

Sampling Designs in Telephone Survey: An Experimental Study*

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ABSTRACT

This research aims to compare the results, costs, and the level of representation of computer-assisted telephone interviewing (CATI) techniques under the following conditions: (1) the same sampling approach utilizing different frames; and (2) different sampling approaches utilizing the same frame. An experimental design was devised specifically for the study. Two sampling frames were employed and both included residential numbers listed nationwide with RDD design. One of the frames was an old

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electronic directory (OED) accompanied by the CATI system. The other frame was a new, updated electronic directory (NED). The area code-prefix combinations in the NED frame with RDD (APD) were used as an alternative sampling approach. Six questions regarding quality of life were applied to examine the possible differences between sampling designs and between sampling frames, in addition to questions concerning the socio-demographic characteristics of the respondents.

Results indicated that the efficiency of the NED design was the greatest, followed by APD. The OED design had the lowest efficiency though only slightly behind the other two. In practice, however, APD is superior to the other two because it provides a probability sample. Regional representation was achieved by all of the three sampling designs, although the results of quality-of-life indicators were found to differ among them.

Key Word: telephone survey, RDD, list-assisted RDD, sampling design

電話調查之抽樣設計： 一項實驗性的研究

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摘要

本文旨在探討不同的抽樣設計對電話調查資料的影響，研究的議題主要有二：一、若採用同一種抽樣方法，但使用不同電話號碼資料庫作為抽樣底冊 (sampling frame)，是否會在訪問結果、樣本代表性及訪問成本上產生明顯的差異？二、若採用不同抽樣法，但使用相同的電話號碼資料庫，對於前述三項是否也會造成影響？本研究所使用

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的抽樣底冊分別爲是電腦輔助電話訪問 (CATI) 系統中內建的 90 年中華電信公司電話號碼資料庫，以及中華電信公司 93-94 年度全國住宅電話簿。在進行實地調查訪問時，是以同一問卷爲基礎，分成三個專案執行：使用 CATI 系統之電話號碼資料庫之「舊電話簿隨機抽樣專案」(OED)、採用中華電信公司 93-94 年度全國住宅電話簿之「新電話簿隨機抽樣專案」(NED) 及「局碼隨機抽樣專案」(APD)。

就抽樣方法來說，三個專案均是採用分層兩階段等距抽樣方式 (stratified two-stage systematic sampling)，第一階段都是以全國二十五個縣市作二十五個分層，並根據行政院內政部提供之民國九十三年度人口統計資料，計算台灣二十五個縣市人口數，以等比例原則計算出各縣市所需抽取之人數。惟三個專案在第一個階段的抽樣方式不同：OED 及 NED 是分別利用各自的電話號碼資料庫以等距抽樣原則抽取各縣市所需之住宅電話號碼數，且爲了降低因涵蓋率因素而造成部分電話號碼的用戶無法被抽中之問題，遂再利用隨機原則進行電話號碼尾數末四碼的選取，即結合電話號碼簿及 RDD 之綜合抽樣法 (list-assisted RDD)。至於 APD 則是統計住宅電話簿中各縣市電話局碼的登記比例，以該比例作爲排序的依據，運用等距抽樣法來抽取各縣市所需之電話局碼數，並搭配末四碼隨機而得。

在控制了訪員因素、訪問時間及訪問內容等可能影響訪問結果的因素後，本研究發現，以抽樣底冊的比較結果而言，NED 具有比較好的執行效率；雖然合格受訪者比較少，完訪率卻比較高。其次，在比較不同的抽樣方法上，若同樣採用 93-94 年度全國住宅電話簿爲基礎，而使用不同抽樣方法來比較執行效益來看，APD 的表現則比結合電話號碼簿及 RDD 之綜合抽樣法要來得好，因爲在整體的訪問結果、調查成本及樣本代表性都非居於最差的情況下，APD 較其他二者具有更近乎均等的機率抽樣，可說是較優的抽樣設計。

關鍵字：電話調查、隨機撥號法、電話號碼簿輔助之隨機撥號法、抽樣設計

I. Introduction

Telephone survey has been a widely applied method for gathering information on populations for academic as well as for commercial purposes; it has various advantages (Glasser & Metzger 1972; Huang 1996; Hung & Huang 2000; Lin & Chen 1996; Tai 1997). The use of a computer-assisted telephone interviewing (CATI) system further enhances the ease of data collection, particularly due to its efficiency and relatively low cost. Given the high level of telephone coverage for residences, the potential for bias in estimates from telephone surveys is small for surveys targeting the general population. At the end of 2004, 97.6% of households in Taiwan had telephones.¹ Listed household numbers are estimated as slightly more than 50% (Directorate General of Budget, Accounting and Statistics, Executive Yuan 2005).² The coverage and representation of CATI samples remain important issues (Hung 1996, 2006).

In order to reduce the likelihood of biased results, many methods have been developed to select random samples of household telephones. Two basic sampling designs are commonly used for general

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1. The information was obtained from the 2005 Household Income Survey for the Taiwan Region. The rate has been slightly decreased to 96.7% at the end of 2007.
 2. By the end of 2004, telephone landlines numbered about 13.5 million, including around three million numbers for business and other uses. According to the 2004-2005 reported figures of the "Telephone Business in the Taiwan—Fukien Area" (Directorate General of Budget, Accounting and Statistics, Executive Yuan 2005), the estimated number of residential telephones exceeded 10 million, but only around 50% of them were listed in directories.

population telephone household sampling in Taiwan (Hung & Huang 2000). One is directory-based or list-assisted sampling procedure with systematic sampling, plus one or minus one dialing, or random replacement of the last few digits. Such an approach may encounter different operational problems and estimation difficulties, depending on the design (Casady & Lepkowski, 1999; Huang 1996; Wu 1996). The other approach is called modified random digit dialing (RDD) (Hung & Huang 2000), which usually involves the combinations of fixed area codes and prefix (the first five or six digits of the telephone number in the case of Taiwan) and four random digits of the suffix. Since the complete combination of area code-prefix usually is hard to obtain, and the databank accompanying the CATI system provides an easy access, the list-assisted approach is more widely applied.³

While the content of the population list is an issue, different sampling designs may alter the results as well. A cost model allows researchers to obtain optimal RDD samples (Brick et al. 2002), the varying costs of budget and time, however, result in a dilemma for efficiency when conducting telephone surveys. By examining the never-perfect population list as the CATI databank from which respondents' telephone numbers are drawn, this research attempts to compare the results, costs, and the level of representation of the sample under the following conditions: (1) the same sampling approach

3. While the growing numbers of cellular phone subscribers and landlines for internet service are not discussed in this study, they have raised a coverage issue because the latter may still create the problem of exclusion from the sampling frame or non-contact numbers.

utilizing different frames; and (2) different sampling approaches utilizing the same frame. An experimental design is employed for this study that controls survey questionnaire and time and interviewer effects. The procedures and results of the aforementioned sampling design are reported.

II. Use of Rdd Sampling in Telephone Survey

Compared to samples drawn from telephone directories, random digit dialing (RDD) increases the potential for achieving a representative sample of the population. However, simple or systematic RDD would generate large proportions of numbers with area codes and prefixes that are not in use. It also tends to have more dialings that require confirmation by redialing and this, in turn, increases the administrative and operational costs in telephone survey operations (Burkheimer & Levinsohn 1988; Lin & Chen 1996). Cooper (1964) first proposed RDD element sampling by using the first seven digits of numbers from directories and adding three random digits to produce 10-digit telephone numbers for a local survey in the United States. Glasser and Metzger (1972) further devoted efforts to a national survey application by obtaining a national list of area codes and prefixes and exchanges with addition of the random generation of the last four digits. Such a method is also known as full RDD (Tourangeau 2004). By design, these samples should include both listed and unlisted numbers (Nicolaas & Lynn 2002). However, the directory-based methods do not give every household non-zero probabilities of selection. Also, the large number of ineligible or eligibility-unknown tele-

phone numbers, which could be as high as 75 percent of sampled telephone numbers (Casady & Lepkowski 1999; see also Tourangeau 2004), remained an undesirable feature.

To resolve the problem of unproductive numbers, including non-residential and non-working numbers, Warren Mitofsky developed a two-stage RDD design that was subsequently elaborated by Waksberg (1978). The Mitofsky-Waksberg method takes advantage of the fact that residential telephone numbers tend to be clustered in banks of consecutive telephone numbers. In the first stage, 100-banks are selected with probability proportional to the number of residential telephone numbers, and a fixed-size sample of residential households is selected in the second stage. By using a self-weighting sample of all residential telephone numbers, the Mitofsky-Waksberg method substantially reduces the proportion of non-residential telephone numbers that have to be dialed. This two-stage sampling design, however, has the drawback of increased variance and estimation difficulties associated with the clustering of the sample in 100-banks of telephone numbers (Casady & Lepkowski 1999; Huang 1996; Lepkowski 1988). The sequential nature of its second stage sampling would also encounter replacement problems when data collection periods are short. Potthoff (1987) proposed using auspicious numbers, referring to eligible numbers under a variety of outcomes, to reduce the uncertainty about the status of numbers at the first stage of selection. The complexities in the second stage are, then, expected to be reduced. Still, operational cost and knowledge about the proportion of auspicious numbers put limitations on the application of this sampling design (e.g. Huang 1996).

A different approach which aims to simplify sampling operations or to increase the proportion of productive dialing with other than RDD methods is referred to as two-stage or two-stratum list-assisted sampling (Brick et al. 1995; Lepkowski 1988; Tucker et al. 2002). With the help of technology development to integrate information from all of the telephone directories, list-assisted designs assume that the entire frame of telephone numbers is available and can be stratified on the basis of several auxiliary variables to improve sampling efficiency. Such information is useful in providing coverage of households with unlisted numbers as well. This approach is also known as truncated frame methods because it does not provide complete coverage of unlisted telephone households; i.e. all of the selected numbers come from banks with at least one residential telephone number (Casady & Lepkowski 1993; Tourangeau 2004). With reduced complexity of the second-stage sampling, an equal probability of selection design can be obtained and no replacement of numbers is required. Casady and Lepkowski (1993) discussed the statistical theory underlying such design and presented empirical analysis of the properties of stratified list-assisted sampling design. Brick et al. (1995) further showed that the potential bias resulting from the loss of residential telephones in 100-banks with unlisted numbers was small.

Considering the substantial changes in the telephone system in the United States, Tucker, Lepkowski, and Piekarski (2002) re-examined the efficiency of list-assisted sampling design. Their findings indicated that the gain in efficiency over a decade for the list-assisted designs was greater than that for the Mitofsky-Waksberg

method. In addition, the non-truncated list-assisted designs were found to be more efficient when the entire telephone population must be covered. Several two-phased RDD sampling designs have been developed (e.g. Ayhan & Islam 2005; Brick et al. 2002), while their application and efficiency for actual survey operations needs more examination.

Similar to some other countries, Taiwan has experienced changes in telephone systems in the past decades, with increased numbers of prefixes and one digit added in large cities. However, only a few studies have been done on different sampling designs of telephone survey other than description of survey conduction (e.g. Huang 1996), often due to the difficulty of obtaining a complete national list of residential numbers or complete area code-prefix combinations. The set of telephone numbers accompanying the CATI software has been a convenient sampling frame, one which included the listed numbers in telephone directories in early years. Replacement with random digits for the last two to four digits of telephone numbers was used to try to cover unlisted residential telephone numbers.

Lin and Chen (1996) employed a simulation method to compare sample representation of telephone surveys among different sampling designs. By using working telephone numbers in a county of middle Taiwan as the sampling frame, the result indicated that stratified RDD and list-assisted stratified RDD had better goodness of fit for sample representation. Tai (1997) used the telephone numbers provided by a CATI software as the sampling frame to examine the matching rate of locations reported by the respondents to that of

the residential numbers under a stratified-RDD sampling design in a northern county. The average matching rate among the 12 townships was 59.8% when comparing the sampled telephone numbers to the numbers in the CATI databank. The rate decreased, however, to 38.0% after the survey was conducted. Although Tai's results cannot be applied to other localities in Taiwan, it should be aware that sampled area code and prefix may not accurately reveal the location of the respondents.

Unlike previous studies of which results had limited applications, Hung and Huang (2000) conducted an island-wide telephone survey to compare two sampling designs. While a list-assisted RDD cost about NT\$10,000 more than directory based systematic sampling design for about 1,000 complete cases, the former remained a preferable choice due to its better performance on coverage rate, sample representation, and ease of operation procedures to be integrated into CATI system.

To a certain extent, most telephone surveys in Taiwan have employed a truncated frame for sampling designs. As mentioned above, such a convenient sampling frame may not keep up with the changes in the telephone system, and may, in turn, cause bias, such as non-response due to inaccessibility (Hung 2005). Moreover, the convenient sampling frame may contain area codes and prefixes that have been reassigned to residential households several times. The probability of contacting residential numbers using such a frame can be high. On the other hand, an updated frame may cover new clusters of telephone numbers to reach those that are rarely called in using the convenient frame. It is unknown whether the outcomes and efficiency

of telephone surveys may differ between the two sampling frames. Therefore, this research employed two different frames so as to compare the results utilizing the same modified RDD design. Furthermore, a different sampling method was designed based on the updated frame to explore the potential dissimilarity between sampling designs. Detailed descriptions of sampling frames and methods are reported in the next section.

III. Study Design

1. Sampling Frames and Methods

Two sampling frames were employed and both included residential numbers listed nationwide which were obtained from Chunghwa Telecom, which has been the largest company providing telecommunication service for landlines with more than 98% market share as well as the issuer of available telephone directories. One of the frames was an old electronic directory (OED, the 2001 telephone directories) which accompanied the CATI system; the other was the most recent electronic directory (NED) at the time of survey. NED includes residential numbers listed in the period of 2004 to 2005 and errors occurred due to scanning the paper directories have been corrected. Unlike other two-stage list-assisted methods, the first stage of the sampling design for both OED and NED was to divide listed residential numbers into 25 district clusters at the city/county level to take geographical representation into account. A systematic sampling method was then used to select numbers with probability proportional to population size in each of the 25 clusters to obtain a

sample of 1,000 telephone numbers. The order of the telephone numbers for OED and NED was not altered. In order to reduce the bias resulting from lack of coverage of unlisted residential numbers, the last four digits of selected telephone numbers were replaced with randomly generated numbers. Information in the OED frame included corresponding addresses, so the geographic allocation of the listed residential numbers could be identified. The updated frame, NED, although having the possibility of reaching more working numbers than OED, does not include corresponding addresses to confirm the actual location of the selected telephone numbers. The geographic locations of NED numbers at the city/county level were roughly identified by using the information obtained from survey results in the past five years.⁴

The updated electronic directories were also utilized as the sampling frame for a different sampling method. Unlike OED and NED, the area code-prefix combinations derived from the NED frame were used to design a full RDD method (APD).⁵ Similar to OED and NED methods, these area code-prefix combinations were divided into 25 district clusters and were used as primary sampling units (PSU).

4. Telephone surveys conducted by the Center for Survey Research have been collecting information about the geographic location of the telephone numbers at the city/county levels and the minor civil division levels for each of the successful interviews. Such information obtained from nearly 61,000 completed interviews in the past five years allowed the researchers to roughly identify the city/county to which each area code-prefix combination belonged.

5. Researchers are fully aware of the possibility of reaching a high proportion of non-working residential numbers under a full RDD design (see Tourangeau, 2004). While it may seem naive, this study may provide a baseline for such information in Taiwan.

After the area code-prefix combinations were sorted based on their proportions, a systematic random sample with probability proportional to the size (PPS) of area code-prefix combinations listed in the electronic directory (NED) was then selected with four random digits added to each combination for a set of complete telephone numbers.

After the telephone numbers were dialed, a within-household selection method developed by Hung (2001) was used to select individuals for each of the OED, NED, and APD sampling designs. By using this method, households were first selected with an equal probability. One qualified adult respondent was then selected within the household, in order to retain the features of a probability sample.

2. Operation and Questionnaire

The CATI system of the Center for Survey Research, RCHSS, at Academia Sinica was used to collect survey data simultaneously for 15 working days in late 2005 for the three different sampling methods while controlling for the time effect. Interviewers were randomly divided into three groups to conduct telephone interviews with the consideration of experience and gender of the interviewers so the interviewer effects could be minimized.⁶ In order to compare the results as they differ between sampling frames and between sampling methods, this research applied a battery of quality-of-life survey questions to collect information on respondents aged 20 or over throughout Taiwan nationwide. Questions of quality of life included

6. The number of interviewers was different for the three sampling designs, with 125 person-times for both OED and NED, and 132 person-times for APD.

six items: change of social security, change of economy in the general society, change of personal economy, satisfaction with life quality in the society, satisfaction with personal quality of life, and general happiness. The first three indicators were three-point Likert scales (1=became better, 2=stayed the same, and 3=became worse) and the latter three were five-point scales (from 1=very satisfied/very happy to 5=very dissatisfied/very unhappy).

Individual characteristics included respondent's age, gender (1= male; 0=female), education, marital status, ethnicity, employment status, and region of residence. For the purpose of testing representation of the samples, age was grouped mainly based on 10-year intervals. Education included five categories: elementary school or less, junior high school, senior high school, associate degree, and college degree or beyond. Marital status was coded as single and never married, married, divorced, separated, and widowed. Ethnicity of the respondents was classified as "Hakka", "Minnan", "Mainlander", or "Indigenous Taiwanese." Employment status included the categories of full-time worker, part-time worker, student, homemaker, mandatory military service, retired, and unemployed. Twenty-five cities and counties in Taiwan were divided into six regions: north, central north, central, central south, south, and east regions. With the exception of marital status, ethnicity, and employment status, individual characteristics were used for the test for representation of these samples compared to the general population.⁷

7. Official statistics of the Department of Statistics, Ministry of the Interior, in 2004 were used as the source of population characteristics.

IV. Comparative Results of Sampling Designs

Telephone surveys using the three sampling designs were conducted for a period of 15 days. Due to the decreasing response rate of telephone surveys over the past decade, seven sets of samples, i.e. 7,000 telephone numbers, were used for each of the OED, NED, and APD designs. The sampling procedure was repeated when selecting a new sample for each of the OED and NED. The selection of a new sample for the APD, however, was different. The selected combinations of area code-prefix stayed the same as those for the first sample while the last four random digits were newly generated for each sample. After selecting the 7,000 telephone numbers for each of the sampling designs, these numbers were compared to the two electronic telephone directories to estimate the rate of listed residential numbers. It was found that rates of listed residential numbers were 35.39%, 33.07%, and 32.81% from the OED, NED, and APD samples, respectively, consistent with the findings of previous studies using the same designs.⁸

For each telephone number, up to six attempts were made. The consequence of each attempt was recorded in the CATI system. The total number of attempted calls for the OED was 16,258 and these obtained 702 completed interviews. The total number of attempted calls for the NED and APD were both 16,520 and these obtained 754

8. For discussions on the rates of listed and unlisted residential numbers as gathered in different sampling designs, please see Lin and Chen (1996).

and 748 completed interviews, respectively. In other words, every 1,000 attempted calls could obtain about 43 completed interviews for OED and about 45 for both NED and APD.

1. Final Disposition Distributions and Outcome Rates

The final disposition of all attempts was coded for the purpose of this research; this was considered the most appropriate outcome to record for each attempt.⁹ Table 1 presents the final disposition distribution of all attempts from the OED, NED, and APD samples.¹⁰ All of the three sampling designs had a similar proportion of completed interviews. The highest proportion of refusal was reported from the OED (26.7%), followed by that from the NED (23.2%). On the other hand, the proportion of non-working telephone numbers was the lowest (22.1%) from the OED, while those from both of the NED and APD were similar (24.6% and 24.4%, respectively). Chi-square tests comparing the final disposition distribution between each two of the three sampling designs indicated significant differences among them.

In respect to the attempts that were not eligible, their distributions varied across cities and counties. The Appendix presents the rates of non-working, non-residential, and fax numbers found with the OED, NED, and APD methods within each of the sampled city/

9. For a discussion of the use of most recent and final dispositions in telephone survey, please see McCarty (2003).

10. Definitions of the final disposition codes can be found in a report of the American Association for Public Opinion Research (AAPOR) (2006). The AAPOR report is also used for the source of calculating outcome rates for the sampling designs.

Table 1 *Final Disposition Distribution of Telephone Survey Attempts under OED, NED, and APD Designs^a*

	OED%	NED%	APD%
Eligible			
Completed interview	10.0	10.8	10.7
Refusal	26.7	23.2	22.4
Non-contact	6.5	6.8	6.7
Other	1.0	1.3	1.3
Not eligible			
Non-working	22.1	24.6	24.4
Non-residential number	7.1	6.0	7.2
Fax	5.0	5.2	5.3
Not eligible respondent	1.5	2.3	1.8
Unknown eligibility	20.1	20.0	20.3

^a Chi-square tests between OED and NED, NED and APD, and OED and APD were 98.962, 30.213, and 82.672, respectively, and were all statistically significant at the <.001 level.

county.¹¹ As shown in the Appendix, counties that were found to have higher rates of non-working numbers were concentrated in less populated areas, in particular the eastern region in Taiwan and off-shore islands. On the other hand, rapidly developing areas such as Taoyuan County and Hsinchu City were found to have much lower rates of non-working numbers. In addition, the distributions indicated that rates of non-working numbers from the APD were spread more widely across cities and counties than those from the OED and NED. When compared to the geographic allocation for the telephone population estimated from the 2004-2005 telephone directories, how-

11. Attempts that were coded as not eligible respondent should not be attributed to the features of sampling designs. The geographic distributions of this for OED, NED, and APD were, therefore, not presented.

ever, most of the rates of non-working numbers from the three methods were parallel to the population compared across cities and counties (data not shown).

On the other hand, rates of non-residential numbers indicated the proportions of numbers used by business, institutions, and others, were as expected to be found in highly industrialized areas, in particular in cities and metropolitan areas. As expected, rates of non-residential numbers were found to be higher in metropolitan areas and big cities. However, the differences were small both among cities/counties and among sampling designs. Similar results can be observed from the rates of fax lines. Fax lines may be used either by business or by residential households. The distributions here provided a general picture of the geographical allocation of fax lines.

The outcome rates of the OED, NED, and APD designs were calculated based on the AAPOR standards.¹² The response rate is calculated by the number of completed interviews divided by the number of eligible reporting units in the sample. A refusal rate is the proportion of all potentially eligible cases in which a household or respondent refuses to do an interview, or breaks-off an interview. A contact rate is a household-level rate measuring the proportion of all cases in which some responsible member of the housing unit was reached by the survey. Selected response rate, refusal rate, and con-

12. Definitions of response rate, refusal rate, and contact rate are drawn from the AAPOR report (2006), as well as the calculations of the selected outcome rates in this research. Please see the report for the formulas of these rates.

tact rate are reported in Table 2.¹³ As indicated, the response rates were about 1.8% higher from the NED and APD than that from OED, while refusal rates were about 4.13% and 4.94% higher from the OED than that of NED and APD, respectively. Moreover, the OED data had the highest contact rate among these sampling designs.

Efficiency of these sampling methods may be estimated by comparing the disposition and outcomes between sampling frames as well as between sampling approaches. Based on the comparative results of final disposition distribution and outcome rates, NED seemed to be the most efficient sampling design. APD was comparably the least efficient but was only slightly behind OED and NED. When sampling errors were taken into account, the differences of the

Table 2 *Outcome Rates of OED, NED, and APD Designs*

	OED	NED	APD
RR1 ^a	15.59%	17.39%	17.41%
REF1 ^b	41.52%	37.39%	36.58%
CON1 ^c	58.68%	56.13%	56.82%
Sampling error	±3.77%	±3.64%	±3.66%

Note: ^a Response Rate 1 (RR1), or the minimum response rate, is the number of complete interviews divided by the number of interviews (complete plus partial) plus the number of non-interviews (refusal and break-off plus non-contacts plus others) plus all cases of unknown eligibility (unknown if housing unit, plus unknown, other). ^b Refusal Rate 1 (REF1) is the number of refusals divided by the interviews (complete and partial) plus the non-respondents (refusals, non-contacts, and others) plus the cases of unknown eligibility. ^c Contact Rate 1 (CON1) assumes that all cases of indeterminate eligibility are actually eligible.

13. The response rate under the APD method was 16.49% when adjusted from 125 person-times.

outcome rates were less important. Sampling errors were all within the range from 3.6% to 3.8% with that from OED as the highest. Such sampling errors were large enough to lower the significance of differences among the methods in terms of final disposition and outcome rates; only the differences of the refusal rates remained noticeable.

In regard to the operation procedures in the CATI system, the difference of the total attempted calls for a sample of 1,000 complete interviews could be 83.3 attempted calls per day between OED and NED and 75 between OED and APD. Such differences may cost 30 line-hours or one-day work load for OED than the others. When the efficiency of different sampling methods is used to estimate the potential monetary cost for a sample of 1,000 completed interviews, OED could cost about NT\$25,000 more than NED. The cost of APD would be about NT\$12,000 to 13,000 higher than NED when response rate of the former is adjusted. When considering the same number of operation person-times instead, the cost of NED and APD was similar. With the advantages of updated frame and a probability sample, APD may be superior to the other two in the operation of telephone surveys.

2. Test for Sample Representation

Sample distribution of individual characteristics of the completed interviews from OED, NED, and APD, which were 702, 754, and 748, respectively, were individually compared with those of population derived from the 2004 Official Statistics of the Department of Statistics, Ministry of the Interior. These characteristics included age, gender, education, and region of residence. The distributions

patterns of the three datasets, however, were significantly different from those of the population, with an exception of region of residence and gender distribution from APD (Table 3). While the distribution of age groups in the general population is more evenly distributed for population aged 20 or over, those from the three datasets were more concentrated in the groups of 30-39 and 40-49 years. The distribution of gender was less surprising, also consistent with previous studies, in finding more female respondents than males, although females and males are equal proportions in the population. The dissimilarity between population and each of the datasets in the distributions of age by gender was, therefore, predictable.

As indicated by the distribution of education, it was found that the respondents from the three datasets reported a higher educational level than the general population. Such difference could be attributed to underestimation in the population statistics. The results were also consistent with previous findings of telephone surveys in Taiwan.¹⁴ Region of residence was the only one characteristic that was found to have no significant difference between the general population and any of the datasets. This finding reflected the sampling stratification based on geographic boundaries. OED, NED, and APD were each demonstrated to be able to produce a nationally represen-

14. A household registration system is used to collect address and demographic characteristics for household members in Taiwan. Such information, however, is not routinely updated so imprecision may occur. In the case of education, a child's recorded information may be junior high school, for instance, but s/he may have a higher degree in later years before the recorded education is updated. For a related research, please see Hung (2005).

Table 3 *Test of Representation of the General Population for OED, NED, and APD Data*

		Population (%)	OED (%)	NED (%)	APD (%)
Age			(N=678)	(N=725)	(N=715)
	20-29 years	23.3	15.9	17.5	17.1
	30-39 years	22.0	24.2	24.7	27.1
	40-49 years	22.2	29.5	29.7	27.6
	50-59 years	14.8	15.6	14.2	15.4
	60 years or over	17.7	14.7	13.9	12.9
$\chi^2(\text{d.f.}=4)$			37.091***	36.877***	39.281***
Gender			(N=702)	(N=754)	(N=748)
	Male	50.4	46.4	45.6	47.9
	Female	49.6	53.6	54.4	52.1
$\chi^2(\text{d.f.}=1)$			4.505*	7.009**	1.996
Gender[×]Age			(N=678)	(N=725)	(N=715)
M	20-29 years	11.9	8.3	9.1	6.9
	30-39 years	11.1	9.0	10.9	11.9
	40-49 years	11.2	13.1	12.7	13.1
	50-59 years	7.4	8.1	5.9	8.8
	60 years or over	8.9	8.7	7.3	7.8
F	20-29 years	11.4	7.7	8.4	10.2
	30-39 years	10.9	15.2	13.8	15.2
	40-49 years	11.0	16.4	17.0	14.4
	50-59 years	7.4	7.5	8.3	6.6
	60 years or over	8.9	6.0	6.6	5.0
$\chi^2(\text{d.f.}=9)$			56.760***	49.799***	54.402***

Table 3 (continued)

	Population (%)	OED (%)	NED (%)	APD (%)
Education status		(N = 700)	(N = 753)	(N = 745)
Elementary school or less	22.4	16.1	17.0	15.2
Junior high school	15.2	12.9	10.0	11.0
Senior high school	30.1	28.1	32.7	32.5
Associate degree	14.5	16.1	16.1	16.6
College or beyond	17.7	26.7	24.3	24.7
χ^2 (d.f. = 4)		49.294***	45.112***	50.602***
Region		(N = 692)	(N = 736)	(N = 737)
North	30.0	33.1	32.5	32.7
Central North	13.9	15.6	15.5	14.4
Central	18.9	16.5	17.8	17.9
Central South	15.3	15.2	14.8	15.1
South	17.1	14.6	14.9	15.2
East	4.7	5.1	4.5	4.7
χ^2 (d.f. = 5)		8.661	5.538	3.925

*p < .05 ***p < .001

tative sample in regard to region of residence.

While significant differences in individual characteristics were found between general population and data from each of the sampling designs, the comparisons with OED, NED, and APD data differed as well. Table 4 reports the results of chi-square tests on the distributions by using unweighted data (distribution data not shown). In respect to the comparison between sampling frames, the distributions of gender, education, and employment status were found to be different between OED and NED. When considering the comparisons between sampling approaches, the cross-tabulation of gender and

Table 4 *Demographic Profiles for OED, NED, and APD Data*
(χ^2 -test with unweighted data)

Individual characteristics	d.f.	OED vs. NED	APD vs. NED	OED vs. APD
Age	4	2.349	4.158	5.503
Gender	1	4.505*	1.510	0.569
Gender \times Age	9	12.463	26.821***	16.169
Education	4	12.267*	2.498	7.934
Ethnicity	3	0.816	1.923	3.501
Marital status	4	6.108	4.660	5.204
Employment	6	22.995***	27.663***	31.907***
Region	5	1.398	0.778	1.860

* $p < .05$ *** $p < .001$

age and the distribution of employment status were found to vary between NED and APD. Data from OED were also compared to those from APD. Similar to other comparative results, the distributions of employment status were found to be different between OED and APD data as well.

Based on the demographic profiles for the three datasets, more consistent information was observed between OED and APD than between OED and NED and between NED and APD. Still, it needs to be noted that none of the samples served as a significantly better representative of the general population.

3. Comparison of Survey Results

Six questions regarding quality of life were used to compare the results of three sampling designs. With consideration of sampling

errors, 95% confidence intervals of differences between each two of these designs were estimated with unweighted and weighted data. Demographic variables including age, gender, education, and region of residence were used for weighting due to the discrepancies between the samples and the general population. The estimation for the response patterns of each of the questions is reported in Table 5. Intervals that did not include zero, as italicized in the Table, indicated significant dissimilarity between designs for a specific response category. Results of the comparisons revealed significant differences between sampling designs in terms of response patterns for both the unweighted and weighted data. Greater differences of response patterns were found between sampling frames, OED and NED, for the unweighted data than those that were found between sampling approaches, NED and APD, for the weighted data. Such differences were found particularly in the response patterns for two questions—change of personal economy and general happiness. The least inconsistency of the response patterns was observed between OED and APD, for either the weighted or the unweighted data.

The response patterns of the six quality-of-life questions were further examined using latent class models. Considering the ordinal feature of the responses, the Latent Class Factor Model (also known as the DFactor Model) was applied by using the Latent Gold 4.0 software. The DFactor model, similar to traditional factor analysis, identifies factors that group together variables sharing a common source of variation.¹⁵ One advantage of the DFactor Model over tra-

15. For discussion, please see Vermunt and Magidson (2005).

Table 5 *Estimation of 95% Confidence Intervals of Differences Using Quality of Life Measures*

	Unweighted						Weighted					
	OED vs. NED		APD vs. NED		OED vs. APD		OED vs. NED		APD vs. NED		OED vs. APD	
Compared to one year ago, do you think that social security nowadays become better or worse, or stay the same?												
Became better	-0.0160	0.0220	-0.0227	0.0127	-0.0104	0.0264	-0.0112	0.0272	-0.0169	0.0189	-0.0124	0.0264
Stayed the same	-0.0483	0.0523	-0.0781	0.0201	-0.0190	0.0810	-0.0443	0.0563	-0.0840	0.0140	-0.0089	0.0909
Became worse	-0.0593	0.0433	-0.0081	0.0921	-0.1011	0.0011	-0.0753	0.0273	-0.0111	0.0891	-0.1141	-0.0119
Nonresponse	-0.0141	0.0201	-0.0232	0.0072	-0.0050	0.0270	-0.0089	0.0289	-0.0207	0.0127	-0.0045	0.0325
Compared to one year ago, do you think that societal economy nowadays become better or worse, or stay the same?												
Became better	-0.0501	0.0081	-0.0442	0.0142	-0.0341	0.0221	-0.0547	0.0047	-0.0404	0.0204	-0.0441	0.0141
Stayed the same	-0.0622	0.0322	-0.1005	-0.0095	-0.0060	0.0860	-0.0430	0.0530	-0.0872	0.0052	-0.0012	0.0932
Became worse	-0.0048	0.0968	0.0264	0.1256	-0.0801	0.0201	-0.0202	0.0822	0.0058	0.1062	-0.0759	0.0259
Nonresponse	-0.0269	0.0089	-0.0232	0.0132	-0.0213	0.0133	-0.0312	0.0092	-0.0248	0.0168	-0.0268	0.0128
Compared to one year ago, do you think that your personal economy nowadays become better or worse, or stay the same?												
Became better	-0.0634	-0.0026	-0.0602	0.0002	-0.0313	0.0253	-0.0528	0.0088	-0.0598	-0.0002	-0.0208	0.0368
Stayed the same	-0.0765	0.0245	-0.0555	0.0435	-0.0706	0.0306	-0.0928	0.0088	-0.0637	0.0357	-0.0790	0.0230
Became worse	0.0303	0.1237	0.0017	0.0923	-0.0180	0.0780	0.0429	0.1371	0.0143	0.1057	-0.0185	0.0785
Nonresponse	-0.0307	-0.0073	-0.0251	0.0011	-0.0158	0.0018	-0.0398	-0.0122	-0.0315	-0.0005	-0.0207	0.0007

Table 5 (continued)

	Unweighted						Weighted					
	OED vs. NED		APD vs. NED		OED vs. APD		OED vs. NED		APD vs. NED		OED vs. APD	
Are you satisfied with life in the society?												
Very satisfied	-0.0127	0.0227	-0.0201	0.0121	-0.0082	0.0262	-0.0081	0.0301	-0.0207	0.0127	-0.0036	0.0336
Satisfied	-0.0805	0.0165	-0.0699	0.0259	-0.0582	0.0382	-0.0910	0.0070	-0.0775	0.0195	-0.0617	0.0357
Neither satisfied nor dissatisfied	-0.0096	0.0236	-0.0041	0.0301	-0.0244	0.0124	-0.0090	0.0270	0.0000	0.0380	-0.0304	0.0104
Unsatisfied	-0.0687	0.0307	-0.0896	0.0076	-0.0272	0.0712	-0.0641	0.0341	-0.0859	0.0099	-0.0255	0.0715
Very unsatisfied	-0.0065	0.0765	0.0213	0.1047	-0.0717	0.0157	-0.0095	0.0715	0.0211	0.1029	-0.0738	0.0118
Nonresponse	-0.0138	0.0218	-0.0246	0.0066	-0.0036	0.0296	-0.0135	0.0275	-0.0272	0.0092	-0.0035	0.0355
Are you satisfied you're your personal life?												
Very satisfied	-0.0278	0.0258	-0.0265	0.0265	-0.0279	0.0259	-0.0251	0.0291	-0.0247	0.0287	-0.0273	0.0273
Satisfied	-0.0903	0.0123	-0.0594	0.0414	-0.0814	0.0214	-0.0754	0.0274	-0.0595	0.0415	-0.0665	0.0365
Neither satisfied nor dissatisfied	-0.0127	0.0247	-0.0295	0.0015	0.0032	0.0368	-0.0175	0.0235	-0.0312	0.0052	-0.0030	0.0350
Unsatisfied	-0.0240	0.0660	-0.0350	0.0530	-0.0334	0.0574	-0.0412	0.0492	-0.0453	0.0433	-0.0402	0.0502
Very unsatisfied	-0.0121	0.0481	-0.0143	0.0443	-0.0281	0.0341	-0.0113	0.0493	-0.0107	0.0487	-0.0316	0.0316
Nonresponse	-0.0144	0.0044	-0.0121	0.0081	-0.0119	0.0059	-0.0154	0.0054	-0.0115	0.0115	-0.0155	0.0055
Taking all things together, how happy are you with life recently?												
Very happy	-0.0296	0.0376	-0.0243	0.0423	-0.0391	0.0291	-0.0416	0.0256	-0.0251	0.0431	-0.0512	0.0172
Happy	-0.1392	-0.0368	-0.1165	-0.0155	-0.0734	0.0294	-0.1203	-0.0177	-0.1225	-0.0215	-0.0484	0.0544
Neither happy nor unhappy	0.0043	0.0517	-0.0194	0.0214	0.0032	0.0508	-0.0025	0.0465	-0.0236	0.0196	-0.0003	0.0483
Unhappy	0.0251	0.1109	0.0171	0.1009	-0.0359	0.0539	0.0168	0.1012	0.0185	0.1015	-0.0453	0.0433
Very unhappy	-0.0294	0.0294	-0.0243	0.0343	-0.0348	0.0248	-0.0235	0.0355	-0.0183	0.0403	-0.0353	0.0253
Nonresponse	-0.0209	-0.0011	-0.0178	0.0038	-0.0119	0.0039	-0.0206	0.0006	-0.0175	0.0055	-0.0131	0.0051

ditional factor analysis is that variables may be ordinal or any combination of different scales, while the emergent DFactor may be ordinal or dichotomous scale. Survey results from the three datasets were analyzed to explore the latent dimension of the six quality-of-life measures. The goodness of fit of latent DFactor models can be assessed with a comparison of the likelihood ratio chi-square (L^2) values to the degrees of freedom for a model. Other useful indices for assessing the goodness-of-fit for a model include the lambda measure of association and the proportion of misclassified cases.¹⁶ Goodness-of-fit indices for models of one factor, two uncorrelated factors, and two correlated factors which can be interpreted as rotated factors, are presented in Table 6 for each of OED, NED, and APD. The results indicated that one-DFactor model had better goodness-of-fit for OED and APD while two-DFactor model had better fit for NED. The results, however, were not conclusive due to lack of previous findings on these quality-of-life measures that were analyzed by using comparable latent class models. The findings remain useful by providing concordance with the dimensionality of these quality-of-life indicators.

V. Conclusion and Discussion

This study compared the costs, the level of representation, and survey results between different sampling frames and between differ-

16. More technical details on the theoretical foundations and estimation of latent class models are available in the existing literature (c.f. McCutcheon, 1987).

Table 6 *Model Goodness-of-Fit Indices for Quality-of-Life Measures*

	BIC (Log-Likelihood)	L²	d.f.	p-value	λ (Factor 1/Factor 2)	Classification error (Factor 1/Factor 2)
OED						
1-DFactor model	7857.5875	1119.2708	628	<0.001	0.8324	0.0663
2-DFactor model	7806.0147	1022.3270	621	<0.001	0.6981/0.6800	0.1010/0.1589
2-DFactor model (correlation)	7807.7263	1017.5570	620	<0.001	0.6992/0.7537	0.0956/0.1152
NED						
1-DFactor model	8142.3787	1067.2004	659	<0.001	0.7459	0.0815
2-DFactor model	8058.8246	937.9506	652	<0.001	0.8367/0.7149	0.0501/0.1385
2-DFactor model (correlation)	8061.9343	934.5323	651	<0.001	0.8286/0.6863	0.0538/0.1483
APD						
1-DFactor model	8294.4443	1062.2292	679	<0.001	0.8222	0.0803
2-DFactor model	8167.5273	889.4147	672	<0.001	0.6683/0.6921	0.1148/0.1412
2-DFactor model (correlation)	8150.3963	865.7269	671	<0.001	0.6675/0.6842	0.1181/0.1426

ent sampling approaches for telephone survey in Taiwan. For the former comparison, OED and NED were both list-assisted RDD sampling designs using older and updated listed residential numbers, respectively. A different approach employing the area code-prefix combinations from the NED frame with RDD was used to select samples, i.e. the APD design. Results of final disposition distributions and outcome rates indicated that NED design achieved better efficiency than OED overall in terms of sampling-frame comparison. The efficiency of the NED was slightly better than that of the APD regarding sampling-approach comparison.

Regional representation was achieved by all of the sampling designs, but representation on most of the demographic variables was not. While such a finding is consistent with previous studies due to various factors other than sampling design, such as survey date/time, use of within-household sampling, multiple uses of telephone lines (e.g. Hung 2005; Hung & Huang 2000), weighting has been suggested to correct estimation bias (Hung 2005; Tai 1997). When examining survey results in terms of the quality-of-life indicators, those of NED were found to be inconsistent with those of OED and with those of APD, while the latter two were rather similar to each other. However, the dimensionality of quality-of-life indicators was demonstrated by all of the sampling designs.

Among the three sampling designs, the lowest proportion of non-working numbers and the highest rate of refusal obtained from OED reflected the characteristics of a frequently used sampling frame for telephone survey. Telephone numbers in the OED frame remain concentrated in the area code-prefix clusters that have been

used for years. It is more likely that used telephone numbers have been reassigned to new telephone subscribers in older area code-prefix clusters, rather than the issuing of new numbers or generation of new combinations of area codes and prefix. A similar idea is to assign residential telephone numbers in sequence rather than randomly (see Tourangeau 2004). Households with these “used” telephone numbers, therefore, have a greater chance of being selected and, in turn, become less likely to have patience or interest in taking a survey. A new sampling frame, on the other hand, encounters a risk of having more non-working numbers, but is more likely to cover new residential numbers, since it is able to deal with the expansion of telephone systems.

Previous research has warned that a full RDD design, i.e. four-digit random dialing appended to the combinations of area codes and prefix, may in the United States, for example, yield as large as 75 percent non-working residential telephone numbers and, in turn, increase the cost of operation of telephone survey (Casady & Lepkowski 1999; Tourangeau 2004). The situation was slightly better in Taiwan in regard to the working telephone numbers (Hung & Huang 2000). This study found that at least 40% of the selected telephone numbers were working residential numbers, as selected by the full RDD design in Taiwan. Such a finding may correspond to different conditions of telephone systems as well as household structures. Despite the low response rate, a full RDD design remains useful in telephone sampling.

Although a new frame has been proved to be superior to an old frame, the sampling design of OED and NED did not give every

household a non-zero probability of selection (Nicolaas & Lynn 2002). On the other hand, a full RDD design with PPS, or the APD in this research, has been used successfully in screening households to obtain residential information necessary for selecting a special sample. By using this method, unlisted numbers and new listings have a true non-zero probability of being selected. Therefore, considerable savings in relative costs may be achieved and a representative sample of population may be obtained. However, when new listings are not available, the sampling frame remains a truncated frame, which may be the case for all of the sampling designs in this research. Consistent with previous studies (c.f. Hung & Huang 2000), a full RDD design with PPS was concluded to be a more appropriate sampling design for telephone surveys in Taiwan. Since this research is exploratory, more studies using full RDD designs should help distinguish benefits and detriments of various sampling methods.

Appendix: *Rates of non-working, non-residential, and fax numbers from OED, NED, and APD*

City name	Non-working			Non-residential			Fax		
	OED	NED	APD	OED	NED	APD	OED	NED	APD
Taipei City	16.69%	17.29%	17.53%	11.04%	11.28%	12.00%	7.08%	7.56%	7.44%
Taipei County	17.09%	19.11%	20.16%	7.36%	5.70%	7.98%	5.87%	5.26%	6.49%
Taoyuan County	13.00%	20.88%	22.16%	8.42%	5.49%	9.16%	5.86%	6.41%	5.13%
Hsinchu County	20.71%	23.57%	23.57%	7.86%	6.43%	6.43%	5.71%	7.14%	5.00%
Hsinchu City	17.65%	23.53%	14.29%	10.92%	5.88%	9.24%	5.88%	5.04%	6.72%
Miaoli County	24.57%	33.14%	28.57%	4.00%	5.14%	5.14%	4.57%	1.71%	5.14%
Taichung County	17.14%	23.08%	20.66%	6.59%	4.40%	6.15%	5.49%	5.27%	6.15%
Taichung City	26.91%	30.56%	24.92%	9.63%	7.97%	7.31%	5.98%	6.64%	5.32%
Changhua County	21.55%	23.81%	20.30%	6.52%	4.51%	2.76%	3.26%	4.51%	4.51%
Chia-I City	33.33%	17.86%	20.24%	4.76%	7.14%	7.14%	1.19%	3.57%	0.00%
Tainan County	24.00%	30.29%	22.57%	7.43%	5.14%	4.29%	2.57%	5.14%	4.57%
Tainan City	22.51%	19.05%	23.38%	7.36%	9.09%	6.93%	6.06%	6.06%	6.06%
Kaohsiung County	28.32%	30.36%	28.32%	4.34%	6.12%	8.67%	4.34%	3.83%	2.81%
Pingtung County	32.14%	32.50%	36.79%	4.64%	3.57%	4.29%	3.21%	3.57%	5.00%
Hualien County	31.25%	34.82%	36.61%	3.57%	5.36%	5.36%	3.57%	7.14%	4.46%
Ilan County	24.29%	34.29%	34.29%	5.00%	2.86%	2.86%	5.00%	6.43%	4.29%
Nantou County	27.38%	37.50%	33.93%	4.76%	2.98%	5.95%	0.60%	2.98%	4.17%
Keelung City	18.49%	22.69%	21.85%	7.56%	6.72%	5.04%	2.52%	2.52%	0.84%
Taitung County	42.86%	41.56%	54.55%	3.90%	2.60%	3.90%	3.90%	3.90%	3.90%
Penghu County	39.29%	39.29%	33.93%	3.57%	7.14%	1.79%	1.79%	5.36%	5.36%
Chia-I County	37.14%	32.00%	38.29%	3.43%	2.86%	3.43%	4.00%	3.43%	4.00%
Yunlin County	32.03%	29.87%	31.60%	3.46%	1.73%	3.90%	3.90%	3.46%	3.90%
Kaohsiung City	22.48%	22.06%	25.84%	6.93%	5.04%	9.03%	6.09%	3.57%	5.88%

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