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The Status of Computer-Assisted Telephone Interviewing: Part I – Introduction and Impact on Cost and Timeliness of Survey Data

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Abstract: Computer-assisted telephone interviewing (CATI) employs interactive computing systems to assist interviewers and their supervisors in performing the basic data collection tasks of telephone interviewing. This is the first of a two-paper series presenting an overview of the status of CATI, based primarily on published articles and unpublished reports describing the development of CATI, and experiences with CATI, in the U.S. and other developed nations. This first paper provides a definition of CATI, reviews its history as an applied technology, and examines current evidence (both summary impressions and quantitative data) on CATI's impact on the costs and timeliness of survey data collection.

Key words: CATI; computer-assisted telephone interviewing; telephone interviewing; survey costs; timeliness.

1. A Definition of CATI

Computer-assisted telephone interviewing has been broadly defined as any interactive computing system that includes some form of online interviewing (Shanks (1983)), or even more generally as any interactive data capture system that collects information from people (Palit and Sharp (1983)). These definitions stress CATI's place within a larger family of related computing applications that has been called "computer-assisted data collection," sometimes abbreviated CADAC (Lyberg (1985)). In addition to CATI, the family includes: (1) computer-assisted personal inter-

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viewing (CAPI) with computer terminals, portable microcomputers, or handheld microprocessors; and (2) computerized self-administered questionnaires (CSAQ) in which similar equipment is operated directly by the respondent.[2]

In this paper we employ a narrow definition of CATI that restricts the term to applications in centralized telephone interviewing. Even with this restriction, CATI systems vary in the range of computing support they provide. Exhibit 1 summarizes current capabilities

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Exhibit 1

Capabilities of Current CATI Systems

1. **Sample management.** The sample is stored on disk files; the system (rather than the interviewing staff) maintains the sample status of each case.

2. **Online call scheduling and case assignment.** The system selects the cases to be called as interviewers request another case. The priority, sequence, and timing of most calls is set by the system at least until the respondent is first reached.

3. **Online interviewing.** The online interview has the following features:
   a) The system displays interviewer instructions, survey questions, and response categories on the interviewer's terminal displays.
   b) Screens may contain "fills" or alterations of the display text based on prior answers or batch input from records prior to the survey.
   c) Answers to closed questions may be entered by numeric or alphanumeric codes; and these codes and other numeric entries may be edited by sets of permissible values, by ranges, or by logical or arithmetic operations.
   d) Edit failures may result either in an unaccepted entry (requiring another attempt) or in display of additional probes or questions to be asked.
   e) Extended text answers may be entered for open questions.
   f) Branching or skipping to the next item is automatic and may be based on logical or arithmetic tests of any prior entries or input data.
   g) Interviewers may interrupt and resume interviews in mid-course; review, backup to, and (if permitted) change prior entries; and enter interviewer notes at appropriate points.

4. **Online monitoring.** The system is able to reproduce any interviewer's screen at a supervisor's terminal where audio monitoring may also occur.

5. **Automatic record keeping.** The system maintains records (or keeps summaries) of online calls, their outcomes, response rates, and interviewer productivity and makes this information accessible to survey supervisors and managers in online or printed reports.

6. **Preparation of data sets.** The CATI output files are produced in a form ready for the next stage of processing. This may be post-interview editing and coding, batch editing or imputation, weighting, or analysis.

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[2] Some writers (Lyberg (1985) and Shanks (1983)), see the CADAC concept as extending to activities following data collection, such as data entry from paper forms, and computer-assisted coding. Even when performed with the same hard-ware and soft-ware, this paper views these post-collection activities as efforts to merge CATI or CADAC into larger systems performing most computer-related survey tasks.

most relevant to evaluations of CATI's survey costs, timeliness, and data quality.[3]

Not all CATI systems offer all the functions listed in Exhibit 1. Furthermore, the different functions tend to have separate effects on costs and quality of data. For example, CATI systems with online interviewing but without online call scheduling and case assignment may affect the quality of CATI data relative to those from paper-and-pencil methods but not the relative productivity of interviewers. As defined here, CATI is an automated form of centralized telephone interviewing. In many organizations, adoption of CATI has entailed a concurrent change to centralized telephone interviewing from personal interviewing, mailed questionnaires, or dispersed telephone interviewing from interviewers' homes. These papers cannot address the broad range of methodological issues these combined changes in data collection procedures may raise. An overview of CATI's place within survey data collection methods (Nicholls (1983)) and the characteristics of centralized telephone interviewing have been described elsewhere (Groves and Kahn (1979), Federal Committee on Statistical Methodology (1984)). This paper reviews these topics only where necessary to distinguish the characteristics of CATI from those of centralized telephone interviewing in general.

[3] The definition assumes that the system is employed for telephone interviewing from a multiple-station site or from dispersed sites served by a common system for sample management, case assignment and monitoring. Single-station CATI systems, such as described by Philipp and Cicciarella (1983), have many of the listed capabilities but lack supervisory functions, such as visual monitoring. Computer-assisted personal interviewing (CAPI) and computerized self-administered questionnaires (CSAQ) also may share many of CATI's online interviewing features but typically differ in other capabilities.

2. Development and Current Status of CATI[4]

The development of CATI as an applied technology will be described in three research environments: commercial market research where it originated; university survey research where its capabilities and objectives were expanded; and governmental data collection where many of its newest applications are occurring.

2.1. CATI in Commercial Market Research

The early development of CATI occurred primarily in the United States. Market research agencies in the private sector created the first computer-assisted telephone interviewing systems and established initial expectations of CATI's data collection characteristics. The concept was initially proposed by R.M. Gryb of the American Telephone and Telegraph Company; and in 1971 AT&T sponsored the first CATI survey to measure customer evaluations of telephone services. Based on this first experience, Nelson, Peyton, and Bortner (1972) described "three distinct advantages" for cathode ray tube interviewing (as it was then called) in comparison with conventional data collection methods. These were: "accuracy, speed, and reduced costs."

Chilton Research Services designed the first CATI system for AT&T and then enhanced its capabilities for broader market research applications (Fink (1983)). By the mid-1970's, additional market research agencies, including Amrigon, Audits and Surveys, Computers for Marketing, Marketing and Research Counselors, and Quantime had de-

[4] Except for the few references cited, the history of CATI is largely verbal and occasionally obscured (especially for its earliest years) by competing claims of system preeminence. The account given here depends partly on the social networks of the authors, including those who read earlier drafts and contributed various corrections.

veloped their own CATI systems. By current standards, many early CATI systems lacked several essential functions. Open questions were often not permitted or were limited to responses of 20 to 40 characters; interviewers could not back to previous answers without erasing intervening entries; and interviews could not be interrupted and efficiently resumed at a later time. The CATI questionnaires sometimes were coded directly in higher-level languages, such as COBOL, or they utilized software packages intended for other purposes, such as computer aided instruction.

The belief that CATI systems are simply modified key entry systems remains the most persistent fallacy about the field. The designers of market research systems were the first to recognize that CATI has differing hardware and systems requirements, including more flexible operator movement between entries and a response time of two seconds or less. Even in its early stages, this new technology found a ready clientele, for it met pressing needs within the market research field. By entering interview responses directly to the computer, tabulations could be produced much more quickly after the close of survey interviewing. By accumulating counts of key respondent characteristics during interviewing, quota targets could be precisely and efficiently met. Finally, by adding visual to telephone monitoring from supervisory (or client representative) terminals, CATI provided sufficient quality and production control to make separate verification surveys unnecessary.

Throughout the 1970's and early 1980's, CATI systems for market research increased rapidly in sophistication (Dutka and Frankel (1980), Fink (1983), Smith and Smith (1980)). Questionnaire setup employing user languages and interactive approaches replaced earlier methods; survey questions, online edit checks, and table lookup routines of greater complexity made new types of market surveys possible; modules were added for interactive coding of open CATI responses; online tabulations were produced for analysts and clients immediately after the close of field work; and systems were expanded to serve larger numbers of interviewing stations, at one site or at linked sites. Single installations of more than 100 terminals now exist, as do networks of geographically dispersed field sites. At present, at least 100 CATI installations are in operation in commercial market research agencies. The majority are in the United States, but market research agencies in Australia, Canada, Italy, Great Britain (Collins (1983)), the Netherlands, New Zealand, Sweden, Switzerland, and West Germany also have acquired production CATI capabilities.

2.2. *CATI in Universities*

University research centers began their largely independent development of CATI five years after its introduction in market research. The UCLA Center for Computer-Based Behavioral Science at UCLA led the way with a CATI system adapted from programs initially written for online questioning of subjects in a computer-based psychological laboratory (Shure and Meeker (1978)). Gerald Shure, the Center's director, coined the CATI name and acronym. Development work at the Berkeley, Michigan, and UCLA Survey Research Centers and the Wisconsin Survey Research Laboratory followed shortly thereafter (Groves (1983), Groves et al. (1980), Palit and Sharp (1983), Shanks et al. (1980)). The first large-scale CATI survey conducted by a university organization was completed in 1978 (Shanks et al. (1981)). First efforts at system design and field work often were missteps resulting in both cost and time overruns. All academic CATI systems passed through at least two major redesigns before basic objec-

tives were largely met and production schedules became reliable in the late 1970's and early 1980's.

Academic survey research centers greatly expanded the range of CATI capabilities. To meet the needs of academic survey research and contract data collection for governmental agencies, modules were developed for probability (rather than quota) sampling, including clustered random-digit dialing. Work was begun on more thorough call scheduling and callback procedures necessary for the higher response rates probability sampling requires. Greater flexibility was added to questionnaire setup methods to accommodate the variety of question styles employed in academic research. Finally, the range of permissible interviewer actions was greatly increased to more closely approximate those of personal interviewers in academic opinion surveys. Work continues toward more effective and efficient approaches to all these needs and on methods of rostering, for example, repeating the same series of questions for different members of the household or for different events of the same person.

Not all academic CATI systems have all the capabilities listed in Exhibit 1; and most lack one or more valuable features found in market research, such as online coding and online tabulation. Nevertheless, sufficient progress was made to partially dispel a common belief (persisting from the earliest market research systems) that CATI is appropriate only for 10- to 15-minute interviews consisting of simple check-answer items and short-answer open questions which must be asked in a consistently forward moving direction.

University developers of CATI played the major role in introducing CATI to the broader survey research and statistical community through professional journals and meetings. They also established new objectives for the field. They sought to utilize the video and audio monitoring capabilities of CATI to study interviewer behaviors, to use the computer to facilitate interpenetrated interviewer assignments for measurement of interviewer variance, and to introduce complex questioning sequences to reduce measurement error by employing CATI's automatic skip logic to reduce interviewer burden. They also stressed its advantages for survey documentation through the production of survey codebooks from online questionnaires (Shanks et al. (1980)). By combining survey questions, interviewer instructions, edit checks, and field work procedures in a single CATI instrument or related set of computer programs, they also observed that survey procedures could be made more explicit and reprocible (Nicholls (1978)). More importantly, they emphasized the value of this emerging technology as a major new tool for survey methodology (Freeman (1983), Groves et al. (1980), Shanks (1983)).

At least 20 university and private survey research agencies, such as Rand, RTI, Westat, and Mathematica, now employ CATI in the United States for social, economic, and related surveys. In Great Britain, Social and Community Planning Research (SCPR) of the City University of London has conducted a feasibility survey (Collins (1983)); and in the Netherlands, the Geographical Institute of the State University of Utrecht has completed a first CATI survey (Dekker and Dorn (1984)). More than half these agencies are employing CATI software designed by others. As in market research, leasing or sharing arrangements are replacing the earlier practice of each agency designing its own CATI system, although the development of new systems, especially for personal computers, continues.

2.3. *CATI in Government*

U.S. governmental agencies demonstrated an early interest in CATI. The National Science

Foundation, the U.S. Census Bureau, the National Center for Health Statistics, and other Federal agencies contributed to the development of CATI systems in the 1970's by supporting design enhancements or by contracting for CATI data collection. Steps by U.S. governmental agencies to acquire their own CATI capabilities did not begin until 1980 when the U.S. Census Bureau and the U.S. Department of Agriculture's Statistical Reporting Service both established internal staffs for this purpose (House and Morton (1983), Nicholls (1983)). The Census Bureau began design of a CATI system tailored to its requirements, while USDA's Statistical Reporting Service acquired access to a university designed system. Both completed their first tests of CATI in 1982. The Centers for Disease Control and the U.S. Bureau of Labor Statistics, which also began internal CATI development before 1985, followed USDA's example of obtaining software from universities. In the Netherlands, the Central Bureau of Statistics began production data collection for continuing surveys in 1984 with a CATI system designed by a market research organization.

A major expansion of governmental CATI installations began in 1985. The U.S. Census Bureau opened a 40-station CATI facility both for production data collection of smaller surveys and for expanded programs of testing for the Current Population Survey and the National Crime Survey. During the same year, the USDA Statistical Reporting Service completed placement of CATI in eight additional state offices (for a total of 10) and plans to similarly equip its remaining state offices by January, 1989 (Tortora (1985)). The Centers for Disease Control installed CATI in 25 state offices (most of them two-station sites) for use in a continuing survey with plans to add the remaining state offices shortly thereafter. The U.S. Bureau of Labor Statistics has begun small scale tests of CATI data collection on three surveys. Additional state and federal governmental agencies are establishing CATI installations or are working to do so in the near future. Even with this recent expansion, CATI accounts for at most only a very small percentage of survey interviews conducted by governmental agencies at this writing. However, if current plans are realized, the growth of CATI data collection in governmental agencies may parallel that in commercial market research and university survey research centers by moving from first steps in system development to widespread production usage within a decade.

2.4. *New Applications*

Increasing applications of CATI, especially in government, have placed new demands on the design of CATI systems and CATI surveys. These include new methods of displaying and moving between questions, systems accommodating multiple methods of data collection methods for same survey, and fuller integration of CATI capabilities into a broader set of computer-based survey activities.

Traditional CATI systems may be described as item-based. They typically display only one question (or a small set of related questions) per screen, while movement between questions is system controlled and follows a fixed sequence of items and contingent branch points. This approach, initially developed for opinion or factual surveys of the general public, has been found less suitable for surveys of establishments such as businesses. Establishment surveys often collect only a few data items from each establishment but often must obtain those data in sequences which vary with individual record keeping practices. To meet these specialized needs, the Bureau of Labor Statistics and the Census Bureau's Business Division have developed "form-based" CATI systems which more closely approximate one- or two-page paper forms.

They display large numbers of items (and sometimes all the survey's data items) on a single screen. The interviewer may make entries in any order by using the keyboard's cursor-control keys or other special commands to move among items on the same screen. While form-based systems represent an important new option for CATI, publications describing and evaluating their features have not yet appeared. The remainder of this two-paper series will therefore focus primarily on item-based systems.

New system capabilities also have evolved with the use of CATI as a supplemental rather than primary method of data collection. An increasingly common governmental application is to followup mail questionnaire nonresponse with telephone interviews.[5] This has required the systematization of procedures for telephone tracing of difficult to locate respondents for incorporation in CATI interviewing and automatic call scheduling systems (Ferrari et al. (1984), Nicholls (1983)). A related application with special promise for longitudinal demographic surveys is the use of CATI for second- and later-visit interviews after an initial interview in person. In such designs, personal visit followup may continue for households unreachable by telephone. The use of CATI in these and other panel designs permits utilization of data from prior interviews in questions, probes, and skip patterns but has placed new demands on efficient methods of accessing and updating panel data bases.

The use of CATI in conjunction with other data collection methods in the same survey also has posed new problems of coordinating sampling, data collection, and data processing flows. Telephone prompting or followup of mailed questionnaires must be coordinated with check-in of late mail returns. Households no longer reachable by telephone may necessitate rapid transfer to the field for personal interviewing. Multiple-mode surveys also raise new problems of maintaining comparability between CATI and paper-based procedures in interviewing methods, data capture standards, and both clerical and computer editing procedures. For example, a CATI survey with online edits may have different types of error than a paper-and-pencil survey key entered and computer edited after completion of interviewing. Proposed solutions to comparability problems may take the form of extending CADAC functions to additional data collection activities, such as CAPI for personal interviewing, or the use of the same interactive systems for data entry of paper forms.

One illustration of the problem of simulating paper-and-pencil methods with traditional CATI design occurs when a one-to-one correspondence does not exist between responding units and sample cases. This may occur, for example, when the same accountant is the designated respondent for more than one sampled business or industry in an economic survey. It also occurs when a separate full interview is required for unrelated persons or "discovered units" in a sample household. With paper-and-pencil methods, these situations are met by clipping related forms together within interviewing assignments and by providing extra forms for field supplements to the sample. CATI requires new systems approaches to facilitate rapid transfers between related cases and to spawn additions to the sample within a telephone call.

Current general-purpose CATI systems also may have an inappropriate set of capabilities for maximum efficiency in some applications. The Centers for Disease Control, the U.S. Bureau of Labor Statistics, and the Busi-

[5] The self-administered questionnaire is the most common form of data collection employed by U.S. government agencies; and telephone followup is among the most common use of the telephone in federal surveys (Federal Committee on Statistical Methodology (1984)).

ness Division of the U.S. Census Bureau are developing CATI capabilities to conduct a single survey or a small set of closely related surveys. Since the interview questions of these continuing surveys rarely change over time, general-purpose methods of questionnaire setup are less relevant. Direct programming of each screen in forth-generation languages may become a cost-effective option. Furthermore, once a commitment to CATI is made, the availability of computing hardware required only parttime for CATI data collection is likely to encourage its use for related purposes.

Agencies often plan to integrate their CATI data collection with other computer-supported functions of the same survey, such as, key entry of forms returned by mail, post-interview editing and analyst review, imputation and weighting, and maintenance of the sampling frame and longitudinal data base. Since the requirements of these added functions are often unique to each survey and change infrequently over time, special-purpose rather than general-purpose solutions again may be more appropriate. For some applications, CATI may be transformed from a general system used in data collection for multiple surveys to one component of larger systems that perform all computer-related functions for relatively small sets of surveys.

3. Evidence About CATI's Data Collection Characteristics

Survey organizations considering adoption of CATI frequently ask the following questions : (1) How much will CATI cost to install and operate?; (2) How will CATI change the time required to design and complete surveys?; (3) What effects will CATI have on data quality compared with conventional methods?; and (4) What does CATI add to survey data collection that doesn't already exist with paper-and-pencil methods. The remainder of Part I of this paper series addresses questions (1) and (2), the impact of CATI on the costs and timeliness of survey data collection. Part II will complete this review by examining questions (3) and (4).

The small but growing literature on CATI provides few clear answers to these questions. This literature consists predominantly of descriptions of CATI capabilities and listings of *potential* advantages and disadvantages of CATI for survey costs, timeliness, data quality, and methodological enhancements (Dekker and Dorn (1984), Dutka and Frankel (1980), Ferrari et al. (1984), Groves (1983), House and Morton (1983), Morton and House (1983), Nelson et al. (1972), Nicholls (1978), Palit and Sharp (1983), Presser (1983), Rustemeyer et al. (1978), Shanks et al. (1980), Shanks et al. (1981), Shure and Meeker (1978)). Support for these speculations about CATI's data collection characteristics typically has been based only on the weakest forms of evidence: (a) *logical analyses* of CATI's capabilities; (b) *case studies* reporting experiences (typically first experiences) in conducting specific CATI surveys; and (c) *summary impressions* of persons experienced in conducting many (or at least several) CATI surveys.

Evaluative studies of CATI, providing quantitative comparisons with paper-and-pencil methods on the same or similar telephone surveys, have only begun to appear in the last three years. Four of these studies closely approximate controlled experiments in which probability subsamples of the same survey are interviewed by CATI and by paper methods at the same time by the same staff under controlled conditions. These are the SRC-Michigan RDD Health Survey Test (Groves and Mathiowetz (1984)); the USDA California Dual Frame Cattle Inventory Survey (House (1984) and Tortora (1985)); the USDA Nebraska Hog Survey (Coulter (1985)); and the Westat Florida Colo-Rectal Cancer Kin Survey (Harlow et al. (1985)). These experimental studies have employed

relatively small samples, ranging from about 130 to 1 200 CATI cases and as few as four or five CATI stations. They also represent relatively early use of CATI by their organizations. Information from organizations with at least three years CATI production experience is generally available only in the form of summary impressions rather than quantitative data (Palit and Sharp (1983, 1985)).

Comparisons of CATI and paper-and-pencil data collection are also available from four comparative studies which do not meet the requirements of fully controlled experiments. The SRC-UCLA Earthquake Survey (Fielder (1985)) and the SRC-Berkeley Malignant Melanoma Survey (Coleman (1985)) approximate before-and-after designs. Their earlier waves were conducted by paper methods and their later waves by CATI. Confounding panel effects can be reduced by limiting comparisons to first-visit interviews in repeated cross-sections and to control samples. The U.S. Census Bureau also completed tests of CATI for telephone followup to mail nonresponse in the National Survey of Scientists and Engineers (Ferrari (1984)) and the 1982 Census of Agriculture (Ferrari (1986)). Each test assigned probability subsamples of 7 000 or more cases to each treatment, but the CATI and non-CATI staffs worked at widely separated sites which followed different hiring, supervisory, and management procedures. These uncontrolled factors and difficulties encountered in obtaining comparable field work records from the non-CATI site requires caution in interpreting their results.

While each of these studies is limited in sample size, design, or experience with CATI, they have the collective strength of representing largely independent efforts by seven different investigators in six different organizations utilizing five different CATI systems. Unfortunately, evidence from more than one study is available for relatively few topics, such as CATI's effects on interview length and unit nonresponse. To address broader questions about CATI's consequences for survey costs, timeliness, and data quality, this two-paper series generally must rely on results from only one or two empirical studies, or more commonly, on even weaker forms of evidence.

4. Costs and Timeliness

Survey costs and timeliness will be considered together because they are frequently opposite sides of the same coin. If one survey method is more efficient than another, it may do the same task either with a smaller staff or with the same staff in less time. Of course, other factors also contribute to costs and timeliness, including overhead costs, the use of CATI in multiple-mode data collection, and existing commitments to current computer-editing and processing procedures.

CATI gained an early reputation for increasing the speed of completing market research surveys. The extreme example is the 24-hour survey with the questionnaire set up during the day, interviewing completed during the evening, and tabulations prepared overnight (Sudman (1983)). These surveys usually consist of a brief set of simple questions and relatively simple survey designs. Generally they employ standardized and prepackaged background items, respondent selection rules, and interviewing procedures, while data analysis is limited to simple cross-tabulations. The same time schedule is met by opinion polls using paper-and-pencil methods, although they probably require more staff to reproduce the paper questionnaires, enter the data, and construct the data set. The 24-hour survey demonstrates the relative ease with which CATI surveys can be *modified* when the change consists of the replacement of one set of simple questions (or one sample) by another. Because of their greater complexity, however, the time required to design and complete CATI surveys

in university and government settings has generally been found to equal or exceed that for conventional methods.

Information on the costs of CATI data collection is largely anecdotal and fragmentary. The first paper on CATI suggested a cost saving in market research on any telephone survey of 1 000 or more interviews (Nelson et al. (1972)). Some market research firms now claim that CATI costs *no more* than conventional methods for the same survey even for samples of a few hundred interviews. Based on experiences with random digit dialing surveys in a university setting, Palit and Sharp (1983) conclude that "When a CATI system is operational and functioning to its full potential, the total cost of any given survey should be less than if the survey were done conventionally." Since these summary impressions have not been accompanied by more detailed cost analyses, it is unknown whether they include such components as survey planning, technical staff support, amortization schedules for computing hardware, and other initial costs.

The primary evidence that CATI is cost competitive with conventional methods for centralized telephone interviewing lies in its continued and expanding usage, especially in market research. Selective usage *within* survey organizations, however, suggests that CATI is not necessarily the more cost-effective option for all applications. Many organizations with proven CATI systems and long experience in the field continue to undertake telephone surveys with conventional methods at least occasionally.

Item-based CATI systems generally are not applicable for surveys using unstructured interviewing; and some organizations regard CATI as less efficient for surveys consisting largely of open questions.[6] The costs of CATI survey design and setup also may play a major role in decisions to use conventional rather than CATI methods. When information on the sample exists only on paper records, or when a paper-and-pencil questionnaire is already prepared, the costs of CATI setup may not be justified for a small, one-time survey. Conversely, a survey already prepared for CATI may be more expensive to repeat with paper-and-pencil methods.

The publication of detailed estimates comparing CATI and other survey methods has been impeded by the difficulties of preparing and defending such cost analyses. The fiscal consequences of CATI are not confined to interviewing costs but extend from survey planning to final data collection products. At the completion of interviewing, CATI can provide a data set ready for final editing or for analysis if no final edit step is required. The total costs of a CATI survey should properly be compared with the traditional costs of survey planning and design, developing a questionnaire, printing it, sample administration, production interviewing, preparation of field work reports, key entry of data, building a data set, and data cleaning prior to analysis. Fixed or overhead costs also change with the added computing hardware, software, and technical support staff CATI requires. For organizations new to CATI, cost comparisons are further complicated by the difficulty of separating training and development costs from production costs and by the uncertainties of future cost efficiencies attainable only with experience. The difficulties of defining costs and appropriately weighing all these factors have discouraged, or long postponed, frequently planned summary assessments of CATI's impact on survey costs.

[6] Since form-based CATI systems provide more interviewer freedom in moving among data items on the same screen, they permit greater latitude in the order in which those items are entered. By omitting the survey questions from form-based screens, the interviewer also may be given more flexibility in the wording of questions. The several consequences of CATI for open questions are further examined in Section 4.4 and in Part II.

The following sections examine what has been learned about CATI's effects on costs and timeliness in four areas : (1) installation and maintenance of CATI capabilities; (2) the planning and setup of individual surveys; (3) survey interviewing; and (4) post-interview processing.

4.1. Installation and Maintenance

The first cost typically considered in CATI installation is computing hardware. Broad generalization about CATI's hardware costs are made difficult by system requirements that vary with the size and complexity of the surveys undertaken and by rapidly declining prices of computing hardware. Some illustrative costs may be cited. Palit (1980) estimated the total 1980 hardware costs of an eight-station microcomputer system at about $5 000 per station. In 1984, the U.S. Census Bureau incurred about the same per station cost for a 40-station minicomputer system capable of accommodating very large and complex surveys. Tortora (1985) listed the costs of a 13-station supermicro computer system procured in 1982 and 1984 at between $3 000 and $4 000 per station. For simpler applications, costs per station may be held to $1 000 to $1 500 by linking small personal computer interviewing stations to a hard-disk microcomputer for sample management, call scheduling, and data storage.

Cost estimates for hardware should consider the expected life of the configuration and various non-CATI uses planned for that equipment. In the late 1970's and early 1980's, it was common for university agencies to undertake major hardware upgrades or to rewrite their CATI software for totally new configurations every two or three years as assessments of computing needs changed. Hardware costs could thus be spread only over short periods. Serious miscalculations have occurred when agencies committed themselves to hardware which was discontinued or which proved inadequate to maintain response times for the required number of CATI interviewing stations. With greater experience, better predictions of hardware costs and system lives may be possible, but organizations newly entering the field often cannot reliably assess long-term hardware costs at the start. Many organizations also procure computing hardware intended both for CATI and for other functions, such as data entry, word processing, and accounting (Tortora and House (1984)). In such multiple-purpose configurations, the portion of hardware costs attributed to CATI will partly depend on organizational policies and decisions.[7]

Computing hardware is only one of several installation and maintenance costs that must be distributed across surveys. Hardware site preparation and maintenance and software development, acquisition, or leasing also must be taken into account. CATI software has become sufficiently sophisticated that only large and well-funded survey organizations may find it cost-effective to design their own CATI systems. Programs can be written in a few weeks to display simple questions and to branch to the next item based on entered precodes, but systems with the capabilities listed in Exhibit 1 on page 94 typically require years

[7] In planning multiple-use hardware, it is important to recognize that the demands CATI places on the system will depend on the architecture of the CATI software. When CATI interviews run in compiled mode, their major demands are on core memory. When they run in interpretive mode, they also place heavy demands on CPU time. If, as is common, they retain data records in core memory until the end of an interview, they place only limited demands on input-output functions; but systems which write a transaction file to disk may also make heavy use of input and output channels. Many organizations have found that CATI shares well with key entry and computer-assisted coding but not with data analysis, program compilation, accounting, and other applications which make extensive use of core memory, unless the CATI and non-CATI uses are confined to different times of the day.

of development. If available CATI systems do not fully meet organizational needs, the approach now followed by most organizations is to contract for needed changes with the initial software vendor or to acquire access to a system and undertake changes with their own staff.

During production interviewing, most CATI systems are operated by the survey staff without programmer or computer operator support. Support by systems analysts and programmers is often required, however, for such purposes as general maintenance and trouble-shooting of the basic hardware and systems, reformatting input files received from other organizations, undertaking systems enhancements for unanticipated needs, and preparing special-purpose reports or programs for unusual applications. Systems and programming support is sometimes available under contract with CATI software vendors; but most large organizations generally develop their own staff to meet these needs. Experiences in both market research and university CATI agencies suggest the need for systems and programming support declines as experience is gained and systems stabilize.

4.2. *Planning and Setup*

The design and setup of individual CATI surveys typically involves at least four distinct activities: (1) survey planning and general design; (2) initial entry of the questionnaire and other survey specifications; (3) checking and debugging all components to ensure that they function properly; and (4) pretesting with interviewers.

4.2.1. General planning and design

Most papers on CATI survey design agree that CATI requires more thorough and detailed planning than comparable paper-and-pencil surveys (Ferrari et al. (1984), House (1985), Nicholls (1978), Presser (1983), Shanks et al. (1980), Smith and Smith (1980)). Survey questions must be designed for the new medium of the display screen, branching or skipping patterns must be specified in greater detail, interviewing procedures typically must be clarified before they are programmable, and edit checks must be specified concurrently with questionnaire design.[8] In some systems, specifications for the final data set also are established during CATI set-up. This typically requires not only more advance planning but greater coordination among specialists located in different branches of most organizations conducting conventional surveys.

Form-based CATI systems have simulated brief one-page paper data collection forms on a single CATI screen; but for longer instruments the design requirements of CATI differ from those of paper forms because the interviewers see the CATI questionnaire only in segments. Sequences of screens or items must flow quickly and smoothly for all possible branching paths; the interviewer must have ready access to all necessary information at or from each screen; and nonstandard interviewer movement, such as backing up, must be facilitated by appropriate design. Additional characteristics of a well designed item-based CATI instrument, both as a survey questionnaire and as a computer program, have been described by House (1985).

The planning and design task is currently complicated by the transition from paper to interactive data collection methods. Many CATI surveys begin the planning process with questionnaires originally designed for large paper forms which cannot be reproduced exactly in CATI displays. In complex surveys, the work of the CATI survey designer often must begin with the redesign of the structure and flow of the questionnaire. Two examples suggest the types of changes required.

[8] These steps in CATI questionnaire design have been thoroughly described by House (1985).

a) Paper questionnaires are often arranged to simplify the interviewers' visual movement from question to question. Contingent questions are usually placed after the item which determines their applicability; and where questions vary by demographic characteristics or prior answers, they may be organized in separate sections by respondent type. The CATI author is freed of these constraints by automatic branching and the opportunity to modify question wording as needed. A restructuring of the interview is often necessary to avoid inefficient use of setup time and computing resources which a straightforward reproduction of the paper form would entail.

b) Paper questionnaires often employ large tables of questions in which the same information is obtained for each member of the household (or for each of a set of related events) in compact form. This arrangement of questions and answers on the same large page is thought to simplify the interviewing process and to provide the interviewer with an overview of the data obtained. Since CATI displays are typically restricted to no more than 24 lines of 80 characters each, they cannot reproduce such tables as they stand. Alternative methods of asking these question sequences and summarizing their answers for the interviewers must be found.

When a paper questionnaire does not exist for a CATI survey, many agencies believe it necessary to prepare one: (1) as a backup for interviewer use in the event of a hardware failure; and (2) as a more convenient vehicle for reviewing the questionnaire with clients. It is presently uncertain whether this practice is an inherent requirement for CATI surveys or an artifact of earlier data collection methods which will decline as systems become more reliable and clients more familiar with CATI. However, when this practice is followed, the cost of the planning and design of CATI surveys will necessarily exceed that for conventional surveys since it requires preparation of both a paper and a CATI questionnaire.

When the survey involves automatic case assignment and call scheduling, attention also must be paid to the case assignment, calling, interviewing, and supervisory procedures. Although conventional methods usually have instructions to guide these aspects of the interviewers' and supervisors' work, they typically rely heavily on the judgment of the field staff for execution and rarely are presented in sufficient detail to be immediately programmable. CATI also provides new opportunities for efficient call scheduling algorithms which should be considered. Organizations new to CATI often devote as much planning effort to clarification and specification of these aspects of the survey as to questionnaire design. However, since call scheduling procedures typically vary less than questionnaire content from survey to survey, planning time in this area should decline as one gains experience.

4.2.2. Initial setup

Once plans are completed, the questionnaire and other survey requirements must be entered into the system. This typically involves more work than typing in the questions, response categories, and skipping instructions of paper questionnaires. Question wording tailored to prior answers must be set up question by question, online edits must be selected or written, and additional probes may be required to reconcile edit failures. CATI systems differ in the ease with which survey questions and other requirements may be entered. Many systems employ specially designed user languages for entry of the questionnaire and related interviewer actions before and after the interview (Nicholls (1983), Shanks et al. (1980)). Others permit interactive setup which supplies menus of options and prompts for each new question, response category, and branching instruction. The latter seems especially suited for inexperienced CATI survey authors and relatively simple questionnaires (House (1985)). Systems also differ in the extent to which they check for setup errors before the survey is

ready for interviewer use. Those which make many checks each time items are added or changes are made, generally require longer turnaround at each stage of setup than those which take greater risks of runtime errors. Systems which run in compiled rather than interpretive mode also require a compilation step which adds further to development turnaround. Case management functions, such as sampling, call scheduling, and the production of progress reports typically are program modules written in higher level languages. When changes are required in these for a specific application, they generally must be made by a computer programmer, although in mature systems they may be available in a parameterized modules which survey staff may select without programmer assistance.

4.2.3. Checkout and debugging

Whichever type of system is employed, substantial time will be consumed in checking out and debugging instruments to ensure that all parts function as intended both in standard forward movement and after backing up, changing prior answers, and other special interviewer actions. The review, checkout, and debugging of complex CATI instruments typically has been a very time consuming task, often requiring as much or even more time than the initial setup. In addition, planning, setup and checkout often prove to be iterative processes, especially when a review of running questionnaires suggest alternative designs that then send one back to the planning stage.

4.2.4. Pretesting

Pretesting of questionnaires with respondents is a good practice for any data collection method but seems especially important for CATI to identify residual problems before production interviewing begins. Since the wording of questions and movement through the instrument is computer controlled, CATI interviewers are less able to compensate for design errors or to recover from them as easily as interviewers using paper forms (House (1985)). At the same time, CATI facilitates rapid changes of question wording and question order during pretesting, permitting more rapid turnaround in fielding alternative versions of the same questionnaire in a brief period of time (Palit and Sharp (1985)).

4.2.5. Consequences for costs and timeliness

Current opinions differ sharply on whether the time to design and set up a CATI survey is more, less, or equal to that required for conventional paper surveys. Data are available only from one informal comparison study that found that the total staff hours expended to set up and conduct the second wave of a relatively simple survey with CATI was less than that for similar activities of the initial wave using paper-and-pencil methods (Coleman (1985)). Data from more controlled comparisons or for surveys of more complex design have not been published.

Based on several years experience with CATI surveys in a university survey research laboratory, Palit and Sharp (1985) conclude: "It is our contention that a comparable amount of time will be required for comparable interview schedules, whether on paper or on CATI. If any additional time is necessary for CATI entry as compared to typing on paper, it will be offset by the time required for paper duplication. To be sure, if a researcher asks CATI to perform a number of on-line data editing and consistency checks that are not possible on paper, CATI will probably take longer". (Palit and Sharp (1985).) They claim that the planning, entry, testing, and debugging of CATI instruments requires no more time than comparable steps in the design of paper questionnaires.

Presser (1983) presents an entirely different view, also based on experience with CATI in a

university setting. "Preparation time is likely to be *considerably longer* [emphasis supplied] for a CATI survey than for a paper and pencil one. Building a CATI application and typing a questionnaire are simply not comparable tasks. With few exceptions, the former will take more time." In complex governmental surveys, where comparability also may be required with paper forms for multiple-mode surveys, preparation time exceeding that for conventional surveys also has been reported by Ferrari et al. (1984).

Each view is probably a correct assessment of the author's experiences. The resources required to design and set up an individual CATI survey undoubtedly depend on : (a) the complexity of the survey; (b) the need for comparability with paper-and-pencil methods; (c) the specific CATI system employed; (d) the extent to which the CATI questionnaire incorporates quality enhancement features not included in the paper forms; and (e) the experience of the staff with CATI survey design.

The extensive time reported to plan and set up complex CATI surveys in some academic and governmental agencies may partially reflect current inexperiences at this task. Frequently both those designing CATI surveys and those managing and reviewing their work are relatively new to the field. Efficient procedures for survey planning, survey setup, checkout and debugging are still evolving, as is the most effective division of labor among survey methods specialists, content experts, programmers, and full time CATI setup staffs.

In most agencies, the designers of CATI surveys are recruited from staff trained in the questionnaire design, interviewing procedures, and field work management of conventional surveys. They must be trained not only in the technical procedures of CATI setup but also in such related areas as the design of edit checks, the characteristics of data records, and general concepts of efficient program design, testing, and debugging. In some systems they also may require a knowledge of data set design. Persons combining all these skills can be difficult to locate or require substantial on-the-job training. Once trained, they typically evolve into a new technical subspecialty, not easily classifiable by organizational boundaries and personnel categories.

House (1985) has observed that the designers of CATI surveys typically are not trained in the principles and methods of computer programming, and that the application of modular design principles should facilitate initial design, checkout and debugging, and portability of questionnaire sections from one survey to another. This view is supported by experiences in commercial market research firms, where the savings in CATI preparation time are possible through the use of standardized procedures and common or parameterized modules transferable from survey to survey. Most university and governmental organizations are just beginning to accumulate archives of common modules.

While progress in standardization, modularization, staff training, and organizational management should shorten the CATI planning and setup process, in the near future the time required to design most complex CATI surveys will probably exceed that for conventional methods, especially when they require backup paper forms and employ online edit checking and related quality enhancement features. Exceptions may occur for sets of related surveys, sufficiently similar in sampling design, interviewing design, or content, that survey preparation consists largely of transferring modules from one survey to the next.

4.3. Survey Interviewing

The interviewing period for a CATI survey should not differ greatly from that of a com-

parable paper-and-pencil survey with an interviewer staff of the same size. However, CATI will typically change the way interviewers spend their time. Interviewer time can be divided into three main activities: (a) making calls to reach respondents to interview, (b) conducting interviews with respondents after they are reached, and (c) clerical review of the questionnaire (sometimes called field editing) before moving to the next case.

CATI systems should significantly reduce the time interviewers spend between telephone calls to sample cases. With online call scheduling and case assignment, the computer chooses the next case to be called, checks its time zone, and maintains records of calls and outcomes. This should increase interviewer productivity by eliminating the time spent selecting the next case to call from those assigned and maintaining paper records of calls. Studies of interviewer reactions to CATI often find the reduction of paper work and paper shuffling one of its best liked features (Coulter (1985)). An equally important gain is that supervisors are largely freed of the tasks of preparing, reviewing, and keeping records of interviewing assignments.

The average length of individual interview, measured by the time spent questioning respondents, may be increased by CATI. Paper-and-pencil telephone interviews have been reported to be about 10 to 15 percent shorter on the average than personal interviews with the same questionnaire (Groves and Kahn (1979)). The available evidence suggests that CATI interviews may be somewhat longer than comparable paper-and-pencil telephone interviews, although not for all surveys. The differences in mean length of completed interview by mode summarized in Table 1 from three experimental and two comparative studies vary greatly in magnitude and may be partly the result of uncontrolled factors. But they suggest that the length of CATI interviews equals or exceeds that of conventional telephone interviews. Although CATI relieves interviewers of the task of turning pages and finding the next question to ask, several hypotheses, none confirmed, have been advanced to explain the apparently longer length of CATI interviews.

First, experienced paper-and-pencil interviewers often begin asking the next question while recording the last. This is more difficult in CATI because the next question frequently is not displayed until the answer to the previous question is entered. Second, the entering of responses to open questions may take longer in CATI because most interviewers write somewhat faster than they can type (Groves and Mathiowetz (1984)). Third, to the extent that CATI ensures completion of items, probes, or interviewing tasks occasionally missed with paper-and-pencil methods, this also will lengthen CATI interviews. The length of CATI interviews will be further increased if the CATI instrument includes edit checks that require further probes or other interviewer actions to reconcile apparent inconsistencies (Morton and House (1983)).

In some paper-and-pencil telephone surveys, interviewers are instructed to review and clerically edit each completed questionnaire after the interview to ensure that written free answer responses are complete and readable and that closed answer responses are properly marked. The interviewing staff also may be asked to transcribe data between forms and to enter missing data codes for inapplicable questions. For complex questionnaires, these tasks may consume half as much time (and occasionally as much time) as completing the questionnaire itself. CATI typically eliminates or greatly reduces these tasks. The only clerical editing possibly needed after the interview is review of textual material typed in by the interviewer, such as responses to open-end questions, other specify entries, and interviewer notes. Interviewing supervisors are

Table 1. Mean Length of Completed Interview in Minutes by Mode for Five Surveys

Survey	CATI	Non-CATI	Ratio[1]
USDA Cattle Multiple Frame Survey (House (1984))	8.2	8.2	1.00
SRC Michigan National Health Survey Test (Groves and Mathiowetz (1984))	52	46	1.13
Westat Colo-Rectal Cancer Survey (Harlow et al. (1985))	28.5	25.1	1.14
SRC Berkely Malignant Melanoma Survey (Coleman (1985))	10.9	8.9	1.22
Census Bureau Survey of Scientists and Engineers Telephone Followup (Ferrari (1984))	20.8	13.7	1.52

[1] Ratio = mean length of CATI interview/mean length of non-CATI interview.

also relieved of the task of reviewing the more extensive clerical editing typically required with paper-and-pencil forms.

Comparisons of CATI and non-CATI interviewer productivity present only gross figures that combine the effects of call scheduling, interviewing, and editing. Nelson et al., (1972) reported a 10 percent increase in interviewer productivity in the first CATI survey conducted in 1971. More recently, Palit and Sharp (1983) report a 20 percent increase in interviewer productivity for CATI (measured in sample points contacted per production hour) compared with the same interviewers using traditional methods in random digit dialing telephone surveys. Neither paper describes the methods by which the comparisons were made nor presents supporting data. Two recent studies suggest that the productivity of CATI interviewers may depend on the use of online call scheduling and case assignment. Coulter (1985) reports CATI interviewers using a system without these features were 12 percent *less* productive than paper-and-pencil interviewers on the same survey. By contrast, Ferrari (1986) found CATI interviewers using a system with these features 45 percent *more* productive than the paper-and-pencil comparison group. Their productivity appears to have been increased by reducing the time spent between interviews. The CATI staff placed 23 percent more calls and spent 31 percent more time on the phone per paid interviewer hour. A higher response rate also contributed to the CATI staff's greater productivity, which was measured in completed interviews per hour. Uncontrolled factors in this comparative study also may account for at least part of the difference. Additional evidence from large, well controlled studies in production settings is required to clarify this key component of CATI's cost-effectiveness.

Interviewer productivity is only one component of total interviewing costs. The initial training of CATI interviewers is often believed to take longer since they must learn to operate a computer terminal or microcomputer. CATI's consequences for interviewing supervision are less clear and may depend on the tasks that supervisors are assigned. Initial supervisory training may require more time for CATI, but a system with online call scheduling, case assignment, and automatic record keeping should free the supervisors of most clerical and report preparation tasks and eliminate the need for clerical support. This may permit a reduction in supervisory staff or more time for direct supervision and monitoring of interviewers.

To date, only one study has attempted to include these elements in cost comparisons of

Table 2. Projected Interviewing and Keying Salary Costs Per Case : Census of Agriculture Telephone Followup[1]

Activity	CATI	Non-CATI
Interviewer training	$1.09	$ .39
Interviewing	2.48	2.07
Interviewer supervision	.77	.44
Clerical support	—	.18
Telephone number search	.11	.11
Data keying	—	1.26
Analyst review	.08	.08
Total per sample case	$4.53	$4.53
Total per completed interview	$8.83	$9.79

[1] Ferrari (1986).

CATI and non-CATI data collection. Table 2 presents cost projections Ferrari (1986) based on comparative data from the Census of Agriculture but adjusted for the differing pay rates and supervisory practices at the CATI and non-CATI sites. Data entry salaries also are included for non-CATI cases since CATI data entry occurs simultaneously with interviewing. In Ferrari's analysis, CATI has higher costs per assigned case in three areas : interviewer training, interviewing, and interviewer supervision. The higher supervisory costs include both added training for the supervisors and a higher supervisor-to-employee ratio than used previously in this survey. At the same time, CATI achieves savings by eliminating clerical staff and data keying. When summed, total salary costs for CATI and paper methods are equal per *sample* case. However, since CATI obtained a higher response rate in this study, CATI's total salary costs per *completed* interview were less, by 11 percent.

These projections are based on the use of CATI for telephone followup to mail nonresponse and may not apply to other applications or organizational settings. However, the analysis suggests the types of data required to begin assessments of CATI's cost-effectiveness as a data collection method. Future analyses should include the salaries of professional and technical staff in survey design and in processing as well as nonsalary costs, such as amortization of CATI and key entry hardware and duplication of paper forms.

4.4. Post-interview Processing

The primary contributions of CATI to timeliness and reduced costs have been anticipated in the post-interview processing. Nelson, Peyton, and Bortner's (1972) original claim that CATI increased the speed with which surveys could be completed was based on its reduction of post-interview clerical editing, data keying, and data cleaning. Cost reductions at this stage should at least partially offset added costs in installation, maintenance, and survey design.

Clerical editing of completed forms may be performed by the interviewers, their supervisors, by a separate check-in staff, or by key entry staff as part of the keying operation. If this step is used in a paper version of a survey, use of CATI should reduce its magnitude wherever it occurs. Since CATI data are recorded in machine-readable form, a separate key entry step also is unnecessary. CATI data may pass directly into the next stage of processing without incurring the separate costs and delays of key entry.

By recording responses to open questions in machine readable form, CATI also may contribute to efficiencies in post-interview processing through the use of automated or

computer-assisted coding. Automated coding of the occupation and industry of employed persons is now in use by Statistics Canada and Statistics Sweden (Anderson and Lyberg (1983)) and further applications of this technology are anticipated (Appel and Hellerman (1983)). Computer-assisted coding differs from automated coding in that it employs a clerical staff to assign numeric codes to open responses, but these responses are either displayed on a terminal or lineprinted for direct access without the necessity of turning the pages of paper forms. Computer-assisted coding has been reported by Nicholls (1978) to have increased coding productivity in one large CATI survey. Palit and Sharp (1985) suggest that CATI finds stronger advocates among the coding than the interviewing staff because it greatly simplifies the reading of open material. Some organizations conducting CATI surveys, especially in commercial market research, also make direct use of machine readable free-answer responses by providing clients with printouts of their content, organized by respondent characteristics.

In principle, sufficient online edit checks can be built into CATI interviews so that a fully "clean" data file is produced ready for weighting, imputation, and tabulation. In practice, utilization of CATI's capacity to incorporate edit checking into the interview apparently varies with the complexity of the survey and with organizational assessments of its cost-effectiveness. In most opinion surveys, it should be possible to build all edit checks into the interview and to avoid a separate data cleaning step. At the Michigan Survey Research Center, only entries made by the coding staff after completion of CATI interviews are subjected to batch computer edits. In complex factual surveys, which typically utilize larger numbers of edit checks, the costs of moving all edit checking into the CATI interview and of designing interviewer probes to reconcile each edit failure must be considered. To date, demographic CATI surveys designed by the U.S. Census Bureau have employed online edit checking selectively, while CATI data sets are still routed through batch editing programs. This practice reflects the availability of batch edit programs prepared for dual-mode surveys and their inclusion of imputation and variable construction routines in the same programs. In establishment surveys, such as those adapted for CATI by the U.S. Bureau of Labor Statistics, highly complex edit checks have been built directly into the CATI system which is used both for telephone followup to mail nonresponse and analyst review of failed-edit mail returns requiring analyst correction or respondent followup.

While the efficiencies of CATI for post-interview processing seem self-evident, published reports of cost or time savings have not appeared other than the partial data and summary impressions cited above. These efficiencies also may be difficult to realize in dual-mode or established surveys whose processing methods have been designed for paper-and-pencil forms. The introduction of CATI may require major revisions of current software and procedures for computer editing, imputation, and variable construction. The merging of CATI output files into existing runstreams, by such means as reformatting CATI data to simulate key entry output, has been a primary operational problem, encountered with CATI at the Census Bureau (Ferrari et al. (1984)). While these problems are solvable with additional planning and programming, in early implementation they may initially increase rather than decrease the processing time of CATI data.

5. Summary and Conclusions

Computer-assisted telephone interviewing began as a data entry method for interviewers

but evolved into a flexible method for online interviewing and a means of automating many functions of centralized telephone data collection. Item-based CATI systems have become increasingly alike over time in their interviewing capabilities although not in their setup methods, sample administration, call scheduling, supervisory functions, and interfaces to coding, analysis, and tabulation. Form-based CATI systems represent a new alternative for interviewing options. These new and continuing differences partially reflect varying organizational practices in survey design, field work, and analysis that are likely to persist. Current efforts to develop larger systems which include CATI, computer-assisted personal interviewing, data entry of paper forms, sample frame and data base management, analyst review, and related functions appear likely to continue the trend toward increasingly broader systems tailored to individualized organizational needs.

While acceptance and use of CATI is rapidly growing in both the private and public sectors, the current literature provides limited information about its efficiency characteristics. This paper has not been able to confirm the frequent claims that CATI reduces the costs and increases the timeliness of telephone data collection. Nor has it disconfirmed those claims. Demonstrations of differences between CATI and paper-and-pencil methods in costs, timeliness, and other characteristics require empirical evidence from appropriately controlled studies. Studies approximating these requirements have been rare, and none have reported detailed cost and time estimates.

The *relative* costs of a CATI survey undoubtedly depend on many factors, including the size and nature of the sample, the length and complexity of the interview, the number of open questions, the interviewing and callback procedures employed, the number of surveys that use the same application, the need to emulate paper-and-pencil methods for series maintenance or dual-mode uses, and organizational experience with this new technology. Initial uses of CATI by organizations new to the field typically cost more and take more time than familiar paper-and-pencil methods. Even with experience, CATI may prove more cost-effective for large, continuing surveys with simple questionnaires than for small, onetime surveys with complex instruments.

To achieve cost parity with paper-and-pencil methods, CATI generally must offset its typically higher overhead costs in hardware, software, and technical staff with cost savings in interviewing and processing. The savings required will depend on the size of the overhead. The increasing power and declining prices of personal microcomputers are encouraging new system architectures transferring support of interviewing functions to interviewer stations. Activities of the computer host are limited to case management after calls to sample numbers, communications between interviewing and supervisory stations, and general maintenance of common files. This new architecture should reduce response time constraints, vulnerability to hardware failures, and hardware costs.

When hardware and system needs are efficiently met, the principal overhead cost may prove to be technical staff support. This includes systems staff, programmers, and specialists in CATI survey design and setup. The development of more efficient methods of designing, setting up, and testing complex CATI surveys remains a primary need for the field. The frequent claim that CATI increases the speed with which telephone surveys are completed (and which may well be true for experienced organizations conducting simpler surveys) has often been disputed by case studies citing extended periods required for survey design. Advances in this area have been impeded to date by proprietary views of setup procedures and a reluctance to share both problems and solutions with potential

competitors. New approaches to CATI setup, based on modular design principles, may permit future gains in this key area of survey costs and timeliness.

Overhead and survey design costs will vary greatly by organization and are perhaps best estimated by each organization individually. Future comparative research contributing to a general understanding of CATI's data collection characteristics may focus more profitably on CATI's relative cost-effectiveness in interviewing and processing. Studies are required which compare and itemize the full range of costs in these areas, preferably on a per case basis, including interviewer recruiting and training, supervision and clerical support, production interviewing, duplication of paper forms, and data entry and computer editing where performed as separate steps. Since these costs will vary with the survey design, the methods of case assignment and call scheduling employed, and with the quality control and quality enhancement features present in each mode, these should be described. Better documentation of CATI's effects on these familiar costs for various types of studies should provide a basis for full cost comparisons including summaries of overhead and setup costs.

Finally, the choice of a data collection method is rarely based on cost considerations alone. Its effects on data quality and the opportunities it provides to undertake surveys not easily conducted in other ways also must be taken into account. These latter topics are considered in Part II of this paper series.

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