Guidelines for Quality Assurance in Travel and Activity Surveys

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ABSTRACT

ISO9001 Quality Procedures for Travel & Activity Surveys

Significant advances have been made in the conduct of travel and activity surveys over the past twenty years. Over these same twenty years, the concepts of Total Quality Management have made major inroads into Western management practices. A by-product of this concentration on quality practices has been the development and promulgation of a range of quality "standards", through a variety of national and international organizations, especially the International Organization for Standardisation. (ISO) quality standards. The purpose of this paper is to apply the concepts of ISO Quality Standards to the design and administration of travel and activity surveys. While the application of the ISO9001 principles is not straightforward in all situations, it is concluded that ISO9001 provides a useful framework for the development of quality standards for travel and activity surveys.

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INTRODUCTION

In the last twenty years, an increased requirement for credible policy advice in transportation planning has given rise to a resurgence of interest in the design and conduct of high-quality large-scale travel and activity surveys (TAS). To provide a focus for professionals engaged in survey design and administration, a series of international conferences have been held in Australia (Ampt, Richardson and Brög, 1985), the United States (Ampt, Richardson and Meyburg, 1992) England (Bonsall and Ampt, 1996), and Germany (Transportation Research Board, 2000) (from where the initial enthusiasm for international comparisons of travel survey practice arose in the 1970s). Over the same period, other national conferences (e.g. Transportation Research Board, 1996) have been held in different countries. In the last few years, the library of specialist texts on travel and activity surveys has also been slowly growing (Richardson, Ampt and Meyburg, 1995; Stopher and Metcalf, 1996; USDOT, 1996).

Over the same twenty years, the concepts of Total Quality Management (TQM) have made major inroads into Western management practices. Many of today's TQM practices stem from the work of Deming (1986) and Juran (1988), who argue that many of the deficiencies in productivity and product quality lie not in the hands of the workers who produce the product, but in the system within which those workers work. It is therefore important to establish systems which give guidance and support to people as they attempt to produce a quality product.

A by-product of this concentration on TQM practices has been the development and promulgation of a range of quality "standards", through a variety of national and international organizations. In Australia, the responsible authority is Standards Australia, and they promote the use of the various ISO standards issued by the International Organization for Standardisation. ISO-certification has now become a standard part of Australian corporate life, where companies (and other organizations) seek third-party accreditation to demonstrate that they have designed, and currently practice, a recognized system of TQM. Such accreditation, to

one of various ISO standards, is taken as independent certification that the organization is actively involved in improving its management practices in line with TQM philosophies.

The ISO-TQM process has gone so far as to have Government departments and other clients requiring such ISO-certification from all organizations responding to public tenders. This has been done to provide a level of confidence to the client that the tendering organization has instituted management practices that have independently been assessed as being high quality TQM practices. This relieves the client from one level of assessment when choosing the successful tenderer. This tender procedure is widespread in a range of areas, such as engineering design and construction, management consultancy, and the provision of computing services. As a result, most transport consultants have either gained ISO-certification or are in the process of gaining such certification. For transport consultants affiliated with large engineering consulting companies, it has often been the case that their ISO-certification has been obtained as a result of a blanket application by the company as a whole.

One question that remains, however, is whether such ISO standards are applicable to the range of work performed by transport consultants. In particular, are they applicable to the collection of data in various travel and activity surveys? Some argue that the ISO standards have primarily been developed with manufacturing industry in mind, and don't readily apply to the 'softer' areas of travel and activity surveys. However, since many client organizations obviously don't agree with this viewpoint, and are requiring transport consultants to have ISO-certification in order to carry out large-scale travel and activity surveys, it is worthwhile examining the application of such ISO standards to the design and conduct of large-scale travel and activity surveys.

The purpose of this paper is not to repeat the information contained in the travel survey texts and conference proceedings. Rather, it is designed to apply the concepts of ISO Quality Standards to the design and administration of travel and activity surveys. In performing this task, the attitude has been taken that achieving ISO-certification is of little value if all it does is to produce a piece of paper stating that ISO-certification has been obtained. Rather, the process of obtaining, and maintaining, ISO-certification must result in an improvement in the way in which travel and activity surveys are performed by the organization.

WHAT IS ISO9000?

While many readers will be familiar with the background and concepts of ISO-certification, it is worth outlining these concepts so that those unaware of the concepts, and hence those most in need of this knowledge, and able to read the remainder of the paper with a better understanding of the underlying philosophies, concepts and procedures.

The ISO9000 series on Quality Management has been produced to provide guidelines on what is expected of organizations that are serious about satisfying their customers' needs and/or requirements. The ISO series consists of several parts; ISO9000.1 provides guidelines for the selection and use of the other specific parts of the series; ISO9001, ISO9002 and ISO9003 are generic guidelines for a range of different applications; ISO9004 provides an overview of quality management and quality system elements. There are a number of other sub-components of the ISO9000 series, but these are less relevant to this paper and will not be covered here.

A key concept in the ISO9000 philosophy is the organization under consideration is but one part of an overall supply chain, which eventually delivers a product to a customer. This organization, called the "supplier", is responsible for taking inputs from "sub-suppliers" (sometimes called subcontractors) and other sources and then converting these inputs into an output which is desired by the "customer". The customer, in turn, may then re-process this output to convert it into another output for another customer further down the chain. Conversely, the sub-supplier may have also obtained processed outputs from another sub-supplier further up the chain. The supply chain process is illustrated in Figure 1.

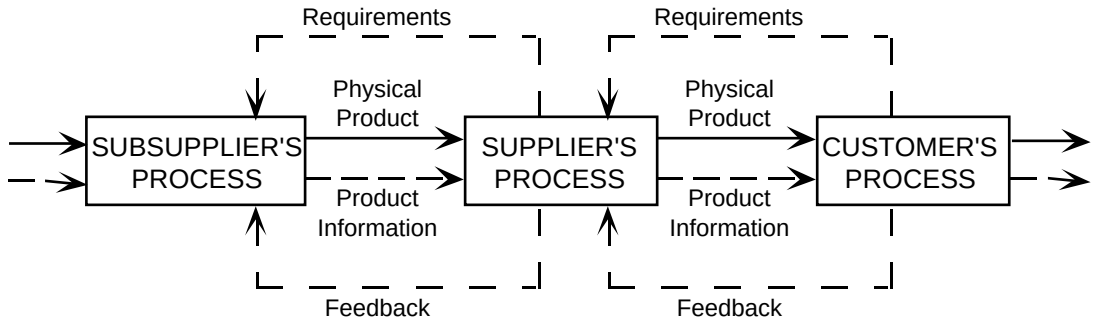

Figure 1 The Supply Chain Process
Adapted from: SA/SNZ, 1994a

In large-scale travel and activity surveys (TAS), where an organization is the supplier of travel and activity survey data to a government department, an example of a sub-supplier might be the private company or government body who supplies the GIS street-files that are used in the geocoding of destinations, while the customer (the government department) may be using the data to development transport policy for a politician or to provide travel forecasts on which substantial public and private investment may be dependent.

In the context of this supply chain, the key objectives of quality management for an organization, as expressed through the ISO9000 standards, are to (SA/SNZ, 1994a):

- achieve, maintain and seek to improve continuously the quality of its products in relationship to the requirements for quality; and
- improve the quality of its own operations, so as to meet continually all customers' and other stakeholders' stated and implied needs.

The introduction of the notion of 'stakeholders' serves to remind us that, in addition to customers, there are at least four other stakeholders who have a keen interest in the performance of the organization. These stakeholders include the owners of the organization (who seek an acceptable return on investment), the employees (who look for work satisfaction and career development), the sub-suppliers (who look for ongoing business opportunities through your organization) and the community at large (who seek responsible stewardship from your organization for the tasks entrusted to it). The ISO9000 guidelines focus on the needs of customers on the reasonable assumption that if customers' needs are truly fulfilled, then the needs of the other stakeholders will also be satisfied.

While some see ISO9000 standards as being more appropriately related to manufacturing industry, because of their emphasis on production and products, such standards are in fact applicable to a wide array of product categories, including:

- hardware
- software
- processed materials
- services

Most organizations are involved in the delivery of at least two of the above products. Suppliers of TAS data are clearly involved in the delivery of software (data and associated analysis

programs) and services (assistance with use and interpretation of the data). In improving quality in the supply of these products, ISO9000 seeks to improve quality in four ways:

- quality due to definition of needs for the product
- quality due to product design
- quality due to conformance to product design; and
- quality due to product support.

Thus in addition to improvements in the physical product delivered to customers, there must also be improvements in market research to clearly define the customer's requirements, and in the provision of supporting information and services to enable the customer to take full advantage of the physical product, shown by the dashed lines in the supply chain in Figure 1.

One part of the ISO9000 process that seems to have gained most attention is the process of quality system audits, the provision of which has grown into a thriving industry in itself. However, this type of audit, the third-party audit, is but one of three types of audit process. Indeed, in the long-term, it may well be the least important of the three types of audit. The other types of audit are the second-party audit, where an organization is audited directly by the customer, and the first-party audit, in which the audit is conducted internally by members of the organization. While third-party audits may seem more independent and unbiased, and hence more useful to future customers, it is the first-party audits which will bring about more longlasting fundamental change within an organization. It is these audits, which require complete honesty and commitment from the organization concerned, that can place them on a higher plane than other organizations who strive for the 'piece of paper' confirmed on them by third-party auditors. In practice, however, most good organizations strive for audits of all three types.

In deciding to adopt an ISO9000 standard for TAS, a final decision must be made as to which of the three standards will be adopted; ISO9001, ISO9002 or ISO9003. There are substantial similarities between these three standards, with the difference being between the scope of the activities covered by the standard, as follows:

- ISO9001 - design, development, production, installation and servicing
- ISO9002 - production, installation and servicing

- ISO9003 - final inspection and testing

For TAS, the real choice lies between ISO9001 and ISO9002. If an organization is simply conducting surveys designed by someone else, then ISO9002 might be appropriate. However, since most organizations involved in the conduct of surveys will also be involved in the design phase of surveys, then it would appear that ISO9001 would be the more appropriate standard.

APPLICATION OF ISO9001 TO TRAVEL & ACTIVITY SURVEYS

The documentation for ISO9001 (SA/SNZ, 1994b) contains guidelines for twenty aspects of the design, development, production, installation and servicing of products. Some of the factors relate to the overall functioning of the organization, while others are specifically related to the design and production of the product itself. Using the wording from the section headings in the ISO9001 documentation, the twenty aspects of quality management are:

- Management Responsibility
- Quality System
- Contract Review
- Design Control
- Document and Data Control
- Purchasing
- Control of Customer-supplied Product
- Product Identification and Traceability
- Process Control
- Inspection and Testing
- Control of Test Equipment
- Inspection and Test Status
- Control of Nonconforming Product
- Corrective and Preventive Action
- Handling, Storage, Packaging, Preservation and Delivery
- Control of Quality records
- Internal Quality Audits
- Training
- Servicing
- Statistical Techniques

While, on first reading, many of these factors may appear to have little to do with the design and conduct of TAS, most can indeed be related to TAS by rewording and reinterpretation of the

language used in the standards. The following sections attempt to perform this reinterpretation, and thus derive quality assurance norms for travel and activity surveys.

Management Responsibility

This section of ISO9001 is concerned with the overall organizational framework within which quality management procedures are to be implemented. Without adequate attention being paid to adoption of quality management at this level of the organization, no amount of tinkering with the product delivery process will achieve lasting benefits. Quality management is all about leadership (Covey, 1992), and hence executive management must take a leading role in the adoption of quality management in the design and conduct of TAS.

Quality Policy

The adoption of a quality policy for TAS is primarily a matter of attitude. Senior management must be committed to quality in TAS, and must document this commitment in clear, unequivocal terms for the benefit of employees and customers. A written statement of this commitment must be freely available for all to see, so that actions by senior management can be compared with the words of senior management. Where one of the organization's primary functions is in the area of TAS, the mission statement of the organization may be an expression of this commitment to quality in TAS.

Organizational Responsibility

Most expressions of commitment to quality on a day-to-day basis come from those involved at the 'coalface' of TAS. Interviewers, data entry personnel, phone operators and front-desk people must be imbued with the quality spirit, and must be empowered by management to put that commitment into action. They should have the authority to make decisions, especially in interactions with TAS respondents, and must then take responsibility for following through on those decisions. No-one in the organization should ever have to say, or be allowed to say, that "it's not my job" when dealing with a customer or survey respondent.

Resource Allocation for Quality

In order to make the above point reasonable, it is necessary for management to make resources available to enable full and proper training for all people involved in the TAS. The reason why people say "it's not my job" is not because they want to shirk responsibility, but rather because they truly feel incapable of dealing with the issue because of lack of training. They would rather avoid the question than give the wrong response. For example, respondents often telephone the survey office with queries about the survey, such as "Why do you need to ask about my income?". There is a valid reason for this question, and the survey designer or administrator can usually allay most people's concerns by explaining why the question is asked and how the data will be used. However, the survey designer or administrator is not always available to take the call, and hence someone else (the receptionist or a professional colleague) must take the call. They should be trained sufficiently about the TAS to enable them to answer the question, even if they are not directly involved in this particular TAS. Such training requires an allocation of resources, in addition to a commitment to quality by the receptionist and the professional colleague.

Management Representative

To demonstrate commitment to the adoption of quality management, the organization must designate a senior manager whose has the specific task of QA Manager - in addition to their other roles within the organization. Ideally, the QA Manager should not be directly involved in the design and conduct of TAS, since this gives them an independence which allows them to be critical of processes without fear of being too close to those processes. Everyone in the organization must know that the QA Manager will often play the role of Devil's Advocate, and will sometimes appear to be overly critical. However, they (and the QA Manager) should also know that the targets of their attention are the TAS processes, and not the people involved in implementing the TAS processes.

Management Review

Having established the QA Manager position, and given them authority to question and report on TAS activities, senior management must be willing to listen to what the QA Manager has to

say, and then be willing to take the necessary actions required to rectify any deficiencies in the system. Senior management must also listen to others involved in the TAS process, including respondents. As voluntary "employees" who are helping to put together a TAS database, respondents often have very cogent observations on how they see the survey process. TAS designers would be well advised to listen to respondents' comments, without feeling that they are being personally attacked. Some respondents, and particularly non-respondents, use strong and emotive language to express their views about the survey; the TAS designer must listen with a "third ear" to hear what the respondent is really saying.

Quality System

Deming (1986), Juran (1988), Peters and Austin (1985) and Covey (1992) all emphasize that the problem in delivering quality is not the people in an organization but the systems put in place by management within which those people must work. Therefore, it is essential that an organization must put in place a system that indicates how things should be done in the design and conduct of TAS.

Quality Manual

The quality system procedures (or "how things should be done") must be documented in a Quality Manual that is freely available to all in the organization, and to all interested stakeholders. The Quality Manual should be rather general, outlining the overall directions to be adopted for quality management. More specific details can be provided for individual TAS in the quality system procedures to be outlined below. The Quality Manual can take a number of forms; it could be a relatively concise description of management's view on quality, or it could be an overview of the basic procedures that apply to all TAS.

Quality System Procedures

The generalities in the Quality Manual must be converted to specific procedures for each TAS by way of quality system procedures. Each TAS is somewhat different to the one that went before or the one that will follow. Different clients have different interests and hence different questions to be answered. Surveys in different cities will mean that available sampling frames

will be different, and hence sampling procedures must adjust accordingly. However, such procedures will all accord with the sampling principles outlined in the Quality Manual, which stress the selection of random and unbiased samples.

Quality Planning

Quality does not just happen. Quality plans say how the things that should be done, as outlined in the Quality Manual, actually will be done. Despite all the best intentions, people will still make mistakes if procedures are not planned and put in place before they are needed. For example, despite a commitment to quality and an understanding that samples should not be biased toward or away from any particular group in the population, many interviewers fail to see any problem with substitution sampling in the field (after all, the house next door could just as easily have been chosen as the one on the list). Therefore, specific instructions must be provided (with explanations) so that field personnel can see how to obtain truly random samples, and why certain practices will result in non-random samples. Such instructions must be formalized in quality plans that can then be used in training programs, as described later. The specification of quality plans is facilitated by taking an overall view of the total TAS process, realizing that the design and conduct of a TAS is not an informal procedure. Rather, it follows a series of logical, interconnected steps that progress towards the final end-product of the survey (Richardson, Ampt and Meyburg, 1995) as shown in Figure 2. Realization of the forward and backward linkages in this process helps in understanding the need for planning to ensure quality in the final product. For example, if one waits until after collecting the data to start thinking about data correction and expansion, then it is already too late. Such planning for quality must have taken place well before the sample was selected and the survey instrument designed.

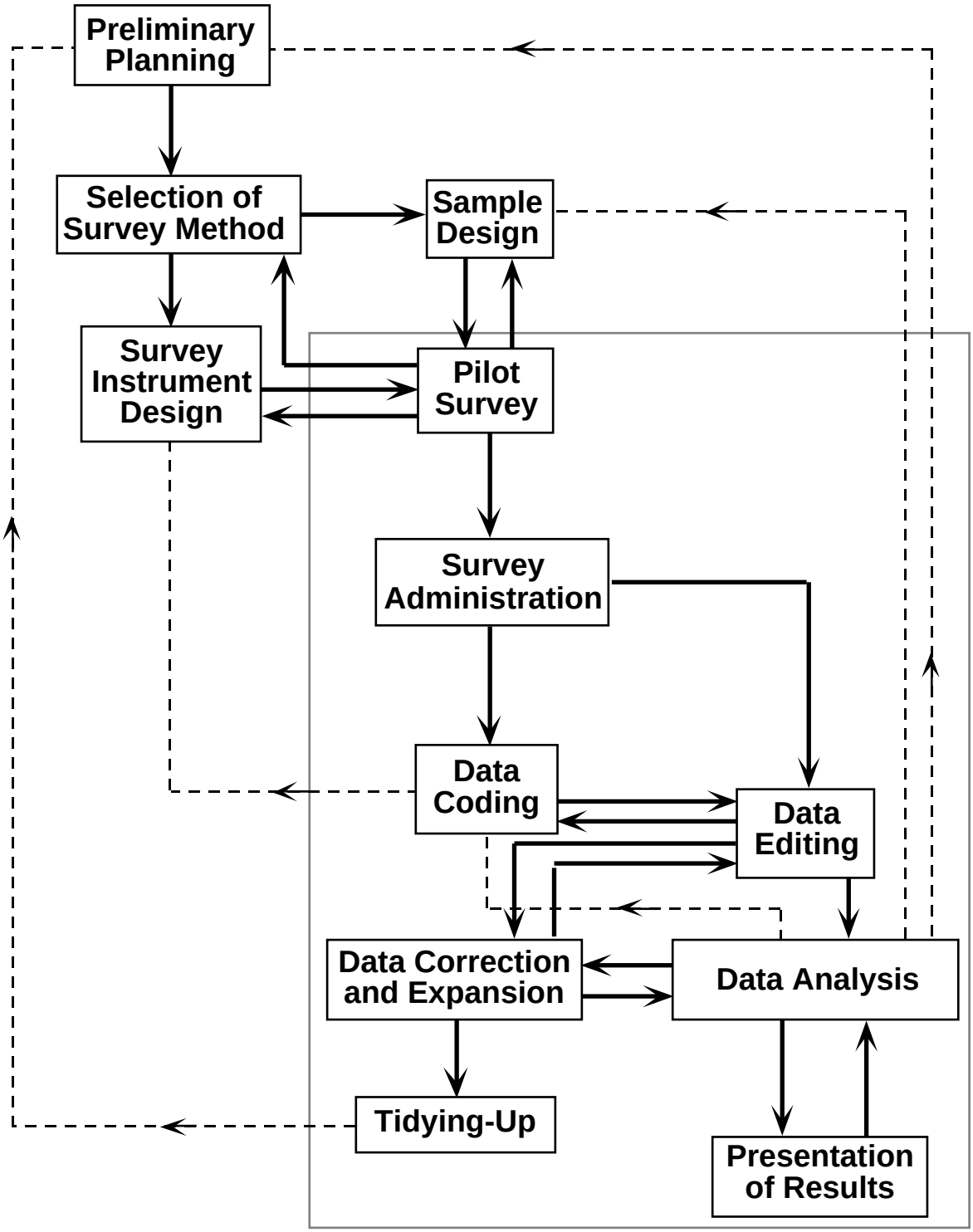

Figure 2 **The Travel and Activity Survey Process**
Source: Richardson, Ampt and Meyburg (1995)

Contract Review

As noted earlier, some parts of ISO9001 relate to the broader issues involved in the design and conduct of TAS. This section considers issues involved in the contractual relationships between the supplier and the customer.

Review of Contracts

Most TAS are performed by organizations on behalf of a third-party client, often in response to a public call for tenders. If a quality product is to be delivered to the client, then it is essential that the basis of the relationship between the supplier and the client/customer is clearly established early in the process. Failure to clarify this relationship at an early stage will often lead to misunderstandings and lapses in quality at later stages. In some cases, it may not be possible for the supplier and the customer to establish an agreeable relationship. This is often the case when the supplier and the customer have different perceptions about quality in TAS. It must be understood that many client/customers have had little or no experience in the design and conduct of TAS. Alternatively, their previous experience with TAS may have been with low-quality TAS. In such cases, it may be difficult for the supplier and the client/customer to reach agreement about quality standards. Despite all that is said in this paper about quality, some client/customers are more interested in obtaining data at the lowest cost, irrespective of the quality. In such circumstances, the supplier can try to educate the client/customer about the value-for-money from quality TAS, but if that fails the supplier may need to make a decision about whether to adhere to their own quality standards or to reduce quality in order to achieve the lowest price tender.

Contract Amendments

It is sometimes possible that the client will accept recommendations from the supplier as to how the tender brief could be changed to improve the quality of the completed TAS. Any such changes should be clearly documented to avoid later misinterpretations about the intent of the brief.

Contract Records

It is obviously necessary, though sometimes ignored, that the expectations of the client are clearly recorded for later reference. This is especially the case with respect to definitions and assumptions to be adopted in the project. Is the TAS to obtain data on linked or unlinked trips; is the sample to be based on households or people; is the required sample size based on completions or initial sample size; what response rates are acceptable; how is response rate to be calculated; what is the definition of a responding household; is imputation of missing data acceptable? All these issues should be decided and clearly recorded before the project commences.

Design Control

One of the main project features that determine whether ISO9001 or ISO9002 is to be used is the extent of design activities inherent in the project. If design is a major component, then ISO9001 should be adopted. Since it is considered that many TAS projects involved a major design effort, ISO9001 should be used for TAS, covering the following aspects of design.

Design Planning

As noted earlier, the design and conduct of a TAS is not an informal procedure. Rather, it follows the design planning process outlined in Figure 2. This process should be documented for each TAS to ensure that adequate attention is given to each phase of the design planning process. For this reason, a Survey Design Checklist has been developed by Richardson, Ampt and Meyburg (1995) as a way of formalizing and documenting the design planning process. Completion of this Checklist for each TAS assists in the design of the TAS, and also serves as a permanent record of the design decisions made during the TAS. This Checklist can be used in conjunction with consideration of the following explicit issues raised by ISO9001.

Organizational Interfaces

As noted in Figure 2, the survey design process is made up of a large number of related activities. Many of these activities may be performed by individuals or groups with very different skills. For example, the sampling may be done by statisticians, the instrument design

done by psychologists, the data coding and editing routines by computer scientists, and the survey administration by clerical and administrative staff. A major factor in the smooth running of any TAS is the definition of areas of responsibility for each group, and the establishment of clear lines of communication between each group. The overall survey designer needs to be conversant with activities in each area, without necessarily being the expert in every one of them. It is the role of the survey designer to ensure that decisions made in one area are consistent with decisions being made in other areas.

Design Input

There are numerous design inputs into the TAS process, but essentially they can be reduced to three major categories of input; time, money, and people. External constraints on these inputs are often in conflict with the design and conduct of a quality TAS. For example, there are often time constraints imposed by clients for production of the output that limit the amount of follow-up that is required for quality control. Budgetary constraints will always be faced and may require some trade-offs between the quantity and quality of data collected.

Design Output

Design output consists of the sample design, questionnaire design and operating procedures that will enable the TAS to be conducted. ISO9001 requires that this output meet the design input requirements (i.e. the project should be able to be completed within the time and cost constraints specified in the design input), and that it contains or makes reference to acceptance criteria. Unfortunately, there is very little attempt in TAS to define what is an acceptable output. In cases where such acceptance criteria have been defined, the result is not always achievable. For example, a recent tender for a TAS in Australia required the supplier to guarantee a specified response rate (even though the method of calculation of the response rate was not defined in the tender brief). In such circumstances, it is very difficult to guarantee a response rate, because that ultimately depends on the respondents. In addition, no indication was given as to what would happen if the specified response rate was not achieved. More fundamentally, if the penalties for not achieving the response rate were high enough, a supplier could always take steps to improve the response rate, but this may well be at the expense of the overall quality of

the data obtained from those respondents. While moves towards the specification of acceptance criteria for TAS are to be encouraged, they should be specified with care and with a thorough understanding of the possible follow-on effects of imposing acceptance criteria on only a limited number of design outputs from the TAS process.

Design Review

During the design process, ISO9001 requires that reviews be conducted, involving representatives of all functions concerned with the design process. In the context of TAS, this would involve people working on sampling, instrument design, data coding and editing, and the administration of the survey. Importantly, however, it should also involve the potential respondents who are perhaps the most important participants in the TAS process. This design review should therefore include a number of "skirmishes" or pre-tests of various components of the TAS process. For example, a skirmish may be held to test the wording of a set of questions, or to test the reliability of the sample frame, or to test a method of questionnaire distribution and collection. These pre-tests should be a conventional part of TAS design to ensure that the final product is fully quality-tested.

Design Verification

An extension of the design review is the design verification where the preferred design option is compared against a number of other design options. In the context of TAS, this may involve the systematic comparison of a range of different survey designs within the same environment. This is particularly relevant in the design of large-scale TAS, where it is important to have selected the best overall survey method. An example of this process has been reported by Ampt (1992), who reported on tests of six different data collection methods: personal interview and self-completion methods, which tested 1 and 2 day variations of "linked" and "un-linked" trip data collection methods. As a result of this comparison, a specific method was then selected for further design and testing before adoption for the main phase of the TAS.

Design Validation

According to ISO9001, "design validation shall be performed to ensure that the product conforms to defined user needs and/or requirements". In the context of TAS, this equates to the

conduct of a full pilot survey to ensure that the output of the TAS design process can in fact collect the required data according to the design specifications. Although pilot testing is one of the most important components of the TAS design procedure, it is also one of the most neglected. The usual reasons for not doing pilot surveys are said to be either lack of time or money (or both). However, not doing a pilot survey almost always turns out to be a false economy. It is much better to find out about problems in a pilot survey, when there is still time to correct the problem, than to find out mid-way through, or at the end of, the main survey, when it is too late to do anything about the problem.

Design Changes

Having found potential problems in the pilot survey, or earlier in the pre-tests, changes can be made to the survey to rectify the deficiencies. According to ISO9001, "such design changes and modifications shall be identified, documented, reviewed and approved by authorized personnel before their implementation".

Document and Data Control

ISO9001 requires the supplier to "establish and maintain documented procedures to control all documents and data" related to the design procedure. In the context of TAS, this requires that all information about the conduct and design of the survey should be recorded and documented. This requires that information systems be set up relating to the survey itself, and not just for the travel and activity data coming out of the survey. This point needs to be re-emphasized. Survey designers are very careful to make sure that the data provided by respondents about their travel and activity behaviour is carefully recorded and available for later analysis. Most of the pages in the technical literature are concerned with results from analysis of the travel and activity data; very little is about the survey process itself. However, respondents (and non-respondents) also provide us with substantial information about the survey process itself, which can then be analyzed to provide insights in the TAS design process. The types of people and households who respond and don't respond, the rate at which they respond, their reaction to specific questions and their views on the design and conduct of the TAS (as perceived by them) are all important pieces of information about the TAS which can be analyzed to improve our

understanding about the TAS process itself, thereby leading to better quality surveys in the future.

Data Approval and Issue

The data which emerges from the TAS process must be "reviewed and approved for adequacy by authorized personnel prior to issue". This requirement has several implications. Firstly, while the editing and review of data is a laborious process, it is not simply a clerical process. While various tasks can be delegated, the final review and approval must be performed by the survey designer who has the experience and intuitive feel for identifying inconsistencies in the data. Secondly, this data review must be performed by someone who is prepared to explore and track down apparent inconsistencies. It is not good enough to accept data that is 95% correct; perseverance and attention to detail are essential traits of the person with final approval of the data. This is important not just for the sake of "getting it right", but for the highly pragmatic reason that societies today are becoming increasingly litigious, and that the survey designer is more likely to be held professionally liable for the quality of the data and for the consequences of any decisions based on the data. Thirdly, and as a consequence of the above considerations, it may be necessary to delay the release of data until the necessary quality control checks have been completed, and to clearly identify areas where the survey designer has any reservations about the quality of data and its application.

ISO9001 makes three additional points about data approval and issue. Relating these points to TAS, they cover the incorporation of documentation and coding frames with the data files, the removal of outdated versions of the data files from use, and the archival and clear identification of these outdated files.

Data Changes

As TAS data gets used for more and varied applications, inconsistencies and coding errors become apparent which were not apparent during the original data review and approval process. This is especially the case with TAS which use GIS as the method of identifying locations, whereby it becomes much more obvious that inconsistencies exist. ISO9001 recommends that "changes to documents and data shall be reviewed and approved by the same organizations that

performed the original review and approval". This means that clients should not be able to make changes to the data set. They should merely make a list of required changes and submit these to the supplier who will then collate the required changes from the various users and then make these changes on a master data set, which is then re-issued to the client(s). This prevents the proliferation of various versions of the data set.

Purchasing

In most TAS projects, the supplier purchases a number of different resources to enable the survey to be undertaken. The three main items purchased are casual labour, in the form of interviewers and other survey personnel, secondary data sets, for expansion of the sample data to population totals, and software, for data entry and data analysis. The supplier may also employ sub-contractors to undertake substantial portions of the TAS project, e.g. some suppliers sub-contract the conduct of field surveys to market research firms who have access to existing labour, hardware and software.

Evaluation of Subcontractors

In all the above cases, the supplier must specify the requirements to be fulfilled by the sub-supplier, and must then evaluate the sub-supplier against these criteria. A relevant question may be whether the sub-suppliers, themselves, have appropriate ISO-certification. The supplier should also "define the type and extent of control exercised by the supplier over subcontractors". This implies that the supplier does not abrogate responsibility for a task simply by employing a subcontractor to do the work. The responsibility for quality still rests with the supplier. As a result of working with various subcontractors, ISO9001 recommends that suppliers should "establish and maintain quality records of acceptable subcontractors".

Documentation of Purchases

Since the supplier is still responsible for the quality of the completed TAS, it is necessary that they document and acknowledge the nature of any subcontractors employed and any other resources purchased for the project. This documentation should be included in the final documentation of the overall TAS project.

Verification of Purchased Product

It is the supplier's responsibility to verify the quality of any products or services provided by sub-suppliers. With respect to casual labour employed by the supplier, this can be done by careful recruitment and extensive training procedures. With software, the verification is less of a problem if the supplier stays with commercially available software, but can be a real problem if the supplier employs someone to develop custom-written software. Even with commercial software, it is not entirely risk-free. Many people have had problems with commercially available data compression programs which have resulted in the corruption and loss of many megabytes of data. There is usually little comeback in these circumstances; careful reading of most software licences will show that the sub-supplier is not responsible for any loss or damage caused by malfunctioning of the software.

A particular issue these days is the verification of secondary data purchased by the supplier. In many situations, secondary data is obtained from reliable sources such as national Census agencies, and the quality of their data is generally very good. However, a new type of secondary data are the GIS topographic files (street-files and boundary files) supplied by commercial GIS companies. These street-files have often been compiled from a range of primary sources, and the quality and consistency of this data is sometimes open to question. Since GIS topographic files are used in a wide range of applications in TAS projects, such as geocoding and zonal allocations, it is important that these files be of high quality. Ideally, the supplier should perform independent verification checks on the quality of the data in these files. However, this is a time-consuming and expensive task for all suppliers to perform, and therefore many suppliers simply accept the GIS data at face value. This can be a risky proposition in some cases, especially when the TAS supplier will be held responsible for the quality of the TAS output based on the use of the GIS files. Evaluations of commercially available street-files have shown a range of deficiencies ranging from mis-named streets, through faulty alignment of street centrelines, to segments of streets and major roads which are totally missing from the street-files.

The verification process can be conducted either by the supplier or the customer. However, even where verification of sub-supplier inputs is done by the customer, responsibility still rests with

the supplier. As stated in ISO9001, "verification by the customer shall not absolve the supplier of the responsibility to provide acceptable product, nor shall it preclude subsequent rejection by the customer".

Control of Customer-Supplied Product

As well as obtaining inputs from sub-suppliers, it is often the case in TAS projects that the client/customer will also supply some inputs that the supplier is expected to use. Examples of such inputs are data files from previous TAS, GIS data files already held by the client, and sampling frames provided by the client. One could also extend these inputs to include advice given to the supplier as to what data is required and how it will be used by the client/customer. As with inputs provided by sub-suppliers, the supplier must verify the quality of the inputs provided by the client. However, in this case, ISO9001 reverses the situation with respect to responsibility for these inputs by stating that "verification by the supplier does not absolve the customer of the responsibility to provide acceptable product" to the supplier. The supplier is also not obliged to accept these inputs from the customer. Indeed, "any such product that is ... unsuitable for use shall be recorded and reported to the customer".

Product Traceability

ISO9001 requires the supplier to maintain procedures for identifying and tracing the product at "all stages of production, delivery and installation". The equivalent situation for TAS is that the supplier must maintain logbooks of all activities during the TAS process, including tracking the fate of sampled households, the performance of interviewers and other survey workers, and the status of data throughout the data entry and editing process. Such information provides the base data upon which the quality of the TAS can be evaluated. The tracing system must be designed and pilot-tested well in advance, and should ideally be computerized and on-line in real time.

Process Control

In a production process situation, ISO9001 requires that the supplier shall "identify and plan the production, installation and servicing procedures which directly affect quality and shall ensure that these processes are carried out under controlled conditions". For TAS, this

requirement emphasizes that the design and conduct of a TAS should be fully planned in advance (according, for example, to the process diagram shown in Figure 2), and should include consideration of how the data will be transferred to the customer (installation), and how their use of the data will be supported by the supplier (servicing).

Inspection and Testing

Design and production processes are never perfect, and mistakes and faults will occur during the process. A system must be in place to observe, detect and rectify such problems.

Receival Testing

As noted above, the supplier uses inputs that come from a variety of sources (sub-suppliers and customers). ISO9001 requires that "the supplier shall ensure that incoming product is not used or processed ... until it has been inspected or otherwise verified as conforming to specified requirements". As noted above, the responsibility for inputs used in the TAS process primarily rests with the supplier.

In-process Testing

During the TAS process, the supplier must ensure that in-process inspection and testing procedures are put in place to achieve high-quality output. Examples of such inspection and testing procedures in TAS projects include random follow-up interviews with respondents, re-entry of data and comparison with original data entry, and a suite of editing procedures which include a wide array of range error and logic checks. ISO9001 requires the supplier to "hold product until the required inspection and tests have been completed". ISO9001 does, however, make provision for release of product under "positive-recall procedures" where product can be released early to a customer on the proviso that, if any problem becomes apparent during subsequent inspection and testing, the customer will be notified accordingly. Clearly, the customer must be fore-warned if product is released to them under these conditions.

Final Testing

At the end of the production process, ISO9001 requires that the supplier complete a final inspection and testing of the finished product to confirm that it conforms to product

specifications. "No product shall be dispatched until all the activities specified in the quality plan and/or documented procedures have been satisfactorily completed and the associated data and documentation are available and authorized". Thus the data must be fully tested and the documentation prepared before the data can be released. This requirement can sometimes place the supplier in a difficult position, where they are being pressured by the customer for early release of the data and where they know that not all the inspection and testing (i.e. editing) procedures have been finalized. In such circumstances, the best that can be done is for the data to be released under "positive-recall procedures", with the customer being fully advised of the status of the data quality. Under such conditions, the customer accepts the data on *caveat emptor* conditions.

Test Records

ISO9001 requires the supplier to "establish and maintain records which provide evidence that the product has been inspected and/or tested". In TAS projects, this would require the documentation of all editing checks used in the process, and the maintenance of a log of all changes made to the data during the editing process. This can be an onerous process. One way of doing this is by the establishment and maintenance of a "tag" file, which identifies all changes made to the data after the initial data entry. Every time a change is made, a record is added to the tag-file recording the variable that was changed and the values of the variable before and after the change. In this way, a complete record is maintained of the history of inspection, testing and corrections made to the data files. Analysis of this tag-file can provide valuable information to the survey designer by showing which variables seem to require more corrections. This may indicate that the design or wording of the question obtaining this data may need modification, or that the coding instructions for this variable need to be revised. Rather than seeing the tag-file as an admission of faulty design in the original survey procedure, it should be seen as an indication that quality control procedures are in place to detect and remove imperfections in the data. Quality control is not just about "doing things right the first time" (although this should be the ultimate aim). Rather, it is more about "continuous improvement" towards this ultimate aim.

Control of Test Equipment

In many production processes, the final product is measured and compared against some external standard by the use of "test equipment" which gives an objective measurement of the quality of the final product. In TAS projects, this compares to the use of "secondary data" against which the sample survey results will be compared. The common assumption in using secondary data is that the secondary data is a better measure of reality than that provided by the sample survey data. In some cases, this may be true. For example, demographic data obtained from a Census are probably a better measure of demographics, provided that the Census data are up-to-date. Other data obtained from Census bureaus, however, should not necessarily be accorded the same status. Sample surveys conducted by the Census bureau which contain information about transport behaviour suffer from all the same limitations as sample surveys conducted by transport agencies, consultants and research organizations. In many ways, these surveys may even be worse because Census bureaus tend not to have people with the same level of expertise in transport. Thus, while their sample design might be acceptable, these surveys often suffer from considerable sample and instrument bias because the survey designers do not have sufficient expertise in the subject matter of the survey.

Another problem area is where TAS data is compared with traffic counts or other observational count data. The assumption is often made that the "field data" must be better because someone actually went out and counted the vehicles. However, this data is also from a sample survey and suffers the same problems of sampling error and bias. In addition, it is not always the case that the traffic data is measuring the same phenomena as the TAS. For example, the traffic data may be including traffic from outside the study area, especially near the boundaries of the TAS study region. It is also unlikely that the traffic data is collected during the same time period as the TAS data, especially when the TAS data collection may be spread over a period of weeks, months or years.

Any secondary data used in a TAS project should be fully tested and verified in the same way as the data obtained from the TAS is tested and verified.

Test Status

ISO9001 requires that the status of a product, with respect to its conformance to established test procedures, should be clearly identified to ensure that only quality product is released for use. In a TAS, such test status relates to the amount of sampling error, sampling bias and measurement bias associated with an item of data. Sampling error has been associated with data items in the past by quoting standard errors for specific results from analysis of the data. Even so, most data is presented without its standard error, and even when standard errors are presented, most readers either do not read or understand the meaning of the standard error. A considerable amount of further research needs to be undertaken to devise ways of presenting the extent of sampling error which are informative, yet understandable. With respect to the amount of sampling bias and measurement bias, the state of the art is even less well advanced. Very little has been researched, and even less routinely presented, about these two types of error. Clear specification of the response rates obtained would be one step in the right direction, but only the first step. Indeed, before this can be done, there needs to be agreement in the profession as to how response rates should be calculated for different types of TAS (see Richardson, Ampt and Meyburg (1996) for a discussion of this issue).

Control of Nonconforming Product

As noted earlier, all surveys contain some mistakes. The challenge is to minimize these mistakes and to adjust and adapt for those mistakes that have occurred. ISO9001 is very clear on the issue of nonconforming product when it states that the supplier shall "ensure that product that does not conform to specified requirements is prevented from unintended use". One way in which suppliers of TAS data have attempted to do this is by having blank cells in cross-tabulations where the results do not meet a specified level of statistical significance. The rationale is that it is better to give no results at all than to give a potentially misleading result. This same process can not be used when providing unit record files, however, since the statistical significance of results will depend on the type of analysis performed on those unit records. For unit record data, all that can be done is to withhold records that have not passed a series of editing checks.

Corrective and Preventive Action

Rather than withholding data from the customer, an alternative technique is to implement some form of corrective action to remedy the fault or, better still, to implement a preventative action to eliminate the problem in the future.

Corrective Action

Implementation of corrective action first requires that the supplier be made aware of the problem. This is best done by having a system of fault notification installed with the customer. Most problems in TAS data only come to light during the course of performing an analysis that has not been performed before. Despite substantial in-house beta testing of the data set, the supplier will never pick up all the possible problems with the data. It is only after the customer has started using the data that many problems come to light. Generally, these problems are small, but nonetheless they must be corrected. However, the supplier cannot correct the problem unless they are notified about it by the customer. Therefore, a system of problem notification sheets should be implemented with the customer. These days, such a system is probably best implemented electronically, with the customer being given an email hotline on which they can immediately notify the supplier of data problems. The receipt of, and replies to, these messages should be automatically logged to provide a documented record of attention being given to such corrective action.

Preventative Action

Some data problems can be avoided by designing preventative actions into the TAS process. Examples of such preventative action include the use of imputation to minimize the problems of item non-response, the use of weighting techniques to allow for respondent non-response, and comparisons with secondary data and the calculation of expansion factors to allow for non-random sampling and non-uniform response rates.

Handling, Storage, Packaging, Preservation and Delivery

While the design and conduct of the TAS is an important process, the relatively mundane tasks of handling, storage, packaging, preservation and delivery of the data are also important in producing a quality product.

Handling of Product

In the context of TAS, handling of the product within the supplier's premises can include the establishment of common sense procedures for how items of computer equipment, especially disks and other storage devices, are to be handled and maintained. Rules about smoke-free environments and protection from electromagnetic fields should be instituted. For example, it is not uncommon to see phones placed on top of external hard-disks containing data worth thousands of dollars, despite the intense electromagnetic fields associated with ringing phones.

Storage of Product

The storage of TAS data during processing requires a careful assessment of the hard-disk and computer server systems to be employed by the supplier. Should a multi-user version of the data base be installed on a central server, or should separate master copies be installed on each user's computer within the supplier's premises while the data set is being constructed?

Packaging of Product

The packaging of the product for delivery to the customer requires an assessment of the type of media to be used for this transferal. This choice will depend largely on the size of the data-base involved. For small to medium sized data sets, transfer on floppy disks is still the norm (especially when used with compression programs to reduce file size). However, for medium to large data sets, a wide variety of transfer media are now available, and the range keeps increasing by the month. Floppy disks, removable hard-disk cartridges, ZIP drives, CD-ROMs, modem transfer, email and Internet transfers are all part of the variety of techniques available. The choice will depend of the size of the data sets and on the hardware and software available to both supplier and customer.

Preservation of Product

The TAS product should be preserved both during processing and after final production of the TAS data set. During processing, a comprehensive system of backup and off-site storage of backup tapes should be implemented to safeguard the substantial investment made in the TAS by the supplier. After production of the final data set, the supplier should produce an archive copy of the data, plus all documentation, and lodge it in safe storage facilities. Depending on the commercial nature of the data, a range of data archiving facilities exist for archiving and dissemination of data sets.

Delivery of Product

The supplier should arrange for delivery of the data and documentation using the selected media, for installation of the data set on the customer's computer system, for training of the customer's staff in the use of the data, and for follow-up support and assistance to ensure that the customer makes best use of the data.

Control of Quality Records

The procedures used to achieve compliance with ISO9001 must be fully documented, and procedures need to be established for collection and storage of this information, preferably in electronic format. The completion of the Survey Design Checklist (Richardson, Ampt and Meyburg, 1995) is a good starting point in this process, but does not include all the provisions of ISO9001 as interpreted for TAS in this paper.

Internal Quality Audits

While a major focus of many companies has been on achieving third-party ISO-accreditation, an integral component of ISO9001 is that the organization must establish a system of internal quality audits to determine whether quality activities are actually taking place on a routine basis. These audits shall be "carried out by personnel independent of those having direct responsibility for the activity being audited". This corresponds with the appointment of a quality manager who is somewhat removed from the day-to-day operations. Having performed the internal audit "the results of the audits shall be recorded and brought to the attention of the

personnel having responsibility in the area audited". This system of internal audits is possibly the most difficult part of the process, since it requires honesty and objectivity from the auditor, and openness and a willingness to accept criticism from the auditee. These attitudes are essential, however, in a quality-focussed organization.

Training

If all the above changes are made to the system to enable the production of a quality product, then it is imperative that staff are given sufficient training to enable them to capitalize on the improvements made to the system within which they work. Most people are eager to produce a quality product, provided they know what they should be doing. Training, therefore, is an essential component of any quality-focussed organization. This training should extend across all levels of the organization, and should not be confined to formal training and education. Career development opportunities should be given to all staff, even if it means that this makes them more attractive on the open market and hence more likely to be lured away by competitors. The organization's challenge is to make their current job so attractive, in terms of work satisfaction, that they do not want to go elsewhere. Organizations should err on the side of giving too much training rather than too little training. For example, new interviewers should be given a complete overview of the entire survey process, rather than just being trained in how to do interviews. In this way, they see where their work fits into the bigger picture and begin to realize how the information they produce gets used later in the process. It also makes them feel that they are part of the overall organization.

Servicing

Many TAS suppliers think that their job ends when they have delivered the data to the customer. Contractually, this may be correct, but from a quality point of view they would be wise to offer support and service to the customer after delivery of the data to ensure that the data is used, and used properly. Commercially, this is also a wise move as it improves the probability that the customer sees the investment in the data as a wise decision, and is more prepared to do repeat business with the same supplier in the future.

Statistical Techniques

While most TAS suppliers are very familiar with a range of statistical techniques which may be applied to the travel and activity behaviour data coming out of a TAS, relatively few of them have applied the same techniques to analyzing the behavioural underpinnings of the survey itself. For example, we have many models of how people make decisions about which mode of transport to choose, but we have virtually no models about how people decide whether to respond to a TAS or not. Such meta-analysis of surveys should be an important focus of organizations designing and conducting TAS. The same statistical techniques applied to the TAS data should also be applied to the TAS itself.

CONCLUSION

This paper has attempted to show how the requirements of ISO9001 can be applied to the design and conduct of TAS. In some cases, the application of the ISO9001 principles was straightforward with a clear application to TAS procedures. In other cases, the analogy was not so clear cut, and some re-interpretation was needed to find a meaning for the principle. Overall, the exercise emphasized the need for procedures that many TAS suppliers would already practice routinely. However, it also highlighted the need for some procedures that are not at all commonplace with TAS suppliers. A summary of the interpretation of the ISO9001 principles for TAS is provided in point form in Table 1.

One of the over-arching themes of quality control is the need to document the procedures being used in the organization. Indeed, Taormina (1996) goes so far as to suggest that the concepts and processes of the ISO9000 series can be summarized in three simple steps:

A. Write down what you do
B. Do what you write down
C. Verify the results

Application of these three steps to TAS would go a long way to improving the quality of TAS.

In essence, the ISO guidelines attempt to describe what needs to be done to deliver a quality product, how it can be done, and how to demonstrate that, as an organization, you are trying to

abide by the ISO guidelines. While the ISO requirements may seem like they require a lot of effort from an organization, the potential benefits from seriously considering the issues raised are substantial in terms of improving an organization's ability to deliver a quality product in a consistent fashion. It does, however, require a lot of work and commitment. Nonetheless, if customers are going to be requiring ISO-certification from their TAS suppliers, then the suppliers would be well advised to embrace the concept whole-heartedly in order to derive maximum ongoing benefit from the effort they put into achieving ISO-certification.

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Table 1 Summary of Interpretations of ISO9001 for TAS

ISO Section	ISO9001 Principles	Interpretation of ISO9001 for Travel & Activity Surveys
4.1	**Management Responsibility**	Quality is concerned with leadership and management commitment
4.1.1	Quality Policy	A written quality policy must be prepared by senior management
4.1.2.1	Organizational Responsibility	Everyone connected with a TAS has a responsibility for quality
4.1.2.2	Resource Allocation for Quality	Organizations must be willing to commit resources to achieve quality
4.1.2.3	Management Representative	A senior, independent staff member must be designated as QA Manager
4.1.3	Management Review	Management must be willing to listen to, and act upon, the QA Manager's reports
4.2	**Quality System**	A system which says how things should be done in TAS
4.2.1	Quality Manual	A formal document saying how the organization performs TAS
4.2.2	Quality System Procedures	A written set of procedures for each specific survey
4.2.3	Quality Planning	A plan of how the quality system procedures will be implemented for each survey
4.3	**Contract Review**	Formalizing the relationship between TAS supplier and customer
4.3.2	Review of Contracts	Educating clients about the need for quality in TAS
4.3.3	Contract Amendments	Suggesting changes in the TAS tender brief
4.3.4	Contract Records	Documenting definitions, assumptions and expected outcomes from TAS
4.4	**Design Control**	TAS have a large component of design activity; therefore use ISO9001
4.4.2	Design Planning	Use of the Survey Design Checklist for planning purposes
4.4.3	Organizational Interfaces	Assign responsibilities and establish clear lines of communication
4.4.4	Design Input	Major inputs of time, money and people; may require trade-offs
4.4.5	Design Output	Definitions needed for acceptance criteria for design outputs
4.4.6	Design Review	Skirmishes and pre-tests
4.4.7	Design Verification	Comparisons of alternative survey methods
4.4.8	Design Validation	Full-scale pilot surveys
4.4.9	Design Changes	Review of procedures and re-piloting if necessary
4.5	**Document and Data Control**	Documentation of the process and performance of each survey
4.5.2	Data Approval and Issue	The importance of editing; interim data sets; coding frames; liability issues
4.5.3	Data Changes	Updates to data; master data sets; version numbers
4.6	**Purchasing**	Casual labour, secondary data sets, software
4.6.2	Evaluation of Subcontractors	Do they have ISO-certification; lists of acceptable subcontractors
4.6.3	Documentation of Purchases	Describe and acknowledge sub-suppliers
4.6.4	Verification of Purchased Product	Responsibility rests with TAS supplier, e.g. quality of GIS topographic files

Table 1 Summary of Interpretations of ISO9001 for TAS (cont.)

ISO Section	ISO9001 Principles	Interpretation of ISO9001 for Travel & Activity Surveys
4.7	**Customer-Supplied Product**	Information provided by client/customer; need not be accepted by TAS supplier
4.8	**Product Traceability**	Logbooks of TAS activities; sampled household logs; interviewer logs
4.9	**Process Control**	Advance planning of the TAS process using the Survey Process Flowchart
4.10	**Inspection and Testing**	Detect and rectify problems with TAS data
4.10.2	Receival Testing	Testing of inputs e.g. secondary data sets
4.10.3	In-process Testing	Random follow-ups; data re-entry; editing procedures
4.10.4	Final Testing	Quality of final product; time pressures from client; positive-recall procedures
4.10.5	Test Records	Tag-files; response rates; continuous improvement
4.11	**Control of Test Equipment**	Veracity of secondary data; demographics; other sample surveys; traffic counts
4.12	**Test Status**	Reporting of sampling error, sampling bias, instrument bias; response rate reports
4.13	**Control of Nonconforming Product**	Blank cells in cross-tabulations; withholding of data failing edit checks
4.14	**Corrective and Preventive Action**	Procedures to minimize the need for withholding of data
4.14.2	Corrective Action	Problem notification sheets; email hotline
4.14.3	Preventative Action	Imputation of missing values; weighting techniques; population expansion factors
4.15	**Handling, Storage, Packaging, Preservation and Delivery**	The tasks involved in getting the final product to the customer
4.15.2	Handling of Product	In-house care of data sets, procedures for protecting disks etc
4.15.3	Storage of Product	Hard-disk and computer server system decisions
4.15.4	Packaging of Product	Choice of media for delivery of data to customer
4.15.5	Preservation of Product	Backup and archiving procedures
4.15.6	Delivery of Product	Delivery of data, computer installation, training, follow-up support
4.16	**Control of Quality Records**	Documentation of TAS process using Survey Design Checklist
4.17	**Internal Quality Audits**	Internal auditing by independent staff member
4.18	**Training**	Training of all TAS personnel; err on the side of too much training
4.19	**Servicing**	Data Support Centre to assist client/customer in making best use of data
4.20	**Statistical Techniques**	Statistically analyze the survey process as you would the TAS data