FACTSHEET IV

THE EFFECT OF THE RESPONSE RATE ON SAMPLE SIZE

The *initial sample size* is the number of customers you attempt to contact and obtain a response from during the survey. The *final sample size* is the actual number of customers for which responses were received during the survey. The *response rate* is the percentage of customers included in the initial sample for which a usable response was received. The response rate will vary depending on the kinds of customers being contacted, the kind of product or service received, the kinds of questions asked in the survey, and so on.

Since the response rate is almost always less than 100 percent, the total number of customers from whom responses are received will almost always be less than the number of customers initially selected to be part of the sample. The table in **Factsheet III** shows the approximate sampling error associated with the *final* sample size. Since a certain *final sample size* is needed (which considers only the customers from whom responses were received), the number of customers included in *the initial sample* (the initial sample size) must always be greater than the desired final sample size.

For *periodic surveys* that reiterate in whole or in part questions asked in the previous iteration of the same survey (in order to determine to what extent customer satisfaction has changed in the intervening period, due to changes in service provision), the response rate for the next iteration of the survey can be estimated by using the response rate actually observed in the previous iteration(s) of that same survey. Where a particular survey is being conducted for the first time, it would be reasonable to assume a response rate of, say, 85 percent when determining how many customers to select for the initial sample. If the estimate of response rate turns out to be too high, then more customers can be added to the sample later, using the procedure described in step 3 g) of the procedures presented on pages 6–7 of **Factsheet III** for selecting the sample of customers to be contacted during the survey.

Note, however, that it is better to achieve the desired final sample size by having a higher response rate and a smaller total number of customers selected to be in the sample than through a lower response rate and a higher number of customers selected to be in the sample. The reason for this is *nonresponse bias*. Nonresponse bias is encountered if the customers who did not respond to the survey are significantly different from those who did respond. Nonresponse may be due to the inability of those conducting the survey to reach a specific customer in the sample, (e.g., because his or her telephone number has changed), or may be due to the unwillingness of that customer to participate in the survey at all, or to answer one or more questions in the survey. Because some customers contacted will answer some questions but not others, the degree of Nonresponse encountered will vary from question to question on the survey questionnaire.

Nonresponse bias is one source of the overall bias in the survey results resulting from the fact that those surveyed are not representative of those in the target group that we are seeking to characterize. Another source of such bias is use of a poorly chosen or poorly constructed master list from which we randomly select the sample of people to be surveyed. One of the best-known examples of such bias is a national poll of likely voters that was conducted by the Literary Digest in 1936, a few days before the presidential election that year. The poll showed that Alf Landon would win the election. In fact, as became clear a few days later, Franklin Roosevelt won the election by a landslide. The reason for the erroneous polling results was bias. The poll was conducted relying primarily on lists of telephone subscribers and 1936 being at the lowest point of the Great Depression, many voters could not afford phone service. It turned out that those voters who could not afford phones were much more likely to vote for Franklin Roosevelt than were those who did have phones.

While this particular case gives an unusually dramatic example of bias, any level of nonresponse (like any serious systematic errors in preparing the master list of people to be contacted) poses potentially serious problems. Furthermore, the magnitude of these problems will generally not be known because we in general do not know if and how the nonrespondents differ from those who did respond. After all, we were never able to gather any information about them in our survey that could be used to see if and how they differ.

For this reason, nonresponse should always be keep to the lowest level achievable. This is accomplished through active follow up with those customers in the sample from whom we were not at first able to get a response. Only after all reasonable follow up efforts have been made should a shortfall in the number of customers responding (compared with the desired final sample size) be made up by selecting additional customers to be part of the sample.

An adjustment factor

The values for the sampling error shown in the table presented in **Factsheet III** are approximate. One reason why they are approximate is that they do not take into account a factor that, if considered, would result in lower values. We will now provide you with an adjustment factor that you may use to account for this additional factor and, in so doing, obtain a more precise value for the sampling error:

An adjustment factor to reflect that the sample result was greater than or less than 50 percent

One significant complication associated with the calculation of sampling error is that the sampling error varies markedly with the magnitude of the sampling result obtained. By *sampling result*, we mean, for example, the percentage of customers in the sample who say they are satisfied with the product or service they received. All else being equal, the *largest* sampling error is associated with a degree of satisfaction of exactly 50 percent. Any higher or lower level of satisfaction will result in a *lower* level of sampling error. The lowest level of sampling error is associated with a level of satisfaction of 100 percent or 0 percent.

Here are the specific values of this correction factor that should be used for various specific values of the sample result:

The sample result (i.e., the percentage of customers in the sample who said they were satisfied with the product or service received)	Correction factor
99 percent	0.20
98 percent	0.28
95 percent	0.44
90 percent	0.60
80 percent	0.80
70 percent	0.92
60 percent	0.98
50 percent	1.00 (i.e., no correction)
40 percent	0.98
30 percent	0.92
20 percent	0.80
10 percent	0.60
5 percent	0.44
2 percent	0.28
1 percent	0.20

Thus, if the sample result shows that 90 percent of the customers in the sample were satisfied with the product or service they received, then the associated sampling error is obtained by multiplying 0.60 times the sampling error shown in the standard tables (including the table provided in **Factsheet III**). So if the sampling error shown in the table is ±10 percent for the sample size used, then the actual sampling error is really only ±6 percent (= ±10 percent x 0.60).

If the sample result shows that 80 percent of the customers were satisfied, and the sampling error obtained from the table was ±10 percent, the actual sampling error associated with that specific sampling error would be ±8 percent (= ±10 percent x 0.80). These are rather significant adjustments.

Since the levels of satisfaction likely to be obtained for most EPA products and services are likely to be in the range of 80 to 90 percent or more, it is highly advisable to take this adjustment factor into consideration: 1) when estimating the sampling error that will result from use of a specific sample size, and 2) when determining the actual sampling error associated with a given sample result after the sampling process has been completed and the results have been obtained.

There is a major implication of the fact that the *sampling error* varies with the *sample result*. Since the *sample result* varies from question to question asked in the survey, there is no one level of sampling error associated with the survey as a whole. Instead, there will be a different level of sampling error for each result obtained (i.e., a different sampling error for the response to each question). If the degree of satisfaction obtained from the customers sampled is close to 50 percent on one question and close to 100 percent on another, the sampling error for the second will be much lower than (possibly much less than half of) the sampling error for the first. The plus or minus figure given should therefore be different for each result reported (i.e., it should be different for each question for which the response is shown). It is common practice, however, for only one level of sampling error to be shown: this may either be 1) the largest sampling error associated with any of the results reported, or 2) the sampling error that would be obtained in the worst possible case, i.e., if the result had been a level of satisfaction of 50 percent.

In presenting the results for customer satisfaction surveys conducted at EPA, those preparing the results may either conform to this common practice or they may give question-specific sampling errors, as they prefer. The latter can be accomplished by simply presenting a plus or minus figure after each sample result shown.

For example

The question on the survey for which the result is being reported	The degree of satisfaction reported
Question 1	83 percent ± 8 percent
Question 2	91 percent ± 6 percent
Question 3	78 percent ± 9 percent
Question 4	87 percent ± 8 percent
Question 5	94 percent ± 5 percent

Precise formula for calculating the sampling error

Here is an alternative approach for 1) estimating the sampling error that will occur in a planned sampling survey or 2) calculating the actual sampling error associated with a specific result in a survey that has already been completed. Instead of obtaining values of the sampling error from a table (like that included in **Factsheet III**) and then applying the adjustment factor presented above in the previous section (and if necessary also applying the second adjustment factor presented in the next section below), simply calculate the sampling error directly from the precise formula.

Here is the precise formula for calculating the sampling error:

The sampling error = (Z) times the square root of

$$\frac{p \times q}{n} \times \frac{N - n}{N - 1}$$

where p = the sample result (i.e., the percentage of customers who were satisfied with the product or service they received)

q = 1- p

n = the sample size

N = the total number of customers served

Z = is a constant coefficient (i.e., multiplier) associated with the confidence level that is being used. (This must be looked up in a table in a statistics book). Each of these constants is known as *the Z-score* for that confidence level.

Here are the coefficients (i.e., Z-scores) for the three confidence levels that have been suggested for use in these Guidelines:

For the 95 percent confidence level, Z = 1.960

For the 90 percent confidence level, Z = 1.645

For the 80 percent confidence level, Z = 1.282

The precise formula presented above is based on the simple random sampling (SRS) procedure, in which the sample is drawn using the sampling *without replacement* procedure. Simple random sampling is the most commonly used sampling procedure and is the procedure recommended in these Guidelines for use in customer satisfaction surveys conducted by EPA. It is the procedure reflected in the table presented in **Factsheet III**, in the sample selection procedure presented in **Factsheet III**, and is assumed in all other discussion of sample selection in the Guidelines, in **Factsheets III** and **IV**, and in all but the last section of **Factsheet V**. For further discussion of this topic, see the last section of **Factsheet V**.

The above formula will give the exact size of the sampling error for any combination of number of customers served, sample size, sample result and confidence level. Using this formula automatically takes into account and reflects the differences in the magnitude of the sampling error due to differences in the sample result (which was discussed in the previous section of this Factsheet) and also automatically includes the finite population correction factor, which is discussed in the next section of this Factsheet.

Another adjustment factor

The table presented in **Factsheet III** reflects both the sample size (n) and the total number of customers served (N) in determining the sampling error for any given confidence level selected. You may come across reference books on statistics or sampling procedures that present tables in which the sampling errors are shown for various different sample sizes but in which no consideration is given to the total number of customers served. In such cases, to get the actual sampling error, it is necessary to multiply the sampling error given in such tables by an additional factor known as the finite population correction factor.

The finite population correction factor

The standard sample survey techniques were developed for use in situations where there is a very large number of people in the pool of those from whom the sample is to be drawn. This is true, for example, of surveys of national public opinion. The standard formulas and tables used are therefore predicated on sampling from a very large pool, one that is, in practical terms, "as good as infinite" and is treated by statisticians as though it were infinite.

When the number of people in the target group from which the sample is to be drawn is much smaller, a correction factor (one known as the *finite population correction factor*) should be used to correct for this circumstance. The finite population correction factor can always be used (its use never gives an incorrect result), but it is generally not needed if the sample size chosen is less than about one-tenth (10 percent) the size of the target group from which the sample is to be selected.

If the sample size of customers to be contacted is greater than 10 percent of the total number of customers served, then the finite population correction factor should be used in calculating the size of the sampling error. These circumstances will apply in a large percentage of customer satisfaction surveys conducted by EPA. Luckily, use of the finite population correction factor always results in a lower sampling error than would have been obtained without its use. Therefore, if you are satisfied with the magnitude of the sampling error calculated for a specific survey without using the finite population correction factor, then there is no *need* to use it for that survey, unless you want to know exactly how much lower the true sampling error is.

The finite population correction factor (FPCF) can be calculated using the following formula:

$$\text{FPCF} = \text{the square root of } \frac{(N-n)}{(N-1)}$$

where: N = the total number of customers served

n = the number of customers in the sample (i.e., the sample size)

The corrected sampling error is obtained by multiplying the finite population correction factor and the sampling error obtained from a standard table that considered only sample size and confidence level (and did not consider the size of *the target group* [i.e., *the population*] from which the sample is to be drawn). Because of the way the finite population correction factor is calculated, the adjustment factor varies with the sample size as a fraction of the size of the target population from which the sample is to be drawn. See the following table:

Sample size as a fraction (percentage) of the size of the target population =n/N	Approximate value of the Finite population correction factor
10 percent	0.95
20 percent	0.89
40 percent	0.77
50 percent	0.71
60 percent	0.63
70 percent	0.55
75 percent	0.50

As can be seen from the above table, if the *sample size* is approximately 10 percent of the size of the *target group* (i.e., the total number of customers served, from which the sample is to be drawn), then the correction factor is approximately 0.95—thus, when using a sample size that is 10 percent of the total number of customers, the sampling error will be reduced to 95 percent of what it otherwise would have been (e.g., the sampling error would be reduced from ±10 percent to ±9.5 percent).

If the sample size is 20 percent of the size of the target group, then the correction factor is approximately 0.89—thus, when using a sample size that is 20 percent of the total number of customers served, the sampling error will be reduced to 89 percent of what it otherwise would have been (e.g., the sampling error would be reduced from ±10 percent to ±8.9 percent).

If the sample size is 50 percent of the size of the target group, then the adjustment factor will be approximately 0.71—thus, when using a sample size that is 50 percent of the total number of customers served, the sampling error will be reduced to 71 percent of what it otherwise would have been (e.g., the sampling error would be reduced from ±10 percent to ±7.1 percent).

There is a general rule of thumb used by many statisticians: The finite population correction factor should be applied whenever the sample size is 10 percent or more of the size of the target group from which the sample is to be drawn.

Note, however, that use of the finite population correction factor always gives a more accurate value for the sampling error than would be obtained by not using it. You should therefore never be reluctant to use it. It is just that there are certain circumstances (i.e., when the sample size obtained from a standard table is less than 10 percent of the size of the target population) when it is possible to disregard it (i.e., not apply it) without there being an undue adverse effect on the estimated size of the sampling error.

Note also that the last element in *the precise formula for calculating sampling error* given in the previous section of this Factsheet is the finite population correction factor. Use of that precise formula therefore will ensure that the finite population correction factor is automatically taken into account when determining the size of the sampling error.

One final technical note: The reason why the second column in the table presented above in this section is labeled the *approximate value* of the finite population correction factor rather than the *exact value* is that the following approximation was used to calculate the value shown in the second column that corresponds to each value in the first column:

Instead of using the precise formula for the finite population correction factor:

$$\text{FPCF} = \text{the square root of } \frac{N - n}{N - 1}$$

The following approximate formula was used:

$$\text{FPCF} = \text{(approx)} = \text{the square root of } \frac{N - n}{N}$$

For most values of N (the size of the target population), the difference between the true value obtained from the precise formula and the approximate value obtained from the approximate formula is very small.

A trial-and-error procedure and an approximate formula for determining sample size

A trial-and-error procedure

The *precise formula* given above can be used directly to determine the level of *sampling error* for any combination of confidence level, number of customers served, and sample size. That same formula can also be used to determine *sample size* when the desired confidence level, the desired maximum level of sampling error and the number of customers served are known. It just cannot be solved directly to obtain sample size in such situations. This is so because sample size (n) appears two different places in the equation, and the form of the equation is such that it is not possible to rearrange the equation so that it can be used to solve directly for sample size. Instead, you must use the precise formula as shown to determine the needed sample size. You can do so as follows:

1) Begin by guessing what the needed value of the sample size is. *(Any* guess will do as a starting point, although the closer to the true value your guess turns out to be, the sooner you will be finished.)

2) Use that value of the sampling size (i.e., your initial guess) to solve the precise formula equation for sampling error.

3) a) If the value of sampling error you obtain from the formula is *less than* the maximum level of sampling error you are willing to accept, then you should *decrease* your guess as to the corresponding value of the sample size and solve the equation again.

3) b) If the value of sampling error you obtain from the formula is *greater than* the maximum level of sampling error you are willing to accept, then you should *increase* your guess as to corresponding value of the sample size and solve the equation again.

4) Continue steps 3) a) and 3) b) above until you arrive at the appropriate sample size. That will be the largest value of the sample size that, when plugged into the precise formula along with the number of customers of served and the Z-score corresponding to the confidence level you have selected, gives you the highest possible value of sampling error, i.e., one that equals (or is slightly less than) the level of sampling error you have set as the maximum you are willing to accept.

The approximate formula for determining sample size

The trial-and-error approach described above will always give you the best possible value for sample size. However, the process for arriving at that value can be rather tedious. For this reason, an *approximate formula* has been developed that will give you a reasonable value for the sampling error that is close to the one you would get from the above trial-and-error procedure. This approximate formula needs only to be solved once—no repeated calculations are needed. The resulting value will, however, in most cases, be a larger sample size than what you would get from the trial-and-error procedure. That is, the approximate formula will give you a *larger* sample size than that actually needed to achieve your target level of sampling error.

Here is the approximate formula:

$$n = \frac{N \times Z^2}{[4 \times (N - 1) \times E^2] + [Z^2]}$$

Where

n = sample size

N = number of customers served (from which the sample is to be drawn)

E = the maximum acceptable level of sampling error, expressed as a decimal fraction (e.g., 5 percent = 0.05)

Z = the Z-score corresponding to the confidence level selected (this can be obtained from most standard statistics references, including most basic statistics textbooks). The Z-scores for the 80 percent, 90 percent and 95 percent confidence levels are given above in this Factsheet in conjunction with the *precise formula*.

A combined approach

You can, if you wish, make use of *both* the approximate formula *and* the trial-and-error approach given above. Begin by using the approximate formula to get an approximate value for the sample size. Then use this approximate value as your first guess for sample size in the trial-and-error approach, and proceed from there with the trial-and-error approach as described above.

This *combined approach* will allow you to come up with the lowest possible sample size with the least amount of effort.

WHY IS SO MUCH ATTENTION GIVEN TO SAMPLE SIZE?

Much of **Factsheet III** and all of this Factsheet have been devoted to considerations related to sample size. Why, you might ask, do people spend so much time worrying about sample size?

The reason is that if a larger sample size is used than is really needed, you will have incurred a greater cost in conducting the survey and you will have imposed a greater response burden on your customers than was needed.

- The extra, unneeded costs alone can be quite considerable. For each extra customer in the sample, additional time has to be spent: conducting the telephone interview (we are here assuming for clarity that a telephone survey was conducted), following up with those who did not answer when originally called, following up with those who did not initially agree to participate, and so on. It also means more data to be recorded and analyzed.

- The extra burden on your customers in terms of time spent responding can also be quite large when the total time spent by all customers surveyed, taken together, is considered.

If the sample size used turns out to be *greater* than was needed, then the extra cost incurred and the extra burden imposed were wasted.

On the other hand, if too *small* a sample size is used, then you may end up with so much uncertainty about the true degree of satisfaction of your customers (because the sampling error was so large) that you do not learn much from the survey. You were uncertain about their degree of satisfaction before (that's why you decided to conduct the survey) and you may now find that your level of uncertainty afterward is not much reduced. In this case, the whole cost of conducting the survey may prove to have been wasted.

Keep in mind that any wasted time and dollars associated with conducting surveys using sample sizes that were too large or too small are time and dollars that could otherwise have been used to improve the products or services you provide to your customers. So the effort you spend helping to ensure that you use the most appropriate sample size will help maximize the time and dollars you will have left for improving customer service in the ways your survey has shown to be needed.

In conclusion, sample size is very important—you want it to be large enough to give meaningful and useful results, but not so large that you incur unneeded extra expense or unduly burden your customers with the time needed to respond. What this adds up to is that *when you conduct a customer satisfaction survey, you should use the smallest possible sample size that will give you results of sufficient precision to be meaningful and useful to you*. And greater precision—which is another way of saying a lower level of uncertainty—comes from a smaller level of sampling error. The smaller the sampling error the greater the precision.

So you want to *choose the smallest possible sample size that will give you a level of sampling error that you can live with*. By that we mean that the results will be precise enough to give you the degree of certainty you need about 1) what the true current level of satisfaction of your customers is, and 2) how their degree of satisfaction has been changing over time—as a result of your continuing efforts to improve your products and services.