questionnaire instrument and obtaining the respondent's answers. Survey organizations are able to leverage features available in CAI for quality assurance and quality control strategies during this process to prevent and correct problems that can affect survey data quality. The shift from paper questionnaire instruments to CAI can also result in significant cost reductions, particularly when the instrument is lengthy or when multiple languages or versions of the instrument are needed (Onono et al., 2011). For example, in a study by Thriemer et al. (2012), the shift from paper questionnaire instruments to CAI resulted in an estimated 25 percent reduction in costs.

The shift from paper questionnaire instruments to CAI began in many high-income countries more than two decades ago and has been occurring across much of the world in recent years. The proliferation of CAI has been accompanied by a growth in the number of commercially available survey data collection software platforms. Many different software platforms are available, each with its own strengths and weaknesses. As a result, not all systems are suitable for all surveys, with survey complexity and capability of the survey data collection organization playing a critical role in determining the appropriate software system for a particular project.

The payoff to adopting CAI in a survey depends on the complexity of a questionnaire instrument which depends, in turn, on several key survey design features: whether the survey is cross-sectional or longitudinal, whether multiple questionnaire instruments are administered in each household, and whether topics require complex features such as loops, an event history calendar, or detailed consistency checks. Panel surveys have more demanding interview software needs than cross-sectional surveys. For panel surveys, CAI software must be integrated with a highly capable sample management system used to track respondents, to document contact attempts and other paradata (data about the data collection process), and to transmit these data, from both cases which are complete and which are still in process, to supervisory staff on a routine basis. The CAI software for a panel must also be able to incorporate preloaded data from previous survey rounds to drive questionnaire skip patterns and logic, a feature needed by few cross-sectional surveys. An example of a CAI system having such functionality is Blaise (www.blaise.com), a software package developed by Statistics Netherlands that supports both data collection and data processing. At SRC, Blaise software is used in tandem with a robust sample management software, SurveyTrak International (STI), which was developed by SRC. The majority of other survey software systems (e.g., SurveyCTO, Qualtrics, and Voxco) have a sample management system with considerably less functionality or are lacking such a system entirely. In particular, the ability to transmit data about cases still in progress is a nearly universal limitation of these software systems, limiting implementation of efficient quality control monitoring and timely interviewer interventions, thereby presenting a significant challenge to data quality. However, these other software systems are more accessible to new users, less expensive, and may be appropriate for cross-sectional surveys.

A second factor determining the complexity of a survey is having multiple questionnaire instruments administered within a household, to one or more people. Such a design is common in more complex panel and cross sectional surveys. In the Chitwan Valley Family Study in Nepal (https://cvfs.isr.umich.edu/), for instance, a household survey requires administering one questionnaire to each adult, a youth-specific questionnaire to each child, and a questionnaire on general household status to a knowledgeable person in the household (Axinn, 2015). Implementing multiple questionnaires within a household requires the "spawning" of a new sample line for each additional questionnaire. Only a few software systems have such functionality.

A final factor related to questionnaire instrument complexity is the design and nature of the questions in the interview. Several types of questions add considerable complexity to a questionnaire instrument. A roster that identifies all household members is common in most surveys; however, it is challenging, although valuable, to have the roster drive sequences of questions for each member in multiple different sections of the questionnaire instrument. This task becomes complex when eligibility for questionnaire items or modules is based on member characteristics—such as age or gender. Event history data can also be challenging to collect using most CAI software. Event history data may cover different periods of time, based on the behavior in question, with longer histories covering more stable events (such as marriages or childbearing) and shorter histories for events that change more frequently or that are more difficult to recall (such as employment, work hours, and earnings). Both of these design elements require complex and conditional "looping" of questionnaire items or modules. And the need to incorporate such complexity into the interview questionnaire will guide the survey software platform selection for most studies.

Recognizing the wide-ranging functionality needed for successful data collection as well as the variation in capacity of existing CAI programs, several prior studies have assessed the available software systems. In 2011, the World Bank supported an assessment of CAPI software (Shaw et al., 2011) and, more recently, the Asian Development Bank (2019) undertook an experimental evaluation of the benefits of switching from paper questionnaire instruments to CAPI.[1] Other recent assessments of CAPI software include Fisher et al. (2016) and CartOng et al. (2017). Over the past decade, the functionality of CAI software systems has evolved alongside technical advancements and some of the systems reviewed earlier are no longer in existence, while other strong competitors entered the marketplace. For governments, NGOs, and other stakeholders with limited familiarity with survey research methodology, the number of options can be overwhelming when considering the selection of survey software suitable for a specific study design.

Rather than a thorough assessment of specific CAI systems, this report briefly reviews the primary features of current data collection software systems, focusing on critical sample management features and quality control features while considering how these features reduce survey error and increase data quality. The report also discusses other considerations critical to stakeholders when selecting CAI software. It then provides an assessment of the quality limitations introduced when there are mismatches between existing features in the data collection software and the requirements of the survey itself by considering a case study from the Tamil Nadu Household Panel Survey (TNHPS) Pre-Baseline Survey (PBS), conducted in 2018–2019 in Tamil Nadu, India. This case study highlights the importance of careful and deliberate selection of the appropriate software to meet the objective of a specific survey.

3. Sample Management Features

A sample management system facilitates release of assigned sample lines to specific interviewers and is set up to capture detailed information on the contact attempt history for each case, such as the day and time of each contact attempt, mode of contact, and the outcome of the contact attempt.

A sample management system is necessary for monitoring production progress against timeline and budget as well as for understanding interview error and reducing it where possible. During

[1] The Asian Development Bank (2019) notes that they have a forthcoming comparative study of existing CAPI platforms.

the selection of respondents in multi-stage area probability samples,[2] there is potential error in the household- and respondent-selection phases due to unintentional as well as deliberate deviation from protocols (Eckman & Koch, 2019; Kohler, 2007; Menold, 2014; Koch, 2019). Such deviations introduce the opportunity for nonresponse bias, which can have significant negative effects on key survey estimates. Nonresponse bias is a function of both the response rate and differences in characteristics between respondents and nonrespondents. If there are no such differences, then nonresponse bias is likely not a concern, regardless of the response rate. However, if nonrespondents differ from respondents, then a lower response rate will lead to higher levels of bias (Groves & Heeringa, 2006). Survey nonresponse and nonresponse bias have both been increasing over time in most parts of the world, leading to concern about the accuracy of population estimates (Beullens et al., 2018; Brick & Williams, 2013; Groves, 2011; Kreuter, 2013; de Leeuw et al., 2019; Peytchev, 2013; Wagner & Stoop, 2019). This is particularly true when surveys include topics that may be sensitive or stigmatizing. For example, reports of certain health-related behaviors, such as abortion, have found significant underreporting, item nonresponse, and inaccuracies in reports (Jones & Forrest, 1992; Jagannathan, 2001; Peytchev et al., 2010). Of course, which topics are stigmatizing can vary greatly within a heterogeneous population, making nonresponse bias associated with sub-population differences in perceived stigma (which can include topics such as occupation, income, and use of public welfare). There is also an increased risk for bias in studies that raise privacy or security concerns among respondents, such as those related to political participation and behaviors (Tourangeau et al., 2010). The potential for unit nonresponse bias is also heightened when segments of the target population are difficult to contact (Tourangeau et al., 2014).

A sample management system provides a platform to collect the contact attempt data to explore nonresponse bias. When such a system is integrated with the data collection (survey) platform, ongoing data analysis of paradata can assess interviewer compliance and performance and inform strategies to reduce various sources of error (Kreuter, 2013). However, to be effective, the sample management system must also be capable of connecting to the internet in near-real time (or at least daily) and of transmitting information on both cases that are complete and those that are still in progress. Given the vulnerability of survey estimates to nonresponse error, use of a sample management system to monitor interviewer adherence to study protocols in order to maximize response rates is essential to understanding and reducing error.

Many survey software platforms do not have a sample management system. When such a system is present, its features can vary greatly across platforms. Table 1 identifies the sample management system features most critical to facilitating interviewer monitoring and management and most likely to affect data quality. The sample management features identified in Table 1 are arranged according to the staff administrative level in which these features are managed: central office staff; local supervisory staff; and interviewing staff. Features at each level contribute to overall quality assurance and quality control of sample assignment.

Availability of several of the features, such as those relating to household listing and the spawning of sample lines, may depend on the interaction between the sample management system and the data collection system. In some CAI systems, the sample management system is a separate software system and its functionality requires the two systems to work in tandem. In other software platforms, the sample management system is a fully integrated component of

[2] Multi-stage area probability sampling—the most common sampling approach for face-to-face surveys—allocates the total sample across geographic units based on their population, and then randomly selects households and individuals within each geographic unit (Kish, 1965; Ustun et al., 2005).

the CAI data collection software. Regardless of integration, very few existing survey software systems include a sample manage system that fully meets the criteria listed in Table 1.

The paradata captured through a sample management system can be used to understand and reduce nonresponse rates and nonresponse bias through a strategy known as responsive design (Groves & Heeringa, 2006). In a survey conducted according to responsive design principles, researchers continually monitor selected indicators derived from the paradata (e.g., contact attempts) to inform the error-cost tradeoff in real time. The results of this monitoring form the basis for altering design features through intervention during the course of data collection or for subsequent waves. For example, monitoring of field progress using project dashboards—visual displays of information on costs, timeliness, and quality across survey processes—can be used to identify inputs (hours, released sample cases), output (completed interviews), and efficiency (costs per interview), and can be used to make adjustments to field processes as needed to achieve overall project goals.

Table 1. Sample Management System Features

Central office staff

- Upload sample lines to the sample management system
- Upload preload data for each sample line
  - In cross-sectional surveys: household/respondent contact data
  - In panel surveys: household/respondent contact data; other data from previous survey waves which interviewers may need to verify and/or update in the field
- Assign individual sample lines to field interviewers; retract and reassign individual sample lines from field interviewers if necessary
- Monitor field production on a daily basis for all cases (complete and in progress), including:
  - Time/date of each contact attempt
  - Mode of each contact attempt (face-to-face; telephone; text)
  - Result of each contact attempt (e.g., no one home, appointment made, completed interview, etc.)
  - Accurate selection of respondent(s) within sampled household

Supervisory staff

- Transfer sample lines between field interviewers
- Monitor field production on a daily basis for all cases (complete and in progress), including:
  - Time/date of each contact attempt
  - Mode of each contact attempt (face-to-face; telephone; text)
  - Result of each contact attempt (e.g., no one home, appointment made, completed interview, etc.)
  - Accurate selection of respondent(s) within sampled household
- Review case history to provide guidance to interviewers on contacting specific respondents

Interviewing staff

- Record detailed call record for each contact attempt, including:
  - Time/date of each contact attempt (automatically recorded)
  - Mode of each contact attempt (face-to-face; telephone; text)
  - Result of each contact attempt (e.g., no one home, appointment made, completed interview, etc.)
  - Detailed interviewer notes concerning with whom there was contact and other information to facilitate subsequent contact attempts
- Administer household listing and/or screener to select eligible respondent
  - Weighted respondent selection based on study design
- Spawn multiple sample lines within a household (e.g., adult #1, adult #2, child)
  - Each such line within the household automatically assigned the same household ID but a unique individual ID
  - Administer multiple, different, instruments to each sample line within the household.
  - Populate field(s) in one within-household questionnaire with data from other within-household questionnaire(s)
    - Note: this functionality is particularly important for a survey wherein there are multiple people interviewed in the household, as well as data collected at the household level
- Upload data to the server on a continual basis, regardless of whether case has been finalized

Monitoring of paradata and use of responsive design principles and practices can have other major benefits for fieldwork outcomes. These techniques can improve a survey's non-sampling error—that is, various systematic and random errors that are not associated with the sampling design. Reductions in non-sampling error can occur through various means, such as ensuring that the correct survey respondents are interviewed. Paradata can decrease non-sampling error in surveys by providing evidence to determine whether the correct respondent was selected within the household; under conditions where data are transmitted on a regular basis, errors in respondent selection can be reversed while staff are still in the field. Paradata-based responsive design can also maximize interviewer efficiency and reduce costs through enhanced project management, informed allocation of effort, and better decisionmaking regarding fieldwork strategy. For example, the optimal times to visit respondent households can be predicted through analyses of paradata to increase efficiency, and respondents can be classified and sub-sampled for more concentrated follow-up according to estimated fieldwork effort, leading to both decreased costs relative to effort as well as increased understanding of nonresponse bias. Finally, this approach can enhance data completeness and quality by analysis of fieldwork outcomes and assessing patterns of responses in the survey data within the questionnaire instrument.

The ability to leverage these paradata to enhance fieldwork outcomes requires that the data from the sample management system be uploaded on a regular (ideally, daily) basis to a central server through a secure data transmission mechanism. A significant limitation among most CAI systems, even those with some form of a sample management systems, is that cases can only be uploaded after they have been closed and assigned a final result code (with a code indicating a completed interview or another final sample disposition such as a final refusal). An illustration of the limitations of such a scenario appears in the case study presented in Section 7 of this report.

4. Quality Assurance and Quality Control Features

Interviewers use a CAI system to administer the questionnaire instrument to respondents and capture responses to each item, following the selection of the correct household and respondent using a sample management system. Existing CAI systems offer important quality assurance and quality control features that can significantly affect the validity and reliability of the final survey data. However, as with sample management systems, quality assurance and quality control functionality of CAI systems vary widely across software platforms. CAI systems generally have quality assurance features that promote the collection of high-quality data and include quality control elements that ensure that the data are valid, consistent, and error-free.

Quality Assurance

Standardization of interviewer behavior is an important component of the survey administration process, producing a uniform response process and less measurement error and resulting in higher quality data.

Critical quality assurance elements in a CAI system that can facilitate standardization and reduce subsequent error are listed in Table 2. These elements include preloading information for questionnaire items from the sample management system, earlier in the questionnaire, or from a prior survey, as well as complex skip logic that allows the response to one or more questions to determine the subsequent questions that are asked. Other quality assurance elements include consistency checks for questionnaire responses against other information, true randomization of questionnaire items and response options, standardized interviewer instructions, and clear definitions of terms and use of appropriate examples.

Table 2. Computer-Assisted Interviewing Software Quality Assurance Features

- Features to facilitate complex instrumentation:
  - Preloading of data from the sample management system (e.g., respondent age and sex)
  - Preloading of data from other sections of the survey (e.g., earlier recording of presence of child in household triggers questions about health insurance coverage of child in subsequent section of survey)
  - Skip patterns
- Consistency checks of data within / across instruments
- Looping of questions (i.e., a repeated set of questions for each of a given set of items)
  - Consistency checks within and across looped sets of questions
- Randomization of question items and response options
- Standard interviewer instructions
- Standard definitions and examples

Quality Control

CAI systems provide many opportunities to promote survey data quality by using paradata to monitor the data collection process and the content of responses to survey questions. Important quality control features in a CAI system include: automatic timestamp paradata for each item in a questionnaire instrument; keystroke paradata for all movement by interviewers through the instrument; Global Positioning System (GPS) coordinates to ascertain the location where an interview occurred; audio recording through an electronic microphone on interviewers' laptop or tablet computer for monitoring the adherence to interview protocols; and digital image capture using the camera on an interviewer's laptop or tablet computer to confirm the interview location or the respondent's identity.

CAI systems' quality control features allow analysts to identify deviation from interview protocols (Jans et al. 2013; Kreuter et al., 2010; Mneimneh et al., 2019; Sharma, 2019; Yan & Olson, 2013). For example, timestamp information can indicate problems of data fabrication or "curbstoning" (AAPOR, 2003). Keystroke information can provide insights into the accuracy of an interviewer's performance and indicate situations when a response is entered incorrectly—either erroneously or perhaps deliberately if a pattern of such errors is uncovered. Audio recordings of the interaction between the interviewer and the respondent can reveal deviation from the interviewing script or incorrect entry of an interview response. Paradata can also be useful for analyzing cases that did not result in a completed interview. Finally, researchers can identify needs for fieldwork interventions, such as additional interviewer training, based on paradata-derived indicators during real-time data collection.

Quality control analyses of survey paradata provide the knowledge needed to design and implement procedures to improve fieldwork and interviewing practices and thereby to achieve appropriate standards of quality control.

5. Other Computer-Assisted Interviewing Features

There are several other important CAI system features relevant to achieving high quality data that should be considered when selecting among the numerous available CAI systems. This section briefly addresses several of these features, including: procedures for testing the CAI system's functionality, the CAI system's compatibility with other components needed for data collection, the CAI system's ability to display information in multiple languages, the ability to use a CAI system in either on-line or off-line mode, and updating the CAI system during fieldwork.

Systems Testing Functionality

Testing of the sample management system and the CAI questionnaire instrument prior to fieldwork is critical for successfully collecting high-quality data. It can be labor intensive to test

and modify the questionnaire instrument, particularly if it has complex skip patterns, looping, and other advanced functionality. The CAI software system Blaise is unique in having a user interface for testing, which was developed by the Survey Research Center at the University of Michigan for in-house use (and is now available to all Blaise clients). This user interface for instrument testing allows multiple users to work simultaneously and record modifications needed to correct errors, remove ambiguities, and improve the performance of the questionnaire instrument. The modifications are typically noted at the question item level, which facilitates the task of collecting all of the requested modifications, adjudicating conflicting requests, then passing along to the project's Blaise programmers to address and resolve. Such a testing interface increases the efficiency of the process and decreases overall programming effort.

Compatibility

CAI software platforms vary in the degree of compatibility with other systems, such as sample management software, graphical image programs, GPS devices, statistical packages, interviewer monitoring software, and reporting and visualization software. Some CAI systems are not compatible with any other applications, while others are compatible with only off-the-shelf products. Still other CAI systems are compatible with custom-built solutions, such as the sample management and testing systems that have been developed specifically for Blaise. Depending on the complexity of the study, the compatibility of the CAI system with other software platform can have significant implications for overall data quality and costs.

Multiple Language Display

Although English is often used in government offices and among researchers and key stakeholders, in many countries around the world it is important for CAI systems to incorporate interviewing in the national language and other regional languages. In particular, CAI systems need to be able to display survey questions, features of the sample management system such as contact observations, and other components of the CAI system in multiple languages. CAI systems must also be able to display non-Latin scripts in left-to-right, right-to-left, and vertical presentation as required by the language convention. The most sophisticated CAI software allows the interviewer to toggle between languages during a single interview, and records at the item level the language used for administration.

On-Line and Off-Line Interviewing Capability

CAI systems are increasingly offering the flexibility to operate in both "on-line" and "off-line" modes. On-line mode is typically used in a centralized telephone facility with interviewers who use networked computers; on-line mode can also be used by respondents to complete a self-administered interview via the internet using a computer, tablet, or smartphone. Off-line mode is typically used by interviewers in the field who may not have steady access to a strong and stable internet connection, such as when they are visiting respondents' homes. The most sophisticated CAI systems allow cases to be moved easily between on-line and off-line interviewing—a feature that allows studies to take advantage of staff and respondent availability at different days and times. This capacity to integrate both on-line and off-line interviewing will be increasing useful as more surveys incorporate data collection over the internet.

Instrument Updates

Changes to a questionnaire instrument may occur after fieldwork production begins, leading to changes in the instrument. These instrument changes may be necessary to correct errors, or they may be due to the urgent need to add new items to the questionnaire—for example, due to an unexpected event that had a major effect on the study population (such as a natural disaster, pandemic outbreak, or other similar event). CAI systems differ in the mechanism for transmitting

updated instruments to interviewers' devices. Some systems permit central office staff to transmit the instrument to the interviewers' devices, while others require interviewers to initiate the downloading of the instrument from a project server or to bring their devices to a central office for a project staff member to install the revised instrument. In the latter situations, the responsibility for obtaining the most up-to-date instrument lies with each individual interviewer, leading to increased opportunity for error when such systems are used. These situations can also lead to significant burden for central office staff in some cases, as noted in Section 6 of this report.

6. Staffing, Infrastructure, and Design Considerations

Adopting a CAI system requires staff and organizational expertise in a number of domains, including technical systems, survey design and methodology, data collection, project management, and data security and storage. There is considerable variation across organizations in possessing such expertise and in their ability to obtain such expertise from stakeholders or collaborators. Understanding staff and organizational capacity across these domains is an important consideration in selecting the appropriate CAI system. This section provides an overview of each of these domains, and ends with a brief discussion of the implications for selecting an appropriate CAI system.

Technical Systems Expertise

Stakeholders can face constraints in the choice of a CAI system due to the technical skills of their staff. CAI software differs in the type of programming language and complexity and ultimately the technical skills needed to design the instrument. Some platforms use a "drag-and-drop" interface, while others allow the programmer to design the survey in another format, such as an Excel spreadsheet, and import it to the platform (SurveyCTO is an example of a CAI system with such functionality). Yet other systems, such as Blaise, require the programmer to use a programming language and thus have the steepest learning curve. When CAI systems with more complex programming requirements are selected, it is critical that stakeholders and organizations allot adequate time for comprehensive training of staff. Such investments can result in significant advances in data quality as well as time savings when revisions to the questionnaire instrument are necessary. Depending on the size of the organization and scope of survey work, at least one staff member experienced in programming questionnaire instruments is required for instrument development and associated testing. Programmers' familiarity with questionnaire instrument conventions (such as skip patterns, looping, and range checks) is also critical for minimizing error in instrument development.

Because CAI systems allow for increased fieldwork monitoring, it is necessary for data managers and supervisors to be able to develop, maintain, and monitor the associated quality control systems and to retrieve both survey and paradata from the system. An organization implementing a CAI-based survey data collection will need at least one data manager and, depending on the scope of anticipated projects, may in fact need multiple data managers. A data manager requires experience with querying, managing, and testing data in applications that store data in relational databases, using common data management tools such as SAS or SQL, as well as general knowledge of relational database concepts and scripting languages. A data manager should also have experience with combining data from disparate sources, debugging data in complex applications, cleaning and preparing data for analysis, conducting descriptive analyses, and preparing reports. Data managers require comprehensive training on the particular CAI system, as well as on developing and using survey research tools such as dashboards (using software such as Excel or R) to monitor fieldwork progress.

Survey Methodology Expertise

Survey methodology is the study of the possible sources of error that arise when designing, collecting, or analyzing survey data—with a focus on optimizing data and survey quality within the given cost constraints. Education in the theory and principles of survey methodology for an organization's staff is also a crucial consideration when selecting a CAI system and programming the questionnaire instrument.

Knowledge and understanding of the role that a CAI system plays in reducing survey error at different stages of the survey lifecycle can maximize the advantage that a comprehensive CAI system provides. For example, some CAI systems can collect complex paradata for use in quality control analyses and subsequent analyses on topics such as interviewer effects and nonresponse bias. However, survey methods theory plays an important role in conceptualizing specific research questions as well as the design and implementation of an analysis plan.

Currently, there are few rigorous academic programs focused exclusively on the discipline of survey research methods. The lack of trained specialists, especially in lower- and middle-income countries, can hinder the design and implementation of the many steps necessary to produce high quality survey data. However, opportunities for survey methodology training are growing and such training offers both survey organizations and stakeholders a valuable opportunity to improve their survey research capacity and take full advantage of CAI system functionality to improve data quality. An organization implementing a CAI-based survey should include at least one project manager with comprehensive training in survey methodology to oversee implementation of the CAI systems and leverage the quality control opportunities these systems offer.

Data Collection Expertise

In shifting from a paper-based questionnaire instrument to a CAI system, interviewers and supervisors require a new set of skills focused on computer literacy for interviewing. Screening activities to select staff with appropriate skills can include assessments to measure typing ability, computer literacy, and basic math and verbal skills, which have been shown to be predictors of overall job success. Successful completion of in-person mock CAI interviews is another tool for evaluating an interviewer's skills, and is predicted by reading skills, ability to record verbatim responses accurately, attention to detail including ability to follow complex instructions, and problem solving ability. Assessment of CAI skills is also predictive of the interviewer's ability to interact successfully with a laptop or other electronic data collection device. After selection, interviewers will require training in appropriate care and usage of the CAI hardware device both generally and for project-specific conditions.

Supervisors in a CAI project require training in roles and responsibilities surrounding CAI implementation, including CAI interviewing protocol and care of the devices. Supervisors also require training on protocols for incorporating feedback resulting from quality control metrics. These quantitative quality control data can be utilized in an empirically driven evaluation of interviewers to inform supervisors of the need for intervention during the fieldwork period as well as an interviewer's suitability for future surveys as well.

Project Management Expertise

The successful adoption of a CAI system for a survey requires staff with project management expertise in the full survey lifecycle. These staff need to incorporate additional steps at the beginning of the development process related to the design and implementation of the questionnaire instrument. It is especially important to allow sufficient time for the adequate testing of all CAI system elements, including the sample management system, the data collection instruments, system integration, language translations of the user interface and the

instruments, and the data-out procedures. It is also critical to allow adequate time for interviewers to conduct a full pretest in the field, testing all aspects of the devices, the CAI system, and the interviewing process. Without expertise in CAI project management to oversee all aspects of software systems development and testing ahead of data collection, there will be a significant likelihood of decreased data quality as well as increased cost to rectify errors.

Data Security and Data Storage

Stakeholders operate under a variety of security environments and regulations regarding data storage and use. Government stakeholders, in particular, face increasing scrutiny regarding issues of data access and ownership. Until recently, survey data collected with a CAI system were transferred to a server physically residing in the data collection organization's office, the office of a study collaborator, or the offices of the CAI system itself. When country-specific regulations specified that data had to be physically retained in that country, CAI systems were adapted to accommodate these requirements. However, in recent years, survey data are increasingly being transferred to a cloud-based server rather than residing on a physical server in a specified location. Such cloud servers may or may not reside in the location of the study, or even the location of the CAI software company headquarters. Indeed, it may be very difficult to determine the exact location of a specific dataset on a cloud server, calling into question the feasibility of adherence to regulations when using certain CAI software systems. In any case, selection of a CAI system must take into account the site of the system's servers and the compatibility with the study country's regulations.

Other data security considerations include use of appropriate computer security procedures for computer networks, devices, and users. Network-level security considerations include firewall protection and intrusion detection systems, as well as disk redundancy for computer servers and state-of-the-art backup systems. Networks require high-speed connectivity and automatic provision of security updates for all connected devices and use of the latest antivirus and antimalware software. Connected devices, including interviewers' and analysts' computers, need to have appropriate security and safeguards, such as unique user logins, strong passwords (including multi-factor authentication where appropriate), full disk encryption, regular backups, and the ability to remotely wipe clean any tablet or laptop computer that has been lost or stolen.

CAI System Selection

Surveys differ tremendously in complexity and design and there is no one-size-fits-all approach when selecting a CAI system, even within individual data collection organizations or stakeholders. Rather, any entity that conducts multiple surveys may elect to invest in more than one different CAI systems. For example, a government statistical agency tasked with carrying out numerous surveys may select one CAI system for cross-sectional (i.e., one-time) surveys that use a questionnaire instrument with limited complexity and a second distinct CAI system for panel surveys or cross-sectional surveys with a more complex questionnaire instrument. Such an approach increases the chances of matching the functionality of the CAI system with the requirements of the survey instrument and will increase the likelihood of study success and the collection of high quality data.

7. Case Study – Tamil Nadu Household Panel Survey (TNHPS)

This section presents a case study in which a CAI system was selected for a new survey in an organization that had little prior CAI experience and had relied almost exclusively on paper questionnaires for administering surveys. The section describes the implementation and results

of adopting a CAI system. The overall data collection effort was highly successful. However, the adoption of a CAI system posed several specific challenges. Describing these challenges, and how they were addressed, will provide useful guidance for other organizations considering the adoption of CAI systems. This section begins by providing background information on the new survey and the participating organizations, and then .describes issues related to the sample management system, instrument dissemination, quality assurance, and quality control.

Case Study Background

To obtain high-quality data for analyzing social and economic dynamics in the southern Indian state of Tamil Nadu, the Government of Tamil Nadu (GOTN) commissioned and funded the Tamil Nadu Household Panel Survey (TNHPS). Data from TNHPS will allow researchers and policy analysts to evaluate government programs and services and to monitor and promote the well-being of Tamil Nadu's population. Design and implementation of TNHPS is a collaboration involving the Madras Institute of Development Studies (MIDS), GOTN's Department of Economics and Statistics (DES), and the Survey Research Center (SRC) at the University of Michigan. MIDS is a research institute based in Chennai that studies development issues in Tamil Nadu and the rest of India. DES conducts surveys and prepares statistical reports for GOTN on a variety of topics. SRC has extensive expertise in complex CAI-administered panel surveys in the United States and many countries around the world. With SRC's methodological support, MIDS and DES are adopting CAI systems for TNHPS data collection in order to collect high quality survey data, improve fieldwork processes and procedures, and achieve timeliness of data delivery while also controlling costs. In addition, implementing TNHPS and adopting CAI systems will build technical capacity within Tamil Nadu to collect and analyze survey data.

The first phase of TNHPS was to conduct a pre-baseline survey (PBS) in 2018–2019 with a sample of almost a quarter of a million households across the state. The goal of TNHPS-PBS was to collect basic demographic and socioeconomic information on each household in the sample, in order to provide state and district-level estimates of key indicators as well as to serve as the sampling frame for Wave 1 of the panel survey. TNHPS-PBS was programmed and administered using the SurveyCTO platform on tablet computers. In contrast, TNHPS Baseline Wave is expected to use laptop computers and Blaise, a data collection software system developed by Statistics Netherlands and suitable for complex data collection. Blaise will be used with SurveyTrak International (STI), a sample management system developed by SRC to work in tandem with Blaise that has been used on complex household panel surveys worldwide.

There were several advantages of using SurveyCTO for TNHPS-PBS. Survey questionnaire instruments for SurveyCTO can either be designed in a Google or Excel spreadsheet and imported into SurveyCTO or designed through the system's "drag-and-drop" tool. These user-friendly options greatly facilitated instrument development for the MIDS staff responsible for instrument programming because they had limited prior survey programming experience. The survey needed to offer respondents the option of completing TNHPS-PBS in either Tamil or English, and SurveyCTO allowed both language options as well as an easy transition between the versions of the survey questionnaire in each of these two languages. SurveyCTO also has a user-friendly interviewer interface, facilitating data collection by DES interviewers with no prior CAI experience.

Interviewers on TNHPS-PBS contacted more than 240,000 households and successfully completed interviews in approximately 92 percent of occupied residential dwellings, a total of 212,282 completed household interviews that also collected information on 745,653 individuals residing in these households (see Sastry et al., 2021). Data collected in the TNHPS-PBS interviews were uploaded to SurveyCTO's cloud server. The resulting TNHPS-PBS dataset was extremely large, but the study encountered no problems or issues with the size of the dataset or

with using the cloud server. Staff at MIDS and DES were able to download the data to their own secure in-house servers without any issues. The TNHPS-PBS project represented the first large scale use of CAI by DES. It yielded an extremely valuable and rich population-level dataset, with contact information and consent for future contact that will support the launch of the TNHPS panel survey but also supported short pulse surveys on the effects of the COVID-19 pandemic on the Tamil Nadu population. Thus the successful effort of DES and MIDS to adopt CAI for TNHPS-PBS is directly responsible for GOTN's ability to collect data to monitor the health and well-being of the state's population.

The data collection of TNHPS-PBS by DES and MIDS was clearly an important success. Nevertheless, the implementation of the survey using SurveyCTO demonstrated a number of limitations that affected the study's ability to collect the highest quality data possible. Most software platforms engage in continuous process improvement and it is possible that one or more of these software limitations no longer applies at the time of production of this report. However, these constraints were present during the duration of TNHPS-PBS data collection. As this case study illustrates, it is imperative that the software selected is compatible with the quality objectives of the specific survey in question.

Sample Management System Functionality

At the time of TNHPS-PBS data collection, SurveyCTO had no independent sample management system.[3] Thus, there was no way to review case call records without first assigning a final sample disposition code and uploading the case to the server. Case call records provide information on the current (interim) disposition of each case, while final disposition codes indicate the ending status of case (e.g., complete, refusal, or vacant). As discussed in Section 2 of this report, call records can be summarized in "dashboards" for monitoring fieldwork progress and incorporated into statistical models to optimize fieldwork strategies—such as finding the best time to call or determining how many call attempts to make. Ideally, during TNHPS-PBS fieldwork MIDS and DES would have used information from the call records to provide feedback to supervisors and interviewers in order to maximize response in real time. The feedback would include guidance such as the optimal time to visit particular sample households and prioritization of fieldwork effort for cases based on their characteristics in order to monitor—and minimize—nonresponse bias (Stoop et al., 2010).

Unfortunately, the lack of a sample management system and inability for real-time intervention resulted in uneven nonresponse in both rural and urban areas in TNHPS-PBS, which was not evident until the end of the fieldwork period. This required expensive and time-consuming effort, nearly one year later, to collect additional data to explore the resulting nonresponse bias and develop nonresponse propensity weights. *A sample management system facilitating real-time analysis of ongoing fieldwork would have permitted more timely intervention, resulting in higher quality data and cost savings.*

Another challenge for TNHPS-PBS that emerged from the absence of a sample management system in SurveyCTO was the inability to transfer a submitted case from the server back to the interviewer in the event of an issue with the data. For example, as discussed in the subsection immediately below, significant errors were uncovered during data processing due to the limitations of SurveyCTO's real-time quality assurance functionality. In a project using a CAI

[3] SurveyCTO subsequently developed a sample management system. However, this new functionality only allows cases to be uploaded after they have been closed and assigned a final result code. Consequently, there is still no mechanism for monitoring interim disposition codes for each interviewer's cases, which significantly hinders effective management of interviewers' case load, quality control assessments, and interventions to improve productivity and data quality.

platform with a functional sample management system, a case with this type of error could have been returned to field so that the interviewer could return to the household and verify or correct the interview data as necessary. *The lack of a robust sample management system necessitated verification of survey responses by research staff at MIDS rather than by interviewers in the field. All changes to interview data had to be implemented manually by research staff at MIDS, introducing a further opportunity for data error*.

Instrument Dissemination

SurveyCTO requires interviewers to download the questionnaire instrument onto their own individual electronic device from the software platform directly. In order to access the questionnaire instrument on the platform, however, each interviewer would have needed to have the TNHPS-PBS project password. This password would grant interviewers access not only to the questionnaire instrument, but also to the overall project site thereby allowing interviewers rights to modify the questionnaire itself as well as other critical parameters of the project. MIDS quickly identified this approach as high-risk, and instead implemented a protocol in which the TNHPS-PBS questionnaire instrument was downloaded to each interviewer's device only by MIDS staff. The PBS data collection effort was sizeable, with more than 400 DES interviewers deployed, each with their own electronic device. Therefore, MIDS staff had to download the SurveyCTO instrument onto more than 400 tablets at the start of the fieldwork period. And, at least once during the fieldwork process, revisions were made to the questionnaire instrument, necessitating that all DES interviewers bring their devices into their local DES offices in order for MIDS staff to repeat the download process with the new questionnaire instrument. *The lack of automatic dissemination of the SurveyCTO questionnaire instrument to the interviewing staff led to delays in timely revisions to the instrument, and increased cost to DES interviewers and MIDS staff in both the initial and subsequent distribution process.*

Quality Assurance Functionality

SurveyCTO permitted the important functionality of being able to loop over a set of questions—for example, collecting responses to the same set of questions for each member of a household. However, at the time of the TNHPS-PBS, SurveyCTO did not have a mechanism for consistency checks within the loop of questions. This limitation resulted in a significant amount of erroneous data, likely resulting from a combination of both data entry error and measurement error. For example, the TNHPS-PBS questionnaire included a section that collected sociodemographic data on each household member in addition to that member's relationship to the household reference person. Because no consistency checks could be implemented, the data included cases where there appears to be, for example, a child of age five years listed as the adult reference person's grandmother. *In the absence of comprehensive quality assurance functionality, the resulting TNHPS-PBS dataset had a large number of errors, requiring significant time and expense to fix through recontact with households to establish data accuracy—an effort compounded by the lack of a robust sample management system to expedite the process.*

Quality Control Functionality

Obtaining audio recording of respondent interviews and evaluating the quality of the interviewer's performance is a powerful quality control tool in survey research. For example, the recordings provide evidence of interviewers' adherence to study protocols. Monitoring audio recordings of interviews can uncover interviewer behaviors ranging from inaccurate reading of survey questions to evidence of complete falsification of data. These types of problems can seriously undermine the quality of survey data and its value for research and policymaking.

SurveyCTO has audio recording capability, but during TNHPS-PBS fieldwork there was a significant delay between the time that the interview was uploaded to the server and the time when the audio files were accessible to MIDS staff for quality control audits. In some instances, audio files were not available for two or three weeks after uploading, leading to a significant delay in quality evaluation and intervention with the interviewer, and ultimately to decreased data quality. TNHPS-PBS collected audio recordings in multiple different parts of the interview, which compounded problems with the associated audio files. Specifically, each part of the interview that was recorded resulted in a separate audio file, and these individual files were uploaded in a random order over the course of the two- to three-week window. Additionally, the individual audio files used a naming schema that made it very cumbersome to match multiple audio files to the correct SurveyCTO interview. Eventual audio auditing of TNHPS-PBS interviews illuminated numerous and concerning instances of deviation from study protocols, including evidence of interviewers skipping the administration of informed consent, a critical component of human subjects research. *Delayed access to and poor usability of interview audio files resulted in an inability to use these files for timely quality control and rectifying deviant interviewer behavior in TNHPS-PBS.*

At the time of TNHPS-PBS, SurveyCTO had no capability to automatically collect timestamp and keystroke paradata related to movement throughout the interview. Rather, the instrument had to be programmed to capture timestamps at pre-specified points in the interview. This limitation was consequential to the validity of the timestamp data because the interviewer was able to overwrite initial timestamps when moving backward and forward through the instrument. However, because there was no alternative method to collect keystroke paradata, it was impossible to capture the frequency at which this may have occurred. The timestamp data in particular is a critical tool in the quality control process because it provides an indicator of the speed at which interviewers are completing the interview. In TNHPS-PBS, even with the dubious time stamp data there was significant evidence that interviewers recorded responses to the questionnaire at a very rapid pace, which required verification to determine whether there were deviations from interviewing protocol that could have affected data quality. *Additional paradata would have facilitated more expedient intervention to address fieldwork problems and led to increased likelihood of high-quality data collection.*

The limitations in being able to undertake necessary quality control using SurveyCTO have an effect beyond the consequences for TNHPS-PBS data quality. In particular, DES interviewers participating in TNHPS-PBS are responsible for conducting numerous surveys for GOTN each year. Interviewer monitoring and identification of deviation from interviewing protocol and rapid intervention contribute to continuous quality improvement in each successive survey within an organization. *It is typical for large-scale surveys to encounter some quality control issues. As anticipated, quality issues were identified in the TNHPS-PBS data collection. Additional concerns would have likely been identified—and many of these concerns addressed through various timely interventions—if the CAI system was more compatible with the design and objectives of TNHPS-BPS. Such interventions would have improved not only the quality of TNHPS-PBS data but also other surveys conducted by DES for GOTN.*

8. Conclusions

This report has assessed the opportunities and challenges associated with a shift in survey data collection from paper questionnaire instruments to the use of computer-assisted interviewing (CAI). CAI systems offer many significant advantages associated with increased quality, richness, and timeliness of survey data.

The report identified and described key sample management features that are needed for the successful implementation of surveys using CAI systems. These features involve new procedures to be undertaken by central office staff, supervisors, and interviewers. CAI systems offer great promise, but also require an upgrading of skills among the relevant staff.

Quality assurance and quality control are major benefits provided by CAI systems, and complementary systems and procedures need to be adopted by survey organizations to make the most of these benefits. The discussion of staffing, infrastructure, and design considerations highlighted the importance of particular types of staffing expertise that are needed.

Finally, the report describes challenges associated with the CAI system that emerged in a recent large-scale test of adopting a CAI system to conduct a major household survey in the southern Indian state of Tamil Nadu. The content of this report is relevant to the Government of Tamil Nadu's efforts to adopt CAI systems for future state government data collection efforts. The report is especially relevant for the Tamil Nadu Household Panel Survey that is now underway through an important collaboration with the Survey Research Center at the University of Michigan and the Madras Institute of Development Studies. In particular, the report points to a number of key issues that need to be addressed in order for the transition to CAI to continue to be successful in context of Tamil Nadu and in other similar settings. The most important issues to be addressed are those associated with technical systems, staffing, and developing appropriate systems to bring all these elements together. The report has highlighted the value of functionality related to sample management systems, which is especially crucial in the context of launching a panel survey such as TNHPS. Appropriate staffing is needed to develop expertise in CAI system design and implementation. A data collection organizational structure needs to be built around these aspects of the shift to CAI so that this new approach to survey data collection can be institutionalized in order to achieve on-going and long-term success.

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