A Practical Guide to
Sampling

This guide is brought to you by the Statistical and Technical Team, who form part of the VFM Development Team. They are responsible for advice and guidance on quantative, analytical and technical issues.

For further information about the matters raised in this guide, please contact:

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This guide is the latest in a series on sampling. It has been produced in response to a large number of requests received by the Statistical and Technical Team relating to sampling matters. The guide aims to consolidate the information required for you to complete the survey process from design to reporting. It provides this advice in an informal and practical way which should also help you understand the work of your consultants, and ask informed questions of the audited body.

This guide replaces the previous guidance
"Use of Sampling - VFM Studies" published in 1992.

Other guides related to this matter:

Taking a Survey (1999)
Presenting Data in Reports (1998)
Collecting, Analysis and Presenting Data (1996)

Contents

Why sample?

VFM reports require reliable forms of evidence from which to draw robust conclusions. It is usually not cost effective or practicable to collect and examine all the data that might be available. Instead it is often necessary to draw a sample of information from the whole population to enable the detailed examination required to take place. Samples can be drawn for several reasons: for example to draw inferences across the entire population; or to draw illustrative examples of certain types of behavior.

> *"Sampling provides a means of gaining information about the population without the need to examine the population in its entirety."*

Caveats

Sampling can provide a valid, defensible methodology but it is important to match the type of sample needed to the type of analysis required.

The auditor should also take care to check the quality of the information from which the sample is to be drawn. If the quality is poor, sampling may not be justified.

Do we really use them?

Of the 31 reports published by the end of July of the 1999-2000 session, there are 7 examples of using judgmental sampling for illustrative case studies and 24 examples of sampling to draw inferences across the population, of which 19 were the basis for surveys.

Can they provide strong evidence?

In the Health area, four studies made extensive use of sampling and survey techniques to form the majority of the evidence which identified the potential for a one off saving of up to £400 million and possible annual savings of £150 million.

Recent examples

Excerpt from **Highways Agency: Getting best value from the disposal of property**
HC58 Session 1999-00

Excerpt from **Charitable funds associated with NHS Bodies**
HC516 Session 1999-00

Sample design

Sample design covers the method of selection, the sample structure and plans for analysing and interpreting the results. Sample designs can vary from simple to complex and depend on the type of information required and the way the sample is selected. The design will impact upon the size of the sample and the way in which analysis is carried out. In simple terms the tighter the required precision and the more complex the design, the larger the sample size.

The design may make use of the characteristics of the population, but it does not have to be proportionally representative. It may be necessary to draw a larger sample than would be expected from some parts of the population; for example, to select more from a minority grouping to ensure that we get sufficient data for analysis on such groups.

Many designs are built around random selection. This permits justifiable inference from the sample to the population, at quantified levels of precision. Given due regard to other aspects of design, random selection guards against bias in a way that selecting by judgement or convenience cannot. However, a random selection may not always be either possible or what is required, in these cases care must be taken to match clear audit objectives to the sample design to prevent introducing unintended bias.

If you are sampling for the purposes of a survey then you should also be aware of the Taking a Survey guidance issued in 1999.
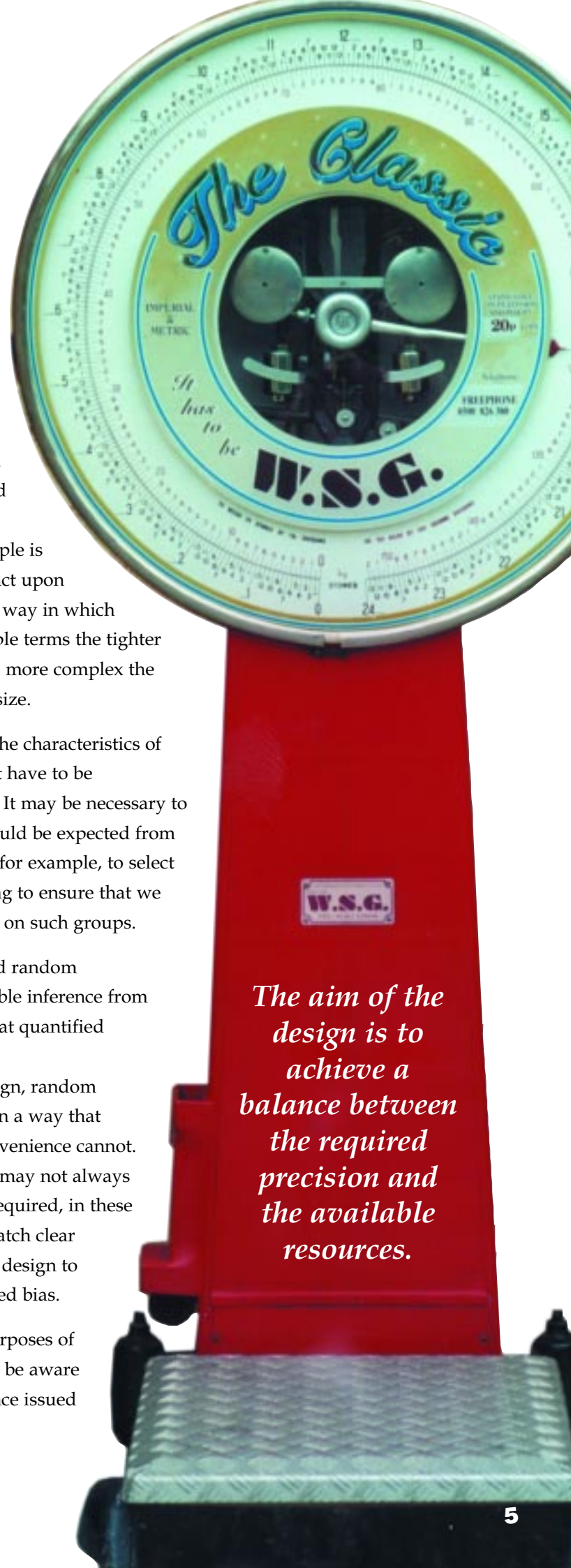
The aim of the design is to achieve a balance between the required precision and the available resources.

Defining the population

The first step in good sample design is to ensure that the specification of the target population is as clear and complete as possible to ensure that all elements within the population are represented. The target population is sampled using a sampling frame. Often the units in the population can be identified by existing information; for example, pay-rolls, company lists, government registers etc. A sampling frame could also be geographical; for example postcodes have become a well-used means of selecting a sample. Try to obtain the sample frame in the most automated way possible for ease of sampling; for example a database spreadsheet file.

All sampling frames will have some defects, despite assurances you may receive from the holder of the data. Usually there are ways to deal with this, for example amending the list, selecting a larger sample and eliminating ineligible items, combining information from varying sources, or using estimated or proxy data. If you are having difficulties identifying a suitable sampling frame come and discuss this with the Statistical and Technical Team.

A sampling frame is a list of all units in your population.

Data Protection Act issues

Often a government database or computer file can be used to identify the population and select a sample. You will need to ensure that this data is accurate, reliable, can be accessed, and that you have permission to draw a sample. The Data Protection Act requires us to obtain agreement to use data which also hold individuals' details. Many databases cannot be accessed because of this or other security reasons. However, it may be possible to extract selected information which is sufficient for the purposes of the study; for example using summarised data so that the individual cannot be identified. If you are in any doubt as to your position in this matter please refer to the Policy Unit.

Contracting out

If you use an outside contractor to carry out the sample they will normally put forward their proposed sample design. The design will often depend on whether you can obtain a suitable sampling frame from which the sample can be selected. If you cannot provide a database the contractor may be able to suggest a sampling frame to use. The contractor may well use a more complex sampling design than simple random sampling and it is important to check that what they have done is reasonable.

The Statistical and Technical Team hold a database of contractors previously used by the Office, or you may wish to search for specific contractors who specialise in certain fields. A useful starting point for this is the British Market Research Association's selectline web page at:

www.bmra.org.uk/selectline

The Team offer their service as a reference partner when drafting the tender for the work, evaluating the bids, or assessing the quality of the work.

Sample size

For any sample design deciding upon the appropriate **sample size** will depend on **five key factors** and these are shown below. It is important to consider these factors together to achieve the right balance and ensure that the sample objectives are met.

No estimate taken from a sample is expected to be exact, inference to the population will have an attached **margin of error**. The better the design, the less the margin of error and the tighter the precision but in most cases the larger the sample size.

The **amount of variability** in the population i.e. the range of values or opinions, will also affect accuracy and therefore the size of sample required when estimating a value. The more variability the less accurate the estimate and the larger the sample size required.

The **confidence level** is the likelihood that the results obtained from the sample lie within the associated precision. The higher the confidence level, that is the more certain you wish to be that the results are not atypical, the larger the sample size.

We normally use 95 per cent confidence to provide forceful conclusions, however, if you are only seeking an indication of likely population value a lower level such as 90 per cent is acceptable.

Population size does not normally affect sample size. In fact the larger the population size the lower the proportion of that population that needs to be sampled to be representative.

It is only when the proposed sample size is more than 5 per cent of the population that the population size becomes part of the formulae to calculate the sample size. The effect is to slightly reduce the required sample size. If you are in this position please refer to the Team.

If seeking to sample for attributes as opposed to the calculation of an average value, the **proportion** of the population displaying the attribute you are seeking to identify is the final factor for consideration. This can be estimated from the information that is known about the population, for example the proportion of hospitals who consider long waiting lists to be a problem.

Confidence level - how certain you want to be that the population figure is within the sample estimate and its associared precision.

Variability in the population - the standard deviation is the most usual measure and often needs to be estimated.

Margin of error or precision - a measure of the possible difference between the sample estimate and the actual population value.

The population proportion - the proportion of items in the population displaying the attributes that you are seeking.

Population size - total number of items in the population - only important if the sample size is greater than 5% of the population in which case the sample size reduces.

Sample size

Our samples tend to be one-off exercises carried out with limited resources. Sometimes that means that the results can only be representative of the population in broad terms and breakdowns into smaller sub-groups may not always be meaningful.

Practical limitations will often be the chief determinant of the sample size. A sample size of between 50 and 100 should ensure that the results are sufficiently reliable for the majority of purposes, although there will be occasions when a sample as small as 30 may be sufficient. Samples smaller than this fall into the category of case studies where statistical inferences to the population cannot be made, however, they can still form part of a valid and defensible methodology.

The decisions surrounding the sample design and methodology should be discussed with all the parties involved to ensure their agreement to the process and avoid problems during clearance.

Figure 1 (opposite) contains a sample size lookup table for samples selected using simple random sampling, the most frequently used method in the Office. If sampling for attributes then read off the sample size for the population proportion and precision required to give your sample size. If there is more than the one outcome, for example A, B, C or D and the proportions were say 20 per cent, 10 per cent, 30 per cent and 40 per cent then the necessary sample size would be the one for the highest i.e. 40 per cent at the required confidence level and precision. If you are unsure of the population proportion then a 50 per cent proportion provides the most conservative sample size estimate and can also be used to provide an approximate sample size when determining a numeric estimate.

The table shows the sample size needed to achieve the required precision depending on the population proportion using simple random sampling. For example, for 5 per cent precision with a population proportion of 70 per cent a sample size of 323 is required at the 95 per cent confidence level.

Should you wish to calculate an exact simple random sample size for your own circumstances the formulae to do this are at appendix 1.

However, should you elect to carry out a sampling methodology other than that based on a simple random sample please contact the Statistical and Technical Team who will be able to help you calculate an appropriate sample size.

As a general rule, a statistical sample should contain 50 to 100 cases for each sample or sub-group to be analysed.

Figure 1: Sample size lookup table

Population Proportion	Precision (at the 95 per cent confidence level)							
	±12%	±10%	±8%	±5%	±4%	±3%	±2%	±1%
50%	66	96	150	384	600	1,067	2,401	9,604
45% or 55%	66	95	148	380	594	1,056	2,376	9,507
40% or 60%	64	92	144	369	576	1,024	2,305	9,220
35% or 65 %	60	87	136	349	546	971	2,184	8,739
30% or 70%	56	81	126	323	504	896	2,017	8,067
25% or 75%	50	72	112	288	450	800	1,800	7,203
20% or 80%	*42*	61	96	246	384	683	1,536	6,147
15% or 85%	*34*	*48*	76	195	306	544	1,224	4,898
10% or 90%	*24*	*35*	54	138	216	384	864	3,457
5% or 95%	*12*	*18*	*28*	72	114	202	456	1,824

If you are expecting non-response or a difficulty in locating your sample selections then it is prudent to over sample to ensure that the sample size achieved provides the required level of precision.

The figures in **bold and italics** denote sample sizes of less than the recommended minimum.

Weighting a sample

If a normal sample would be insufficient to reflect the population characteristics then it may be necessary to look at ways in which this can be improved. One way of doing this is to weight the sample. If, for example, you are looking to sample three regional offices and they have varying workloads, you may want the sample to reflect the workloads at each location. Figure 2 shows an example where a total sample size of 384 (50 per cent proportion for a 5 per cent precision at 95 per cent confidence) is required.

A simple random sample of 384 cases might give the breakdown shown in figure 2. Whilst this does not reflect the population characteristics it may still be perfectly valid if you are interested in the locations as well as the workload. In the last column the sample has been weighted to reflect the population characteristics. This approach would be more suitable if you are interested more in the actual cases than the locations. The method of calculating the results for a weighted sample are different than for the simple random sample.

Figure 2: Example of a weighted sample

Location	Population workload	% of population workload	A simple random sample of the total workload	The effect on sample size at each location when the sample is weighted
North	50,000	13%	128	51
South East	250,000	67%	153	256
South West	75,000	20%	103	77
TOTAL	**375,000**	**100%**	**384**	**384**

A weighted sample more accurately reflects the workloads at the regional locations.

Post-weighting the sample

Should this weighting be required, but had not taken place at the sample selection stage then it is possible to weight the sample in the results phase. This is done by applying the population proportions to the results of the unweighted sample to produce an adjusted result. In this case an unweighted result of 37 per cent becomes a weighted proportion of 49 per cent.

Figure 3: Example of a post-weighted sample

Location	Simple Random Sample (A)	Displaying Required Attribute (B)	Unweighted Proportion (B/A)	Location Percentage (C)	Weighted Proportion (B/A)xC
North	128	21	16%	13%	2%
South East	153	98	64%	67%	43%
South West	103	23	22%	20%	4%
TOTAL	**384**	**142**	**37%**	**--**	**49%**

A weighted sample more accurately reflects the workloads at the regional locations.

This example shows that the most important thing is to gather sufficient information to enable you to make judgements about the population that you are sampling, whether it be that the information comes to light prior to selecting the sample or as a result of selecting the sample. Always be aware of what the results are saying and how true a reflection of the population they are.

Ensure that the sample reflects the population characteristics whether before or after the sample selection.

Sampling methods

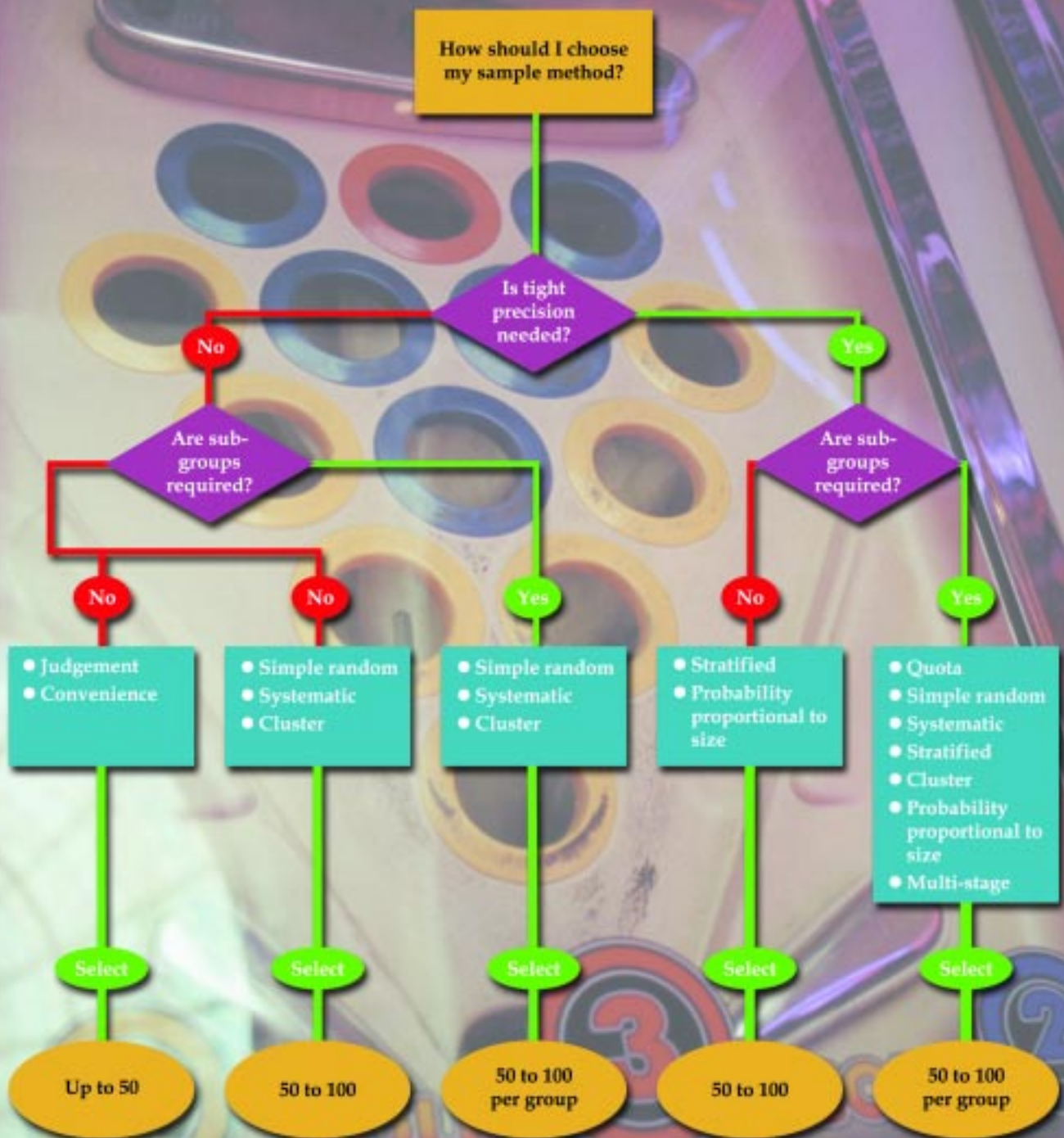## Methods, their use and limitations

There are many different ways in which a sample can be selected. Nine of the most common methods are illustrated below.

Method	Definition	Uses	Limitations
Cluster sampling	Units in the population can often be found in geographical groups or clusters eg. schools, households etc. A random sample of clusters is taken, then all units within those clusters are examined.	• Quicker, easier and cheaper than other forms of random sampling. • Does not require complete population information. • Useful for face-to-face interviews. • Works best when each cluster can be regarded as a microcosm of the population.	• Larger sampling error than other forms of random sampling. • If clusters are not small it can become expensive. • A larger sample size may be needed to compensate for greater sampling error.
Convenience sampling	Using those who are willing to volunteer, or cases which are presented to you as a sample.	• Readily available. • The larger the group, the more information is gathered.	• Sample results cannot be extrapolated to give population results. • May be prone to volunteer bias.
Judgement sampling	Based on deliberate choice and excludes any random process.	• Normal application is for small samples from a population that is well understood and there is a clear method for picking the sample. • Is used to provide illustrative examples or case studies.	• It is prone to bias. • The sample is small and can lead to credibility problems. • Sample results cannot be extrapolated to give population results.

Select a method that fulfils your objectives and matches the information and resources available.

Method	Definition	Uses	Limitations
Multi-stage sampling	The sample is drawn in two or more stages (eg. a selection of offices at the first stage and a selection of claimants at the second stage).	• Usually the most efficient and practical way to carry out large surveys of the public.	• Complex calculations of the estimates and associated precision.
Probability proportional to size	Samples are drawn in proportion to their size giving a higher chance of selection to the larger items (eg. the more claimants at an office the higher the office's chance of slection).	• Where you want each element (eg. claimants at an office) to have a equal chance of selection rather than each sampling unit (eg. offices).	• Can be expensive to get the information to draw the sample. • Only appropriate if you are interested in the elements.
Quota sampling	The aim is to obtain a sample that is representative of the population. The population is stratified by important variables and the required quota is obtained from each stratum.	• It is a quick way of obtaining a sample. • It can be fairly cheap. • If there is no sampling frame it may be the only way forward. • Additional information may improve the credibility of the results.	• Not random so stronger possibility of bias. • Good knowledge of population characteristics is essential. • Estimates of the sampling error and confidence limits probably can't be calculated.
Simple random sampling	Ensures every member of the population has an equal chance of selection.	• Produces defensible estimates of the population and sampling error. • Simple sample design and interpretation.	• Need complete and accurate population listing. • May not be practicable if a country-wide sample would involve lots of audit visits.
Stratified sampling	The population is sub-divided into homogenous groups, for example regions, size or type of establishment. The strata can have equal sizes or you may wish a higher proportion in certain strata.	• Ensures units from each main group are included and may therefore be more reliably representative. • Should reduce the error due to sampling.	• Selecting the sample is more complex and requires good population information. • The estimates involve complex calculations.
Systematic sampling	After randomly selecting a starting point in the population between 1 and n, every n^{th} unit is selected, where n equals the population size divided by the sample size.	• Easier to extract the sample than simple random. • Ensures cases are spread across the population.	• Can be costly and time-consuming if the sample is not conveniently located. • Can't be used where there is periodicity in the population.

Selecting an appropriate method

As you can see there are many methods available for use with varying degrees of complexity. Certain methods suit circumstances better than others and the following diagram is designed to help you select an appropriate method.

How should I choose my sample method?

Is tight precision needed?

No → **Are sub-groups required?**

Yes → **Are sub-groups required?**

Are sub-groups required? (left)
- No → • Judgement • Convenience
- No → • Simple random • Systematic • Cluster
- Yes → • Simple random • Systematic • Cluster

Are sub-groups required? (right)
- No → • Stratified • Probability proportional to size
- Yes → • Quota • Simple random • Systematic • Stratified • Cluster • Probability proportional to size • Multi-stage

Select → Up to 50

Select → 50 to 100

Select → 50 to 100 per group

Select → 50 to 100

Select → 50 to 100 per group

Extracting the sample

For simple random sampling it is possible to use either Excel or SPSS to select the sample for you. An illustration of how to extract a sample using both of these methods is shown below:
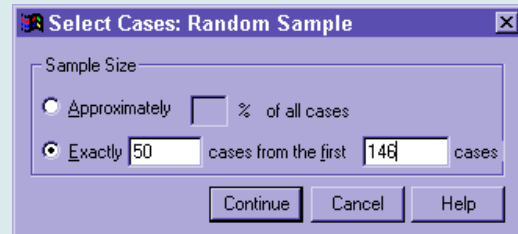
In Excel

In Excel use "Tools > Data Analysis > Sampling" to bring up the dialogue box shown. Enter the population value range as the input range and the number of samples. You can simply put a single cell at the start of an adjacent blank column for the output range.

The sample items will then be extracted and placed in the output range.

In SPSS

In SPSS use "Data > Select Cases" then use the option "Random" and complete the dialogue box as above.

This will create a filter column which when selected will only allow any analysis or printing functions etc. to be carried out on the sample data rather than the population.

It is also possible to use IDEA to extract the sample, contact the Statistical and Technical Team if you want help to do this. If the population is not held electronically then an interval sample from a random starting point could be used as an alternative.

If you are not intending to use a simple random sample then the Statistical and Analytical Team can advise on how to extract the sample.

Interpreting & reporting the results

Interpreting the results

The choice of sample design and how well it mimics the population will impact on the results. The closer the sample design to the population characteristics the more precise the estimate from the sample. It is therefore important to match the calculation of the results from the sample to the design of the sample.

The following shows an example of a population of 146 properties priced between £176,000 and £17,750 with an average value of £35,760. The population distribution is illustrated and shows that the majority of the population is priced below £50,000. Two samples of 50 properties were selected, one using simple random sampling and the other stratifying the population into above and below £50,000.

The simple random sample gave an average price of £35,630 ranging between £30,480 and £40,780 i.e. at the 95 per cent confidence level the average property value is £35,630 plus or minus 14 per cent. The stratified sample gave an average of £36,260 ranging between £34,370 and £38,150 i.e. at the 95 per cent confidence level the average property value is £36,260 plus or minus 5 per cent. In this case, the stratified sample provides a more precise estimate of the population average.

To obtain the sample estimate for a simple random sample you can use a package such as Excel or SPSS which will return not only the average but also the standard deviation, and the precision at the 95 per cent confidence level.
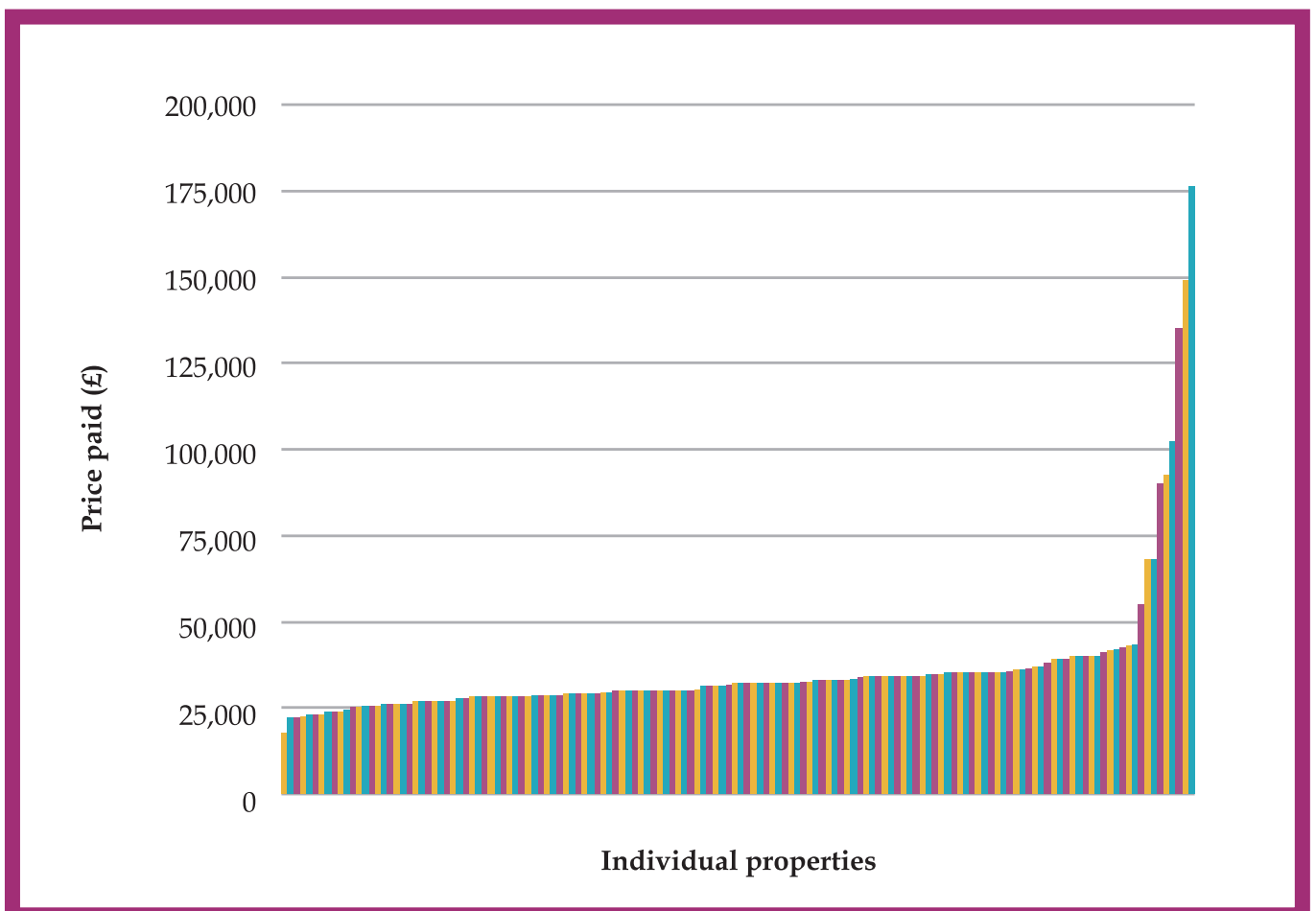
In Excel

In Excel use "Tools > Data Analysis > Descriptive Statistics" to bring up this dialogue box. Put the sample values as the input range.
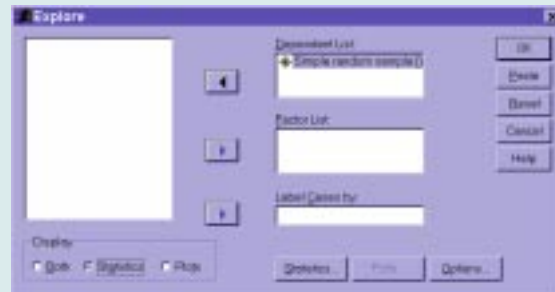

The output produced is shown above and provides all the required information.

In SPSS

In SPSS use "Analyze > Descriptive Statistics > Explore" to bring up this dialogue box. Select the required variable.

The output produced is shown above and provides all the required information.

For attribute sampling the results are often quoted as "70 per cent agreed that cleanliness would reduce infection". If the sample size was 250 then what would be the precision of the answer. You could use the table at Figure 1 to provide an estimate, looking along the 70 per cent proportion row you will find that a sample size of 250 lies between 5 and 8 per cent precision. The accurate result is 6 per cent precision.

The formulae used to calculate the results in this section are given in appendix 1.

If you are using a sample other than simple random then seek advice from the Statistical and Technical Team when it comes to calculating the results.

Reporting the results

When reporting the results of a sample it is important to cover several key facts:

- the sample size;

- the sample selection methodology;

- the estimates resulting from the sample, and

- the precision and confidence intervals for the estimates.

Methodology

The survey was conducted during July and August 1999, with a closing date for returns, after several 'chases', of the end of September. A questionnaire was sent, addressed to the named Principals of a sample of 138 English Further Education Colleges. The questionnaire was sent by post from the National Audit Office, together with a covering letter explaining the objectives of the survey, giving assurances on confidentiality, and explaining how the results would be used.

The sample is a random selection (within category) of 429 FE colleges in England. After chasing up non-responders, and allowing for the fact that two colleges subsequently ceased to exist as separate entities, a total of 136 completed questionnaires were achieved in time for analysis: a 100 per cent response rate. Responses were entered and analysed on an anonymised basis by Independent Data Analysis Ltd. to produce the aggregated tabulated results and grouped listings of verbatim responses to open questions. In statistical terms, the sample provided 67 per cent confidence limits of plus or minus three percentage points at the 50 per cent level, on average.

Excerpt from **Managing Finances in English Further Education Colleges**
HC454 Session 1999-00

Survey methodology

2   The format of the survey and the questions were agreed with the Authority and the Appeals Panel. For reasons of client confidentiality, the survey was sent out via the Authority in July 1999 to the 5,970 applicants whose applications were resolved by the Authority or Panel in May 1999. This month, which was not unusual in terms of case mix, was selected since applicants' responses would be fresh. Questionnaires were returned by respondents in a confidential format to an independent firm *Independent Data Analysis Limited*, who input details from the questionnaires onto a database, which we then analysed.

Response rate

3   Responses were received from 1,407, or 24 per cent, of the 5,970 applicants, a slightly higher response rate than had been anticipated. It gives a precision of +/- 4 per cent to the findings from the cases which involved working at first decision, +/- 6 per cent to findings from cases which went to review, and +/- 10 per cent to findings from cases which went to appeal.

Excerpt from **Compensating the Victims of Violent Crime**
HC454 Session 1999-00
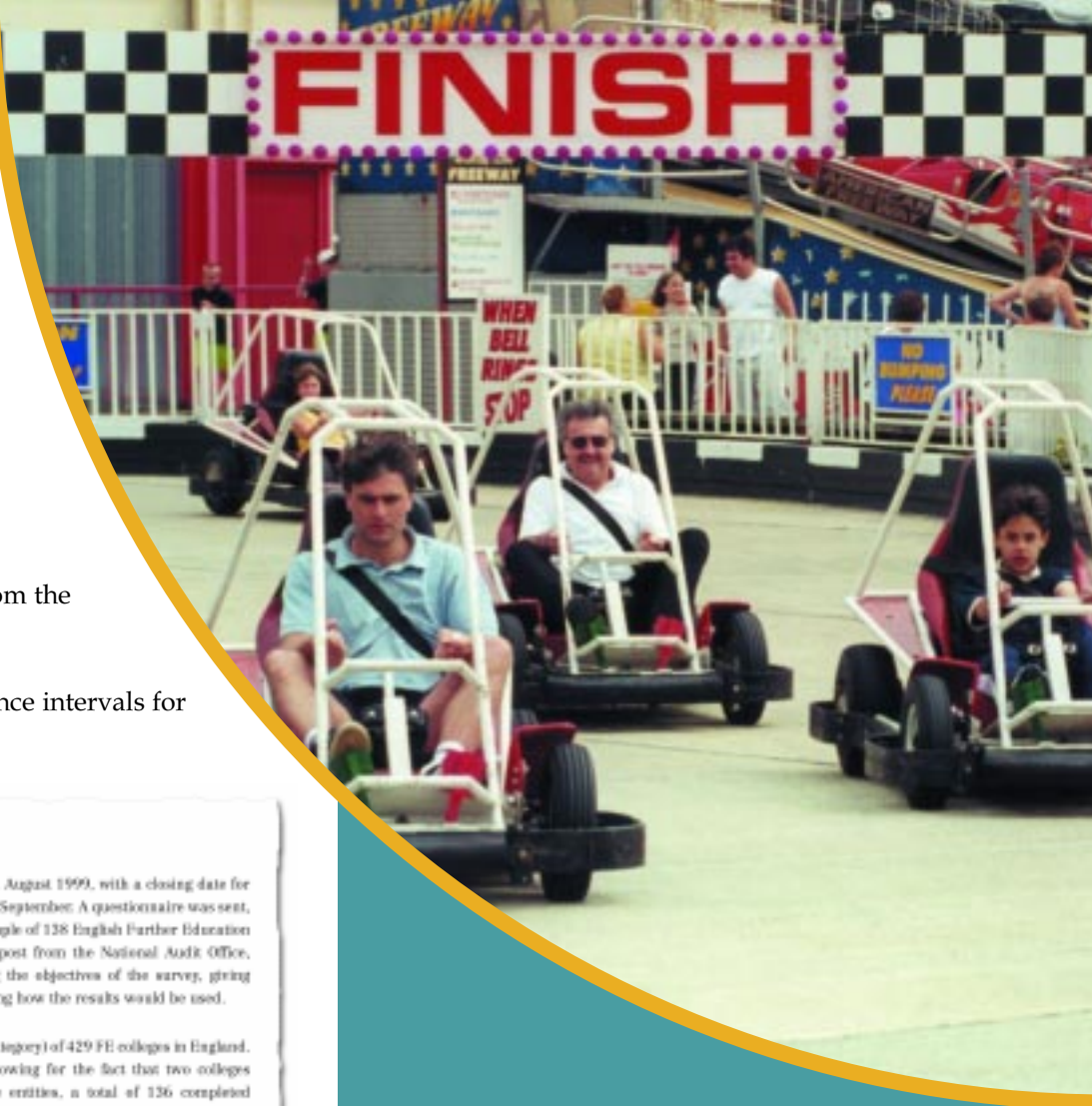
For advice on graphical presentation of the data see Presenting Data in Reports (1998) or contact the Statistical and Technical Team.

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Confidence *level*	The certainty with which the estimate lies within the margin of error.
Margin of error	A measure of the difference *between* the estimate from the sample and the population value.
Population	The number of items from which to draw your sample.
Population proportion	The proportion of items within the population which exhibit the characteristics you are seeking to examine, this is only required when sampling for attributes.
Precision	A measurment of the accuracy of the sample estimate compared to the population value.
Sample	A selection of items from which you may estimate a feature of the population.
Sample size	The number of items in the sample.
Standard deviation	A measure of the variability in the population values, this is only required when sampling for values.

Appendix 1

Relevant formulae for simple random sampling

Sampling for proportions

Sample size

$$n = \frac{Z^2(p)(1-p)}{E^2}$$

where Z is the z score associated with the confidence level required, E is the required precision, and p is the occurrence rate within the population.

Estimate of proportions

$$p = \frac{\sum_{i=1}^{n} y_i}{n}$$

where $y_i = 0 \text{ or } 1$, so that the estimate becomes a count of all the relevant cases divided by the number of cases in the sample.

Precision

$$E = \sqrt{\frac{Z^2(p)(1-p)}{n}}$$

Z score values

Confidence level	Z score value
80%	1.28
85%	1.44
90%	1.65
95%	1.96
99%	2.58

Sampling for values

Sample size

If the sample size, n, is at least 5% of the population size, N, then the calculation becomes:

$$n = \frac{Z^2\sigma^2}{E^2}$$

Adjusted sample size

$$n = \frac{Z^2 N\sigma^2}{NE^2 + Z^2\sigma^2}$$

where σ is an estimate of the standard deviation.

Estimate of the average

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

where y_i are the individual values from the sample.

Precision

$$E = \sqrt{\frac{Z^2 \frac{\sum_{i=1}^{n}(yi - \bar{y})^2}{n-1}}{n}}$$