bureau of transport economics

National Travel Survey 1977/78: Determination of Regional Sample Sizes

Occasional Paper

The NTS is a postal survey being conducted over a twelve-month period between July 1977 and June 1978. Its general aim is to determine domestic non-urban travel characteristics on a fully national basis. All modes of travel are to be encompassed, and the seasonal nature of this travel will also be identified. This Occasional Paper discusses the geographical distribution of this total sample.

Subject
Series
Date
A to Z
Search
Results
Print
Exit
GO BACK

BUREAU OF TRANSPORT ECONOMICS

NATIONAL TRAVEL SURVEY 1977-78
DETERMINATION OF REGIONAL SAMPLE SIZES

J.W. Moll
D.A. Russell

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1978

Printed by Watson Ferguson and Co., Brisbane

FOREWORD

As part of its general research into transport needs and development, the BTE is conducting a survey of domestic non-urban travel throughout Australia. This survey, known as the National Travel Survey (NTS), is being conducted over a twelve-month period from July 1977 to June 1978. Its purpose is to fulfil a requirement for quantitative information regarding both the amount of travel undertaken in Australia and the general geographical characteristics of this travel.

The NTS is being conducted on a large scale and is intended to achieve a comprehensive coverage of all modes, in spite of the limited staff and financial resources which can be devoted to the project. These factors dictate that the survey must be conducted using a postal questionnaire. They also dictate a careful analysis of the sampling strategy to be adopted for the project.

It is necessary for the sampling strategy to reflect the relative importance of travel routes in Australia, so that the statistical accuracy of the survey information can be maximised in those areas where the requirement for reliable information is greatest.

This Occasional Paper is one of a series of BTE publications describing the planning and conduct of the NTS. It discusses the derivation of the sampling strategy adopted for the NTS. The implementation of the strategy is described, and results are provided in terms of the regional sample sizes selected for the survey.

(W. P. EGAN)
Assistant Director
Transport Resources Investigation

Bureau of Transport Economics
Canberra
May 1978

CONTENTS

TABLES

FIGURES

SUMMARY

In conducting any survey, careful consideration must be given to the balance between the cost of mounting the survey and the quality of the information to be obtained from it. The problem of achieving an appropriate balance is compounded in the case of a survey with multiple objectives, from which a variety of information will result. Usually, in this case, the trade-off between cost and quality must be decided on the basis of one particular measurement objective which constrains the survey while not necessarily being the main objective. This is the situation which applies in the case of the National Travel Survey (NTS).

The NTS is a postal survey being conducted over a twelve-month period between July 1977 and June 1978. Its general aim is to determine domestic non-urban travel characteristics on a fully national basis. All modes of travel are to be encompassed, and the seasonal nature of this travel will also be identified. The total sample size which could be allocated for this survey was determined by fixed financial and staffing budgets. This Occasional Paper discusses the geographical distribution of this total sample.

In planning the geographical distribution of the sample, several regional zoning schemes were examined for suitability to the sample allocation process. For a variety of reasons, none of the existing regional schemes was suitable for this task without modification. This process of modification resulted in the derivation of a new regional scheme which defined the National Travel Survey regions. These became the basic sampling zones for the survey.

Although a variety of personal, household and travel information will be gathered from the NTS, the general philosophy adopted in distributing the data sample among NTS regions revolved around the concept of travel corridor significance. In terms of the

objectives of the survey, the regional sample sizes were chosen on the basis of achieving levels of statistical accuracy of travel information appropriate to the significance of various inter-regional routes. This approach involved the three-way classification of seventy inter-regional routes into major, secondary and minor corridors, depending on their estimated traffic volumes. Regional sample sizes were chosen according to the relative significance of the O-D pairs representing corridors traversing a region. The net result of this sampling strategy was to produce a distribution of the (resource-constrained) total sample among all NTS regions. It is believed that this distribution adequately reflects the relative travel intensity in various parts of Australia.

CHAPTER 1 - INTRODUCTION

Initial planning for a National Travel Survey (NTS) commenced some years ago, when a need for detailed information on personal domestic non-urban travel came into prominence. Out of this grew the concept of a survey which would be aimed at measuring travel behaviour within Australia generally. It was also to be the first fully comprehensive non-urban travel survey conducted in Australia. This implied that:

- The survey would have to be carried out on a national basis with all parts of Australia being represented in the survey sample;
- All modes of travel would need to be included in the survey;
- The survey would be conducted over a twelve-month period in order to assess temporal variations in travel behaviour.

In order to satisfy these conditions and to achieve a statistically acceptable sample size under a fixed budget constraint, it became clear that the survey would have to be conducted by mail. A mail survey is substantially limited in the amount and range of information which can be obtained. In turn, this imposes certain constraints on the overall objectives of the NTS.

An attempt to obtain a very wide range of information through a mail survey is likely to depress the total response through the complexity and detail of the survey questionnaire. This would be unacceptable, not only because of the resulting unfavourable statistical considerations but also because of possible adverse public reaction to a survey requesting a large amount of detail. On balance therefore it was decided that the NTS should be aimed primarily at establishing a benchmark information base on non-urban travel.

. is worthwhile discussing this concept of a benchmark study further because it provides the rationale for carrying out the NTS in its present form with the available resources. It also provides the basis for the sample derivation procedure presented later in this Paper.

At the present time the information available to transport analysts on Australian travel behaviour is extremely scant. Various types of travel surveys have been conducted in the past. These have generally been limited in their objectives; they usually have been aimed at providing detailed route-specific, mode-specific or purpose-specific information. These surveys have been valuable in their own right, because as well as providing information required for specific purposes and projects, this information has also been used for more general transport analysis. However, the extrapolations which usually have to be made to apply the data from the various specific surveys to general transport planning are often of questionable validity.

Furthermore, because of the dearth of information, the initiation of many of these surveys often occurs in a 'vacuum' in which there are no existing guidelines on the best form for the survey nor even on its real necessity.

The general aim of the NTS is to provide information on non-urban travel in Australia, covering the mainland and Tasmania, all modes of travel and all seasons of the year. In fulfilling this aim, it is also intended that the information obtained through the NTS will provide a benchmark or reference point for the planning and effective conduct of more restricted transport surveys in the future. A full discussion of the background and general approach to the planning and conduct of the NTS can be found elsewhere (Moll 1978).

Clearly, the intended scope and duration of the NTS require that a careful trade-off be made between the accuracy of the resulting information and the resources (financial and otherwise) to be devoted to the survey. This trade-off has been of prime importance in the development of the sampling procedure adopted for the NTS.

This Paper is one of a series prepared by the Transport Resources Investigation Branch of the BTE to document the planning processes and operations involved in carrying out the NTS. The Paper presents the approach adopted for determining the size of the postal sample to be distributed to various parts of Australia. It follows and uses the results of two previous publications (Aplin and Flaherty 1976; Piko 1977).

NATURE OF THE STUDY

Essentially, the problem of determining the regional sample size distribution involves allocating a given total sample size (which is fixed by resource constraints) to various regions so that the statistical accuracy of the results is commensurate with the importance of those results. In the case of transport statistics and, more particularly, personal travel statistics, the importance of the results is often related to the numbers of trips made between particular origins and destinations. Thus, the sample should be allocated to reflect the relative significance of travel between specific origins and destinations.

As Aplin *et al.* (1976) have shown, enormous sample sizes would be required to measure total origin-destination (O-D) trip distributions to a reasonable accuracy. Fortunately, measurement of the complete pattern to a uniform high accuracy is not required for the reasons just stated. Further, since presently-available statistics on non-urban travel cannot be considered in any sense comprehensive, provision of further quantitative data is regarded as being advantageous, even if that information is subject to considerable statistical tolerance. This is in accordance with the concept of the NTS as a benchmark exercise, as outlined above.

In the following Chapters the sampling procedure is presented in some detail. Chapter 2 briefly describes the regional basis for the sampling structure, while Chapter 3 presents the essentials of the sampling philosophy adopted for the NTS. Chapter 4 relates this philosophy to the method used in deriving regional sample sizes under resource constraints. Chapter 5 discusses some of the statistical implications of the derived sampling structure. Finally, Chapter 6 summarises the presentation.

CHAPTER 2 - NATIONAL TRAVEL SURVEY REGIONS

In planning any survey involving geographic characteristics, a system of zones or regions must be defined to allow the total survey sample to be distributed in a statistically appropriate way. Many zonal systems have been used in the planning of surveys. Some of these systems include:

- Statistical divisions used in the conduct of surveys by the Australian Bureau of Statistics;

- Electoral divisions - used (for example) by some commercial polling organisations;

- Traffic zones - defined for individual small-scale traffic surveys.

The NTS requires a regional system covering the whole of Australia. Such a system should ideally satisfy a number of criteria, the most important of which are as follows:

- The regions involved should represent reasonably homogeneous populations in terms of their respective travel characteristics;

- The regions should allow important long-distance corridors to be identified and surveyed at appropriate levels[1];

- The regions should be compatible[2] with other established regional systems.

---

(1) This implies that the extremities of these corridors (i.e. the origins and destinations) should tend to be the focal points in separate regions which can be sampled independently.

(2) That is, the regions should allow aggregation or disaggregation to other regional systems involving larger or smaller zones.

Aplin *et al.* (1976) discuss the formulation of geographic regions which constitute the primary sample regions for the NTS. These regions (which will be referred to as NTS regions) are broadly based on the Australian Government Regions (AGR's) developed by the former Department of Urban and Regional Development (DURD). However, the AGR's were not regarded as being entirely appropriate for use in the NTS. The following examples illustrate some of the reasons for the unsuitability of the AGR's as sampling regions for the NTS:

- Each of the State capital cities (except Brisbane and Hobart) consisted of several AGR's, whereas they would be more appropriately considered as single regions for the NTS;

- Some of the AGR's (particularly those in Western Australia) were not closely comparable to the remainder in terms of apparent trip generation and attraction parameters;

- Some AGR's had unusual geographic shapes which would have inhibited their use in the NTS;

- Brisbane was aggregated with a large surrounding area to form one region (this was also the case with Hobart but the Tasmanian situation was regarded as rather less serious);

- The ACT, Northern Territory and northern South Australia were not included in the AGR system.

Considerable re-design of the AGR boundaries was required to achieve a regional structure which met the criteria mentioned previously, and which therefore could be regarded as being suitable for the NTS. This resulted in a reduction of the original 76 AGR's to 64 NTS regions (including the NTS regions generated for the ACT, NT and part of South Australia). Of the 64 NTS regions, 43 remained identical to the corresponding AGR's. It is important to note that in line with the criterion relating to compatibility between regional structures mentioned above, all NTS boundaries follow Local Government Area (LGA) boundaries. A number of other regional structures are also based on LGA boundaries.

In the course of developing the NTS regional structure, it was found that no readily-available directory could provide a convenient correspondence between individual placenames and the various related geographical zones (LGA, NTS region, AGR, Statistical Division and so on). Such a directory(1) is essential in generating the geographical sample distribution for the NTS and also for subsequent analysis of its results. Therefore, the BTE undertook compilation of a directory relating placenames and various geographic zoning systems. This directory should have much wider application than its direct use in the NTS, and it will therefore be published by the BTE (Aplin and Hirsch 1978). Maps showing the NTS regions are provided in that publication and also by Moll (1978).

---

(1) Also referred to as a 'geographic converter' by geographers.

CHAPTER 3 - SAMPLING PHILOSOPHY

BASIC CONSIDERATIONS

The primary aim of the NTS is to obtain reliable statistical information on both regional and inter-regional non-urban travel behaviour characteristics, together with related household and personal socio-economic characteristics.

The basic sampling unit chosen for the survey is the household, and only trips made by members of each sampled household are to be recorded in the survey. There are a number of reasons for choosing the household as the sampling unit. These include the following:

- Households tend to be relatively homogeneous units as far as their long-distance travel behaviour is concerned. For example, household members tend to travel together on trips in this category;

- Households are effectively independent entities in terms of travel behaviour. Therefore, they satisfy the essential requirement of a random sampling process that entities selected should be independent of each other. This permits application of relatively straightforward statistical considerations;

- The number of households in a region is a relatively stable and known demographic quantity. This facilitates expansion of results from a sample to a population;

- One questionnaire addressed to a household will allow all the person-trips generated by that household in a given period to be sampled. This is economical from the point of view of minimising postal expenditure on the survey;

- By restricting the surveyed trips to household members only, possible double-counting of persons travelling is avoided when expanding to population levels.

With the household as the sampling unit, the problem arises of choosing the particular households to be included in the survey sample. Clearly, any survey involves a trade-off between resource commitment and the accuracy of the resulting statistics. The NTS is constrained both financially and by limited staff. In particular, the finance available for the NTS determines the maximum number of questionnaires[1] which can be posted. Therefore, given the ceiling on the total number of households which can be sampled, a method is required for determining the distribution of those households among the various NTS regions.

Final distribution of the NTS sample should reflect the statistical accuracy required from the survey in different regions. In turn, a convincing case can be put that the accuracies desired for the regional statistics should be related to the significance of the transport routes which serve individual regions. Assessment of the significance of any transport route is to some extent arbitrary, but three main approaches have been used for the purposes of the NTS. These approaches involve:

- An assessment based on the distribution pattern of trips from a region, allowing the transport links which are important to that region to be identified regardless of the traffic volume generated in the region;

- An assessment based on estimated annual traffic volumes between individual regions;

---

(1) Including reminder questionnaires to those households which do not respond to the initial questionnaire.

- A canvass of interested parties in the BTE, the Department of Transport and other organisations, inviting their assessments of those transport routes which they would regard as being significant now, or which may become significant in the future.

Whereas the first two approaches are designed to rank transport routes objectively in order of significance according to existing traffic conditions, the latter approach allows also for potential development areas to be given special consideration in the NTS.

THE CORRIDOR CONCEPT

In the previous Section the rather vague term 'transport route' was used to indicate the underlying philosophy of the NTS sample distribution. The intention in this Section is to define the concept of a transport route in a way which is useful for developing a sample distribution procedure.

Aplin *et al.* (1976) describe the derivation and calibration of a gravity model which yields estimates of the proportion of trips from an NTS region to each of the remaining NTS regions[(1)]. The results from this gravity model can be summarised in the form of an origin-destination (O-D) matrix of size 64 x 64[(2)] in which the elements (p_{ij}) represent the proportion of trips from NTS region i to NTS region j. Such an O-D matrix has 4096 elements, most of which are extremely small in magnitude. In order to allow attention to be focussed on the most significant travel routes, the concept of a route as having the dual characteristics of both an O-D pair and a corridor was developed.

---

(1) It should be noted that a gravity model has some inherent limitations. In particular such a model will not estimate intra-regional trips. However, the criteria applied to the trips to be included in the NTS and the nature of the NTS regions have been designed to minimise the effects this limitation has on the sampling philosophy.

(2) There are 64 NTS regions defined for Australia.

For many O-D pairs the major surface transport link[1] between the origin and destination regions will geographically traverse certain intermediate NTS regions. Thus, the interaction of these intermediate regions with the transport link ascribes the characteristics of a corridor to the O-D pair.

Two of the criteria previously discussed allow the identification[2] of significant O-D pairs objectively. These criteria are:

- The proportion of trips from the origin region to the destination region;

- The absolute traffic volume encountered on an O-D pair.

The first criterion allows at least the more important transport links from most of the NTS regions to be identified regardless of the volume of traffic generated by the regions along these links. Using this criterion, significant O-D pairs can be identified directly from the O-D matrix mentioned above. Hence all O-D pairs which represent trip proportions greater than some arbitrary value can be identified as being worthy of particular consideration in distributing the NTS sample most effectively. However, unless the trip proportion taken as the arbitrary cut-off level is chosen to be very small, some O-D pairs which sustain high absolute traffic volumes will be ignored in this process[3].

---

(1) For practical purposes the major transport link has generally been assumed to follow the most direct road link. There are obvious exceptions to this, as in the case of Tasmania.

(2) The process used for this identification is explained in detail in Chapter 4.

(3) Clearly if the cut-off proportion is very small the number of O-D pairs which remain to be analysed is exceedingly large in relation to the size of the total sample available for distribution. However, some O-D pairs represent small <u>proportions</u> of trips but high trip <u>volumes</u>. These situations tend to arise in the cases of O-D pairs representing links between large capital cities and other major centres. These O-D pairs are obviously significant in the terms defined earlier. Hence the second criterion becomes appropriate in identifying significant O-D pairs in certain instances. In effect, as will be detailed in Chapter 4, both of the above criteria are used to develop a hierarchy of O-D pairs based on their levels of significance as transport links.

Hence the second criterion is required to ensure that all significant O-D pairs are considered.

Using the above approach a set of significant O-D pairs can be identified which, in size, is sufficiently manageable for more detailed investigation. In developing the approach to the distribution of the NTS sample it was decided that NTS regions which were traversed by the main links joining the significant O-D pairs should be treated in more detail than if they were considered solely in isolation. This empirical argument is based simply on the general social and economic interactions which are known to exist between populated geographic regions and the transport routes serving these regions. In this sense, the significant O-D pairs can be regarded as corridors in which the regions situated between the origin and destination regions have a relationship to the transport link represented by the O-D pair.

Since all of the significant O-D pairs have been identified according to the criteria discussed above, the most significant NTS regions in terms of travel attraction and generation have effectively also been identified. These regions represent the terminal regions of the significant O-D pairs. Hence it is considered that for the purposes of sample distribution, the sample sizes for the intermediate NTS regions can be based solely on the travel relationships which these regions have with the regions representing the terminal points of the associated[1] significant O-D pairs. The result of this approach further minimises the number of regional travel interactions which need to be examined and allows attention to be focussed on the most important of these interactions. Further details of this process are given in Chapter 4 and Appendix I.

---

(1) The associated O-D pairs represent the corridors traversing the intermediate NTS region.

STATISTICAL CHARACTERISTICS

Many statistical characteristics are associated with any sample. In the case of the NTS, primary concentration is clearly centred on those statistical properties associated with travel characteristics.

In estimating the travel characteristics of a zone or region, statistical errors are associated (amongst other things) with:

- Estimation of the absolute traffic volume generated in the region(1);

- Estimates of the proportion of this volume which arrives at each possible destination(2).

The statistical error associated with estimates of the absolute magnitude of a characteristic is essentially a function of the sample size and the variance of the particular characteristic among sampling units (households in this case). The statistical error in the estimate of a simple proportion is a function of that proportion and sample size. These statistical errors are independent in the present situation, although both are influenced by the sample size. A regional sample size could therefore be specified through a criterion which either:

- Specifies an allowable error tolerance on the estimated absolute traffic volume generated in the region(3); <u>or</u>

- Specifies an allowable error tolerance on the proportion of traffic which is attracted to some particular destination.

---

(1) As measured, say, by the average number of person-trips generated per household in a given period.
(2) This represents estimation of the fractional distribution by destination of the total traffic generated in the region.
(3) An estimate of the variance over sampling units would also be required for application of this criterion. This variance depends both on regions and time of year, and its characteristics with respect to these are not known prior to the conduct of the actual survey.

Both of the sources of statistical error mentioned above contribute to the statistical errors associated with estimates of traffic between particular O-D pairs. However, as discussed in the previous Section, the significance of the transport corridors serving[1] each region is measured in the present context primarily by the proportion of trips generated along the corridor by the particular region. Hence the second criterion mentioned above was chosen as the sampling criterion and used to distribute the fixed overall sample among all of the NTS regions. The first type of error (associated with estimates of travel generation levels) mentioned above will then be determined, inter alia, by the regional sample sizes, rather than the converse.

Aplin *et al.* (1976) illustrate the use of the gravity model in deriving relative trip distributions for sampling purposes. The details of the procedure involved in deriving actual regional sample sizes for the NTS are given in the next Chapter. However, it should be noted that this method is completely empirical and incorporates a number of arbitrary criteria which will be mentioned where appropriate. Some of these criteria are necessary as a result of the requirement for quite stringent limitations on the total sample size.

---

(1) As previously mentioned, regions traversed by transport routes represented by O-D pairs are assumed to have a transport-based relationship with those routes. In this sense the O-D pairs assume the nature of corridors 'serving' the regions.

CHAPTER 4 - SAMPLE SIZE DERIVATION

PRELIMINARY SURVEY

In order to derive an appropriate NTS sample distribution under the constraints to be described in the next Section, certain information is required on the response characteristics to be expected from the survey. The usual way of obtaining such information is to conduct a small pilot survey in advance of the main survey. Obviously, there are also other valid reasons for conducting such a pilot survey (such as testing of questionnaire design and so on).

A pilot survey(1) (Piko 1977) was carried out in April 1977, using questionnaire forms close to the style eventually adopted for the final survey. This pilot survey was conducted in three of the regions representing the main geo-demographic types of regions in Australia(2). It requested details on trips carried out during the previous month (March 1977). The results from this pilot survey were used to plan the distribution of the total sample for the main NTS. In addition to data on travel and personal characteristics of respondents, two useful items of household information were obtained from the pilot survey. These were:

- The response rate to be expected from the NTS, together with its distribution over time;

- The average number of person-trips generated per household per month.

---

(1) It is worth mentioning that an earlier pilot survey was also carried out, but used a quite different questionnaire. Some of the results of this earlier pilot survey were also used in the analysis.

(2) The regions surveyed and the sample sizes were as follows:
- ACT (NTS region 101) - 100 households;
- Southern Tablelands, NSW (NTS region 209) - 100 households;
- Melbourne (NTS region 311) - 500 households.

The pilot survey indicated that an overall response rate of around 50 per cent could be expected from the NTS, assuming that a reminder questionnaire would be sent to all non-respondents to the initial questionnaire. Approximately 85 per cent of the original response appeared to be distributed over a period of ten days. However, this period is affected in the NTS itself by the inevitable delays associated with the much greater distances generally involved in delivery and return of the questionnaires.

The survey also indicated that the number of person-trips (1) sampled from each responding household should average approximately 1.2 for a particular month. Of course, this average refers to the travel generation level estimated for the particular month surveyed (March). It is to be expected that this generation rate would vary not only seasonally but also by NTS region (2). In particular, the travel generation rates for holiday periods such as those around Christmas and Easter can be expected to be substantially in excess of that shown by the pilot. However, this pilot survey value of 1.2 person-trips per household per month does represent a reasonable working figure for sample planning purposes.

CONSTRAINTS

The postal budget for the NTS is restricted to $36000 for the twelve-month period of the survey. This is by far the most important constraint on the size and scope of the NTS. With postage rates (3) estimated at $0.16 per mailed questionnaire and $0.21 per reply-paid returned questionnaire, approximately 7800-8000 questionnaires can be mailed each month, given the

---

(1) It is important to note that when 'trips' are discussed quantitatively throughout this Paper, the reference is to 'person-trips'. This quantity is a more appropriate measure of travel generation levels than, say, household trips.

(2) As indicated by results presented by Piko (1977).

(3) The postage quoted for mailed questionnaires assumes that bulk mailing rates will apply in distributing the monthly samples and the reminders.

estimated response rate of 50 per cent and an appropriate distribution of reminders. Hence the total size of the postal sample is effectively pre-determined. An initial planning figure of 8000 has been used for determining the actual sample. If the response rate of 50 per cent estimated from the pilot survey is achieved, this sample should result in around 4000 replies being received each month. Assuming a value for trip-response of 1.2 person-trips per household per month, an estimated trip sample of 4800 can be expected to result from the 4000 replies which in turn are expected from the 8000 households sampled.

As indicated in the previous Chapter, the statistical accuracy of the travel information produced by the survey is affected by both:

- The number of households replying, which affects the standard error of travel generation estimates;

- The number of trips sampled from these households, which affects the standard errors associated with estimates of trip distribution characteristics.

Since the primary sampling criterion is based on acceptable error tolerances on estimated regional trip distributions, the total number of trips to be sampled is of prime importance in determining the sampling structure. In this context, the 4800 trips expected to be sampled each month represent a working figure to be used in the process of distributing the household sample throughout Australia.

Having arrived at a figure for the total number of trips expected to be sampled each month, the most effective distribution of the household sample must be determined. This is achieved by ensuring that the 4800 trips sampled each month are distributed in such a way as to reflect the relative significance of the related corridors. The sample distribution which achieves this aim is expressed in terms of the number of trips to be sampled in individual NTS regions each month.

CORRIDOR DETERMINATION

The general philosophy adopted for determining the significant transport links was outlined in the previous chapter. Essentially, this involves the use of the results from a gravity model which yields inter-regional trip distributions. This gravity model indicates (by nature) that all destinations attract a finite (though often very small) proportion of the traffic generated in an origin region. In order to produce a manageable assessment of significant corridors, all O-D pairs which involve a travel distance of 100 km or more and which were estimated to account for 10 per cent or more of trips from a particular origin region were identified. A second screening criterion was necessary to ensure that some high-traffic-volume O-D pairs were not ignored. Thus, in addition to the O-D pairs accounting for 10 per cent or more of trips from a particular region, other O-D pairs accounting for more than 100000 trips annually were included in the list(1).

The O-D pairs identified in this way were ranked according to the number of trips represented by them, as estimated from the gravity model. For the purposes of sample size selection, three groups were defined for these O-D pairs. These groups are defined as follows(2):

---

(1) This latter constraint is important, especially in the cases of Sydney and Melbourne, which generate large numbers of trips to diverse sets of destinations. For example, the gravity model results for Melbourne indicate a very uniform trip distribution. However, it was also estimated that the Melbourne-Sale O-D pair accounts for 107000 eastward trips annually, even though this represents only 3 per cent of trips originating in Melbourne.

(2) It should be noted that this grouping is quite arbitrary, and simply represents a practical way of developing a classification of relative O-D pair significance suitable for the process of distributing the sample.

- Major O-D pairs - O-D pairs estimated to represent over 100000 trips generated annually from a given NTS region;

- Secondary O-D pairs - O-D pairs estimated to represent between 50000 and 100000 trips generated annually from a given NTS region;

- Minor O-D pairs - O-D pairs estimated to represent less than 50000 trips generated annually from a given NTS region.

The results of this grouping are shown in Table 4.1. The estimated traffic volumes were calculated using the calibrated gravity model mentioned previously, together with data from a previous survey on domestic travel carried out for the Australian Travel Research Conference (ATRC 1974). These data were never intended for this application and their limitation is reflected to some extent in Table 4.1. In particular, the actual trip values shown in Table 4.1 should be treated with a great deal of caution. Nevertheless, it is believed that the O-D pair framework given in Table 4.1 does provide a reasonable representation of the relative significance of various O-D pairs throughout Australia.

As described in Chapter 3, O-D pairs are assumed to have the dual characteristic of a corridor for the process of sample distribution. This implies that the basically abstract concept of an O-D pair is assumed to be associated with the major surface transport link joining the origin and destination regions. Hence the corridor represented by the O-D pair may traverse a number of intermediate regions. As already discussed in Chapter 3, intermediate regions are assumed to have a relationship with the corridor. Nearly all of the NTS regions[1] are traversed by at least one of the corridors represented by the O-D pairs listed in

---

(1) Only two NTS regions are not traversed by any of these corridors. These regions were NTS region 801 (Darwin) and 802 (Alice Springs).

TABLE 4.1 - SIGNIFICANT O-D PAIRS (a) (b) (c)

O-D Pair	Trips (d) ('000)	O-D Pair	Trips (d) ('000)
	MAJOR O-D PAIRS		
Sydney-Newcastle	582	Melbourne-Sydney	170
Sydney-Wollongong	512	Melbourne-Warrnambool	144
Melbourne-Moe	337	Bunbury-Perth	144
Melbourne-Ballarat	301	Albany-Perth	141
Sydney-Bathurst	263	Brisbane-Sydney	131
Northam-Perth	252	Sydney-Goulburn	130
Melbourne-Bendigo	241	Melbourne-Wangaratta	129
Brisbane-Lismore	219	Adelaide-Melbourne	114
Melbourne-Shepparton	213	Brisbane-Toowoomba	114
Sydney-Canberra	172	Melbourne-Sale	107
	SECONDARY O-D PAIRS		
Sydney-Wagga Wagga	91	Melbourne-Deniliquin	63
Sydney-Armidale	83	Sydney-Dubbo	60
Brisbane-Taree	80	Sydney-Cooma	59
Brisbane-Armidale	77	Brisbane-Bundaberg	57
Melbourne-Wagga Wagga	75	Melbourne-Albury	53
Melbourne-Canberra	72	Sydney-Deniliquin	51
	MINOR O-D PAIRS		
Melbourne-Horsham	48	Launceston-Hobart	22
Melbourne-Mildura	45	Bundaberg-Rockhampton	22
Melbourne-Cooma	43	Adelaide-Broken Hill	21
Sydney-Lismore	41	Toowoomba-Nambour	20
Brisbane-Grafton	39	Melbourne-Broken Hill	19
Adelaide-Mildura	36	Melbourne-Grafton	17
Adelaide-Horsham	36	Sydney-Grafton	16
Perth-Derby	35	Perth-Kalgoorlie	15
Perth-Geraldton	35	Sydney-Broken Hill	15
Whyalla-Adelaide	32	Gold Coast-Lismore	14
Toowoomba-Gold Coast	30	Cairns-Townsville	10
Melbourne-Dubbo	28	Port Hedland-Perth	8
Adelaide-Kadina	26	Townsville-Mackay (e)	6
Melbourne-Hobart	25	Mount Isa-Brisbane	5
Adelaide-Port Lincoln	25	Melbourne-Queenstown	4
Brisbane-Rockhampton	24	Launceston-Queenstown	3
Melbourne-Burnie	23	Hobart-Queenstown	3
Sydney-Albury	23	Longreach-Brisbane	2
Melbourne-Launceston	22	Carnarvon-Perth	2

(a) Apart from major O-D pairs, these O-D pairs account for 10 per cent or more of trips from the origin region. Major O-D pairs account for at least 100000 trips annually and are included regardless of the proportion of trips accounted for. Secondary O-D pairs account for between 50000 and 99999 trips annually and minor O-D pairs account for less than 50000 trips annually.

(b) The dominant direction along the link is indicated by the stated order of the O-D pair.

(c) O-D pairs involving a nominal travel distance of less than 100 km have not been classified in this table.

(d) Trip levels are estimated on an annual basis in the dominant direction along the link. The fact that the figures are only approximations, derived on a fairly crude basis for sampling purposes, should be emphasised.

(e) The Townsville-Mackay O-D pair is to be sampled at major O-D pair level - see text for explanation.

Table 4.1. An objective basis is therefore available for distributing the total survey sample. Schematic representations of the corridors represented by the O-D pairs of Table 4.1 are provided in Figures 4.1 to 4.7. Figure 4.1 shows corridors which transcend State boundaries. Figures 4.2 to 4.7 show corridors in NSW, Victoria, Queensland, SA, WA and Tasmania respectively. As mentioned above, no significant corridors in the terms previously defined, occur in the Northern Territory. Also, for the purposes of this analysis, the ACT was regarded as part of NSW.

SAMPLE SIZE SELECTION

The sample size required for each NTS region needs to be determined according to the relative significance of its links with other regions (i.e. whether the links are corridors represented by major, secondary or minor O-D pairs). Tables by Aplin *et al.* (1976) show the sample size (in terms of trips) required to achieve relative errors of 10, 20 or 50 per cent (at 95 per cent confidence level) in estimated proportions of trips from particular NTS regions to other NTS regions. As the trip proportion decreases, a larger sample size is required to achieve a given relative accuracy. From the tables referred to above, it is clear that enormous sample sizes would be required to maintain even a 50 per cent relative error level for the estimation of trip proportions along all O-D pairs. For practical purposes therefore, certain minimum levels were chosen for trip proportions, below which an increase in the relative error in the statistical estimate would have to be tolerated. These so called cut-off values (p_C) of trip proportions were used as criteria for establishing the theoretical maximum trip sample size (n_{MAX}) to be obtained from NTS regions traversed by the corridors represented by the significant O-D pairs.

The implication of this approach is as follows. Suppose that some minimum level of relative error in the estimation of the proportion of trips from a particular region is chosen as being

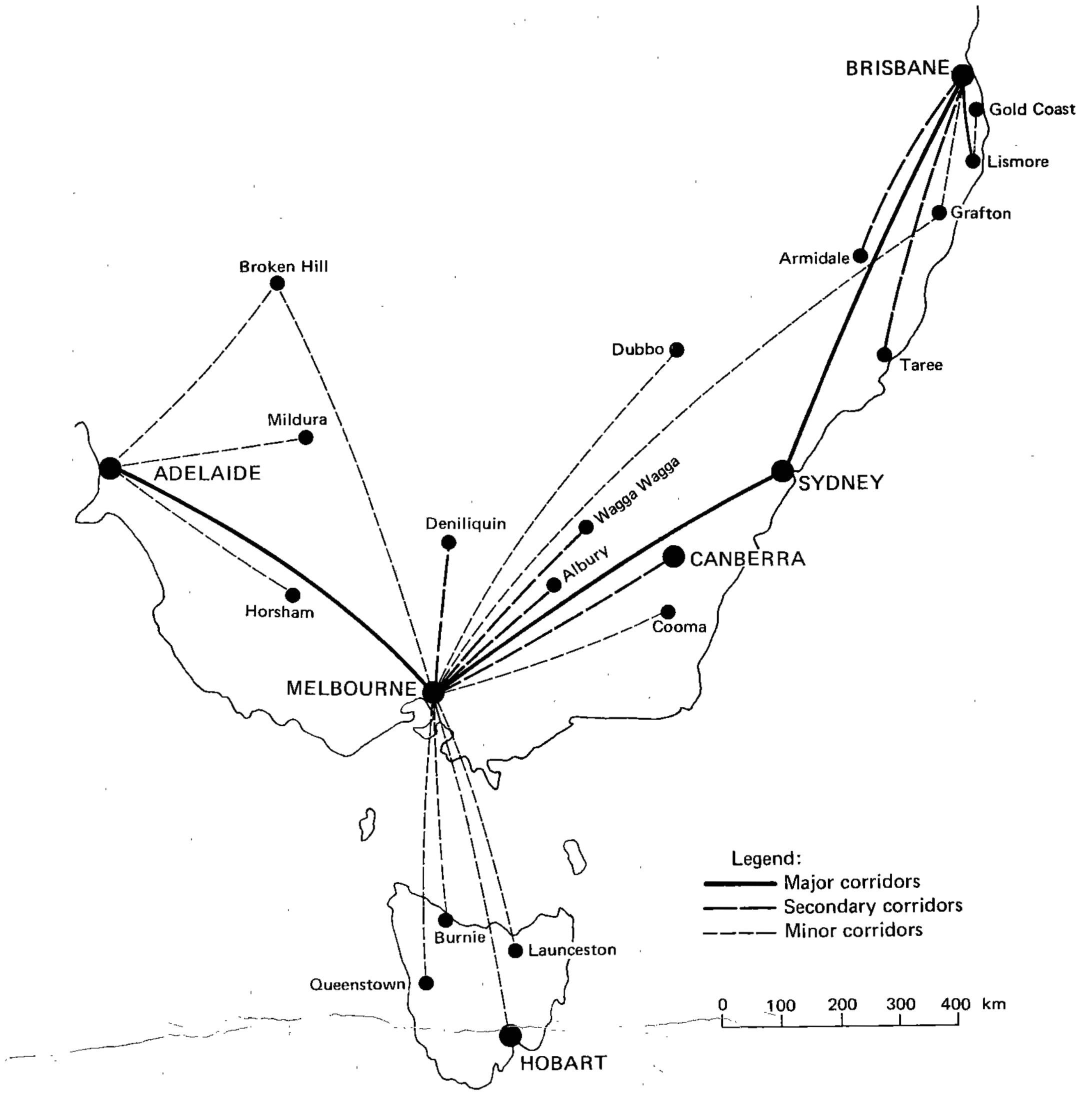

FIGURE 4.1 – NTS INTERSTATE CORRIDORS

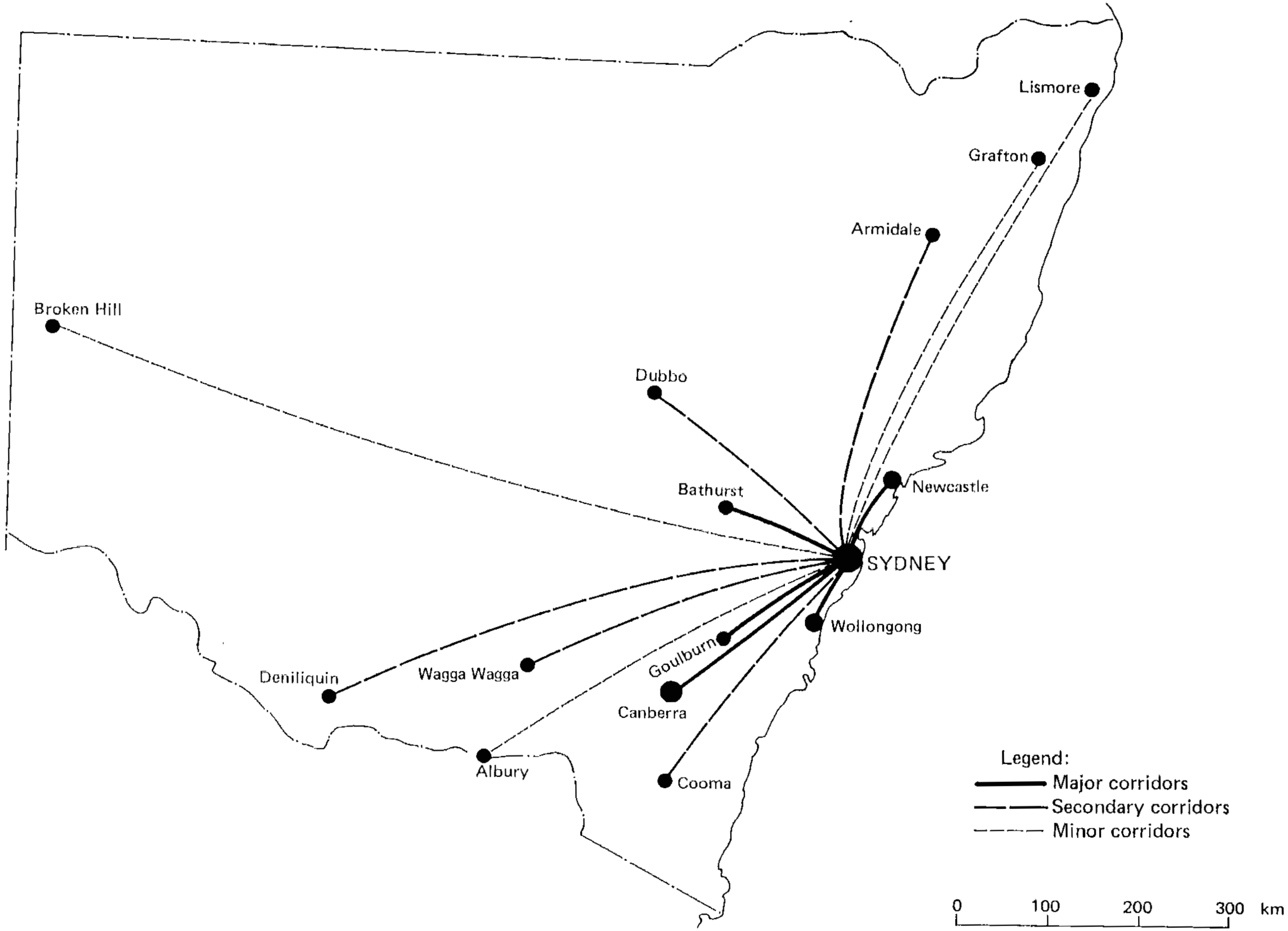

FIGURE 4.2 – NTS CORRIDORS WITHIN NEW SOUTH WALES

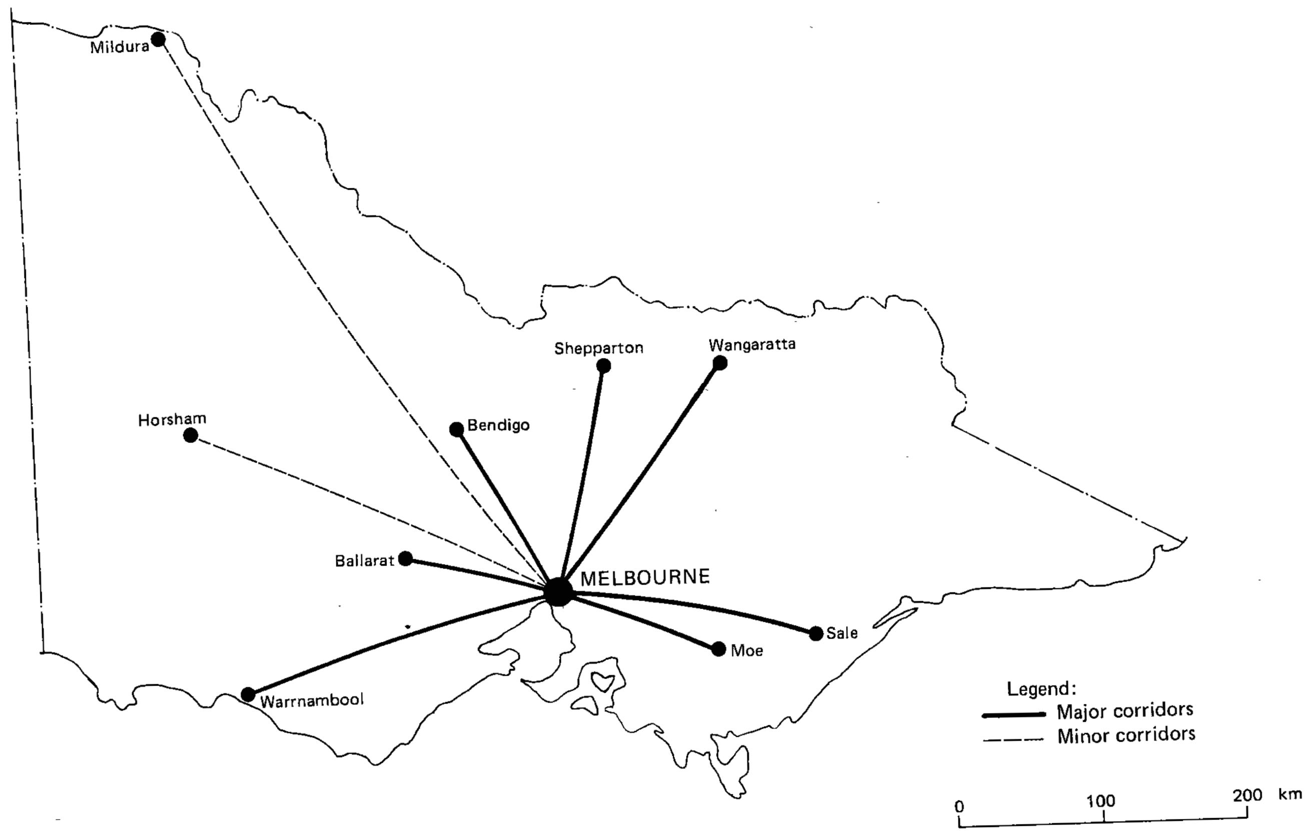

FIGURE 4.3 – NTS CORRIDORS WITHIN VICTORIA

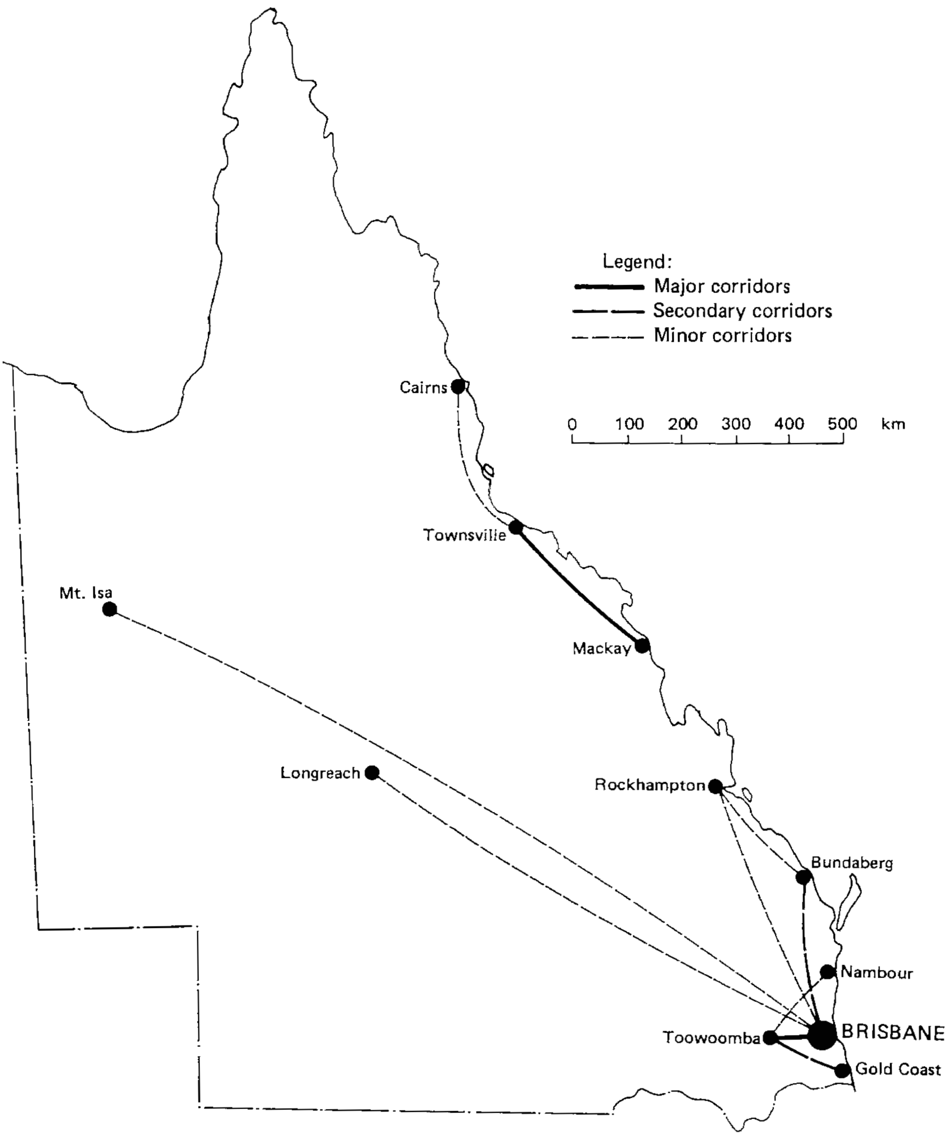

FIGURE 4.4 — NTS CORRIDORS WITHIN QUEENSLAND

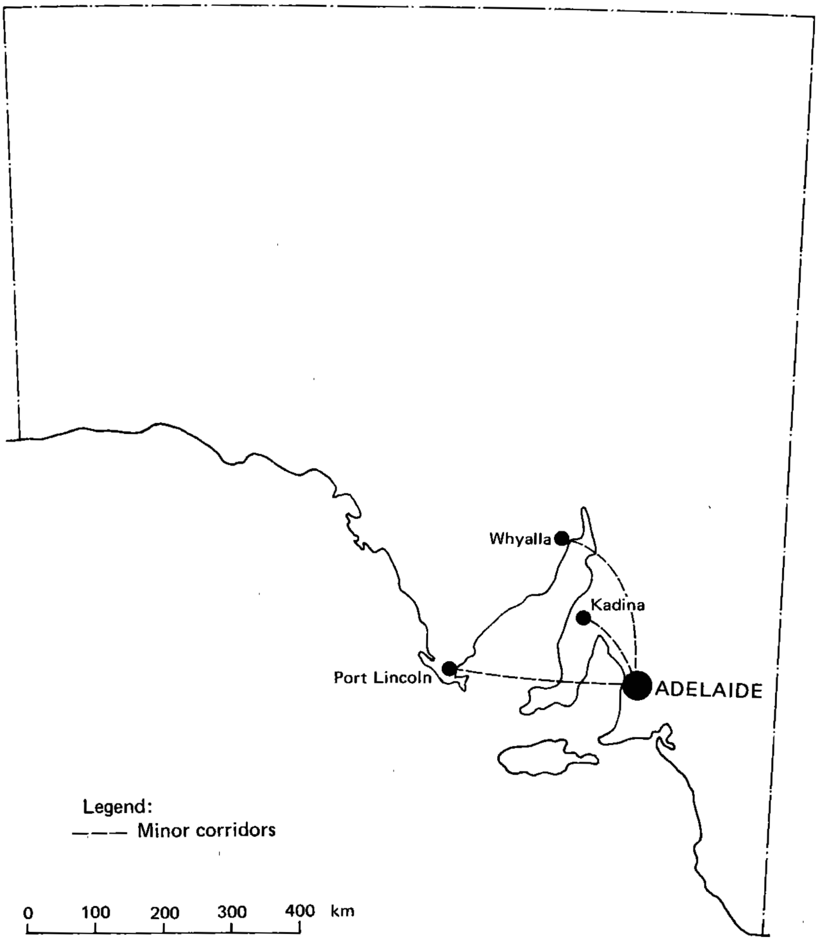

FIGURE 4.5 – NTS CORRIDORS WITHIN SOUTH AUSTRALIA

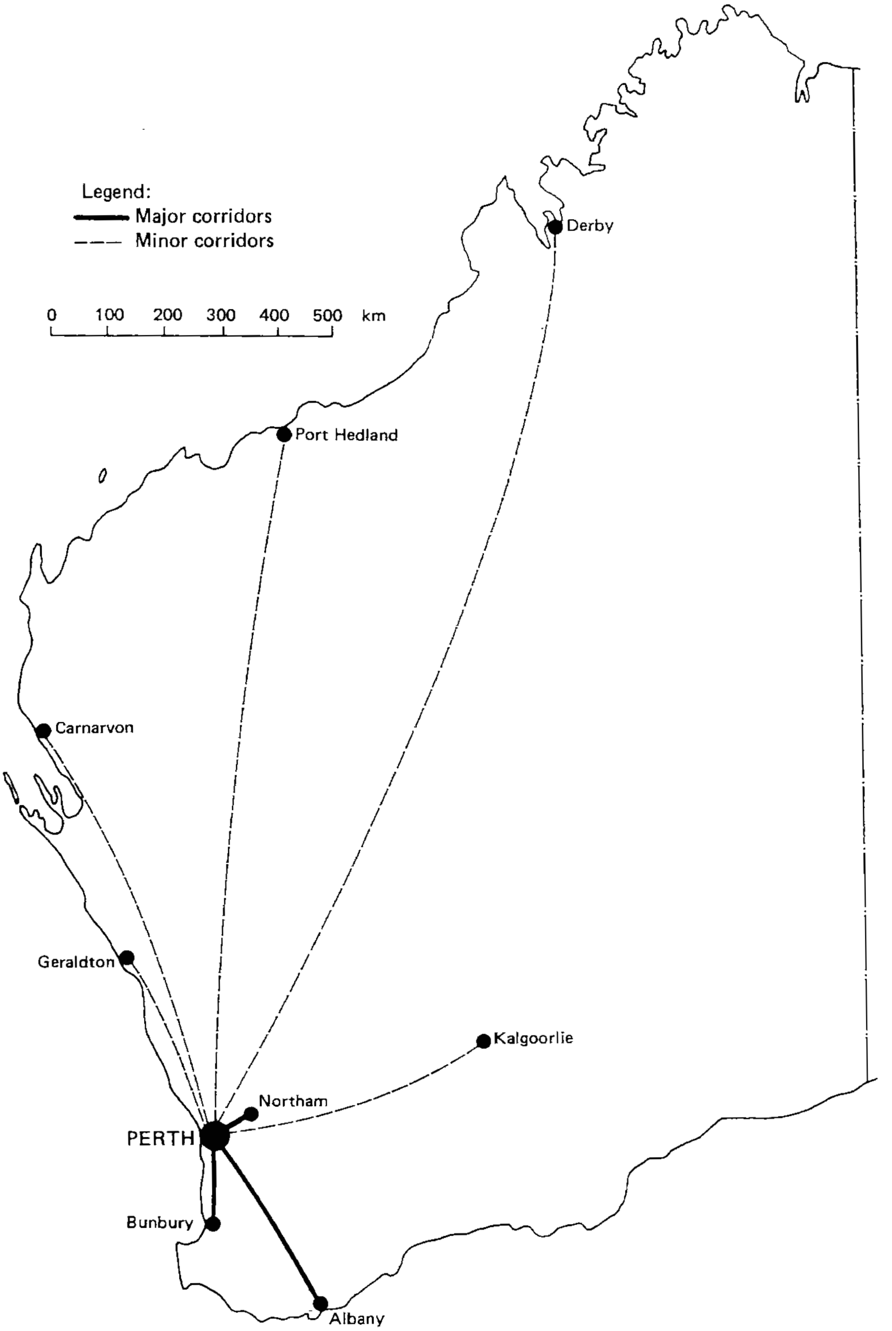

FIGURE 4.6 – NTS CORRIDORS WITHIN WESTERN AUSTRALIA

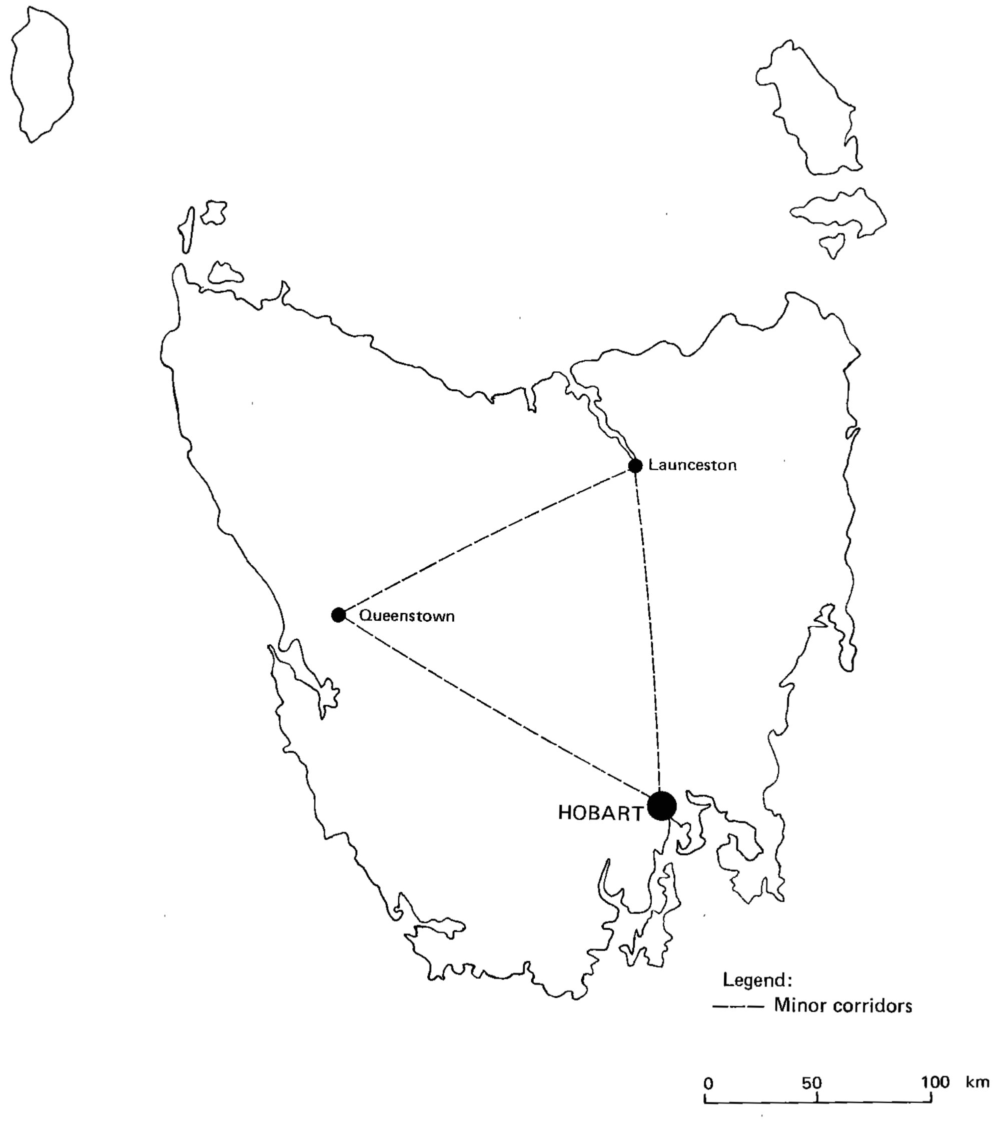

FIGURE 4.7 – NTS CORRIDORS WITHIN TASMANIA

desirable[1]. O-D pairs representing a proportion p_C of trips from the origin region will have this proportion estimated with the chosen level of accuracy. Similarly, other O-D pairs representing trip proportions which are greater or less than p_C will have these proportions estimated to a level of accuracy which is greater or less than the minimum desirable level. The value of p_C to be applied in an NTS region depends upon the significance of the O-D pairs which represent the corridors traversing that region. The value of p_C applied to regions traversed by corridors represented by major O-D pairs should be smaller than that applied to regions traversed by corridors represented only by minor O-D pairs[2]. This means that the sample size for the regions traversed by corridors represented by major O-D pairs will in general be greater than that for other regions.

The actual selection of values of p_C to be applied to regions traversed by corridors in the three categories depends greatly on the total sample constraint on the survey. Selection of these values will be considered later.

However, a further consideration must be taken into account. The application of the above procedure alone would not allow the actual volume of traffic between an O-D pair to affect the required trip sample size. Since only trip <u>proportions</u> are considered, O-D pairs which contain a high traffic <u>volume</u>, but which represent only a small <u>proportion</u> of trips made from a major city would be comparatively undersampled[3]. This would produce errors in traffic estimation which could be quite large in absolute terms. To overcome this difficulty, it was decided that all regions generating more than 100000 trips annually

---

(1) The desirable accuracy criterion will be discussed in the next Section.

(2) It is more important to improve the accuracy of the estimated trip distribution along the major corridors.

(3) The case of Melbourne which (on the basis of limited gravity model results) generates a fairly uniform trip distribution along various corridors has already been mentioned.

between an O-D pair (i.e. a major O-D pair) should be sampled so as to achieve the desired level of accuracy[1]. If the particular O-D pair represents a proportion of trips smaller than the value of p_C set for major O-D pairs, the trip sample size is chosen to exceed n_{MAX} and allow the chosen accuracy criterion to apply to the trip proportion estimates obtained for that O-D pair.

ACCURACY CRITERION

So far the discussion has been in terms of 'a desirable level of accuracy' for O-D trip-distribution estimation. The problem of choosing the desired level of accuracy remains. After an examination of the various factors influencing the survey, the type of information required from the survey and the practical constraints imposed on it, it was decided to set this desired level of accuracy at 50 per cent relative error for the monthly samples. This accuracy level was foreshadowed by Aplin *et al.* (1976), who also indicated the resulting accuracy for the statistics accumulated over the course of a year. Further investigation since the publication of that paper has indicated that the above level of statistical accuracy represents a reasonable compromise between survey precision and survey cost.

The preceding discussion on sample selection philosophy can now be summarised and clarified in terms of the level of accuracy chosen as being desirable. A number of situations can be distinguished as follows:

---

(1) This is irrespective of the proportion of trips from the origin, accounted for by the major O-D pair. It is also worth noting that the definition of major O-D pairs used throughout this paper is very conservative; it implies only approximately 300 person-trips per day, admittedly in a non-urban context.

- An NTS region generates more than 100000 trips annually to a particular destination region. The origin region is sampled to the level required for the proportion of trips for this O-D pair to be estimated to within 50 per cent relative error[1].

- An NTS region is traversed by a corridor represented by a major O-D pair but does not itself generate 100000 trips annually to any particular destination region. A value appropriate to major O-D pairs is assigned to p_C. Provided that the proportions of trips from the NTS region to the end points of the corridors (represented by the major O-D pairs) equal or exceed p_C, the region is sampled so that these proportions are estimated with a relative error which is not greater than 50 per cent. Trip proportions less than p_C will be estimated to a lower level of accuracy.

- An NTS region is traversed by a corridor represented by a secondary O-D pair (but not by a corridor represented by a major O-D pair). A value appropriate to secondary O-D pairs is assigned to p_C. This value will be larger than the corresponding value for major O-D pairs, and so the maximum regional sample size will be smaller. Again the result in terms of relative errors is similar to that for major O-D pairs. Provided that the proportions of trips from the NTS region to the end points of the corridors (represented by secondary O-D pairs) equal or exceed p_C, the region is sampled so that these proportions are estimated with a relative error not greater than 50 per cent. Trip proportions less than p_C will be estimated to a lower level of accuracy.

---

(1) This criterion (which is referred to in all the situations to be described) refers to the error to be expected from any particular monthly sample. If trip distributions are derived from the data accumulated over the course of 12 months, the error will reduce to $12^{-\frac{1}{2}}$ or 0.29 of 50 per cent, i.e. 14 per cent relative error. See Aplin *et al.* (1976).

- An NTS region is traversed by a corridor represented by a minor O-D pair (but not by a corridor represented by a major or secondary O-D pair). Such cases are treated as for regions traversed by corridors represented by secondary O-D pairs, except that a higher value of p_C is used to reflect the reduced significance of the less travelled corridors.

The sensitivity of the total sample size to various values of p_C for each of the three O-D pair categories was examined. Full details of the underlying process are given in Appendix I. The results of the sensitivity tests are summarised in Table 4.2. Quite a substantial variation in the required trip sample size occurs for comparatively small variations in the values of p_C chosen for the O-D pair categories. Option 2 in Table 4.2 meets the overall sample size constraint(1) quite closely, after the adjustments are taken into account. It therefore represents the sampling criteria to be used in distributing the sample for the NTS.

REGIONAL SAMPLE SIZES

This section discusses the derivation of regional sample sizes using Option 2 in Table 4.2. Values of p_C used in generating the regional sample size distribution are 14 per cent, 20 per cent and 26 per cent applied to major O-D pairs, secondary O-D pairs and minor O-D pairs, respectively. These values imply that the monthly trip sample sizes which should be obtained from the various regions should not exceed the following values:

- Regions traversed by corridors represented by major O-D pairs - 92 trips;

---

(1) 4800 trips per month. As explained previously, the major constraint is the postal budget.

TABLE 4.2 - THE IMPACT OF p_C VALUES ON MONTHLY SAMPLE SIZES

Option	O-D pair Category	Values of p_C	Max. Sample Size for Intermediate NTS Regions (person-trips)	Basic Sample Size (person-trips)	Adjustments to Sample			Final Sample Size (person-trips)
					Mackay-Townsville Corridor (a)	Regional Sample Limitation (b)	Inclusion of Two Extra NTS Regions (c)	
1	Major	0.15	86	3172				
	Secondary	0.20	61	397				
	Minor	0.25	45	1126				
				4695	82	134	90	4733
2	Major	0.14	92	3286				
	Secondary	0.20	61	397				
	Minor	0.26	43	1072				
				4755	98	122	86	4817
3	Major	0.14	92	3286				
	Secondary	0.20	61	397				
	Minor	0.25	45	1126				
				4809	94	134	90	4859
4	Major	0.12	112	3646				
	Secondary	0.18	69	447				
	Minor	0.24	48	1207				
				5300	128	152	96	5372
5	Major	0.10	138	4040				
	Secondary	0.20	61	397				
	Minor	0.30	35	865				
				5302	206	78	70	5500
6	Major	0.10	138	4040				
	Secondary	0.20	61	397				
	Minor	0.25	45	1126				
				5563	186	134	90	5705
7	Major	0.10	138	4040				
	Secondary	0.15	86	547				
	Minor	0.25	45	1126				
				5713	186	134	90	5855

(a) If the Mackay-Townsville O-D pair is upgraded for sampling purposes from a minor to a major O-D pair (in order to comply with a request from within the Department of Transport) the increase in total monthly sample size will vary from 82 to 206, according to the particular set of p_C values selected;

(b) In up to six NTS regions, the available number of addresses sufficiently complete to permit delivery of the questionnaire is less than the number required to satisfy the various criteria. Hence, the effective sample size will be reduced by a total of between 78 and 152;

(c) Two regions were not represented in the set of corridors defined by the significant O-D pairs. A sample size for each of these regions was selected (at the appropriate minor corridor p_C value) in order to ensure that the NTS has a comprehensive national coverage. The result increases the sample total by between 70 and 96, depending upon the p_C values selected.

- Regions traversed by corridors represented by secondary O-D pairs - 61 trips;

- Regions traversed by corridors represented by minor O-D pairs - 43 trips;

- Regions generating more than 100000 trips annually to a particular destination - sampled to level necessary to meet the 50 per cent relative error criterion on those O-D pairs. As previously mentioned, details of the method used to produce Table 4.2. are given in Appendix I.

As noted on Table 4.2, various additional adjustments were made to the sample distribution. The most significant of these were the sampling of two regions not traversed by any of the corridors previously defined, and the increased sampling of two Queensland NTS regions.

As noted previously, two NTS regions (Darwin and Alice Springs - NTS regions 801 and 802 respectively) were not traversed by corridors of the type defined in this Paper. It was considered desirable to achieve a national coverage. These two regions were therefore allocated a sample at the level of the other regions traversed by corridors represented by minor O-D pairs.

Particular interest was expressed(1) in the Proserpine, Shute Harbour and Mackay areas of Queensland. Based on the analysis described above, the relevant NTS regions (Mackay and Townsville - NTS regions 406 and 407 respectively) would have been sampled at a level corresponding to regions traversed by corridors represented only by minor O-D pairs. As a result of the particular interest in this area, these regions were sampled at the level appropriate to regions traversed by corridors represented by major O-D pairs(2).

(1) By the Ground Facilities Division of the Department of Transport.
(2) This results in more than doubling the sample size for these regions.

Table 4.3 shows the regional trip samples corresponding to Option 2 (see Table 4.2), which comes closest to satisfying the 4800 trips per month constraint. Also shown in Table 4.3 are the expected numbers of household responses required in order to obtain each regional trip sample[1], and the number of households which need to be surveyed[2] in order to achieve those response levels. As a result of certain practical difficulties with obtaining a satisfactory address file on a national basis, the monthly household sample to be surveyed has been restricted in certain regions (as indicated in Table 4.3). The number of satisfactory postal addresses in these regions is severely limited. The region with the least number of suitable household addresses is Woomera (NTS region 509); a total of only 44 addresses in this region is available at present. To maintain consistency with the remainder of Table 4.3, these addresses have been apportioned to achieve an effective monthly household sample size of approximately three. However, this region will be sampled once with all of the available addresses being surveyed. The possibility of obtaining a greater household sample for this region and some other regions has been investigated. A limited number of addresses will be selected manually to supplement those available from the survey address file. Minor alterations to some of the remaining regional sample sizes may be necessary to accommodate the increased sample for these regions within the total sample size constraint.

---

(1) As mentioned earlier, an average of 1.2 person-trips per household sampled each month is assumed.
(2) This assumes a 50 per cent response rate.

TABLE 4.3 - MONTHLY SAMPLE SIZES FOR EACH NTS REGION - OPTION 2

Region Number	Major Centre	Households Contacted	Expected Response Households	Expected Response Trips
ACT				
101	Canberra	102	51	61
NSW				
201	Lismore	154	77	92
202	Armidale	102	51	61
203	Dubbo	72	36	43
204	Broken Hill	72	36	43
205	Deniliquin	102	51	61
206	Albury	154	77	92
207	Wagga Wagga	126	63	76
208	Bathurst	102	51	61
209	Goulburn	154	77	92
210	Cooma	72	36	43
211	Newcastle	154	77	92
212	Gosford	154	77	92
213	Wollongong	154	77	92
214	Sydney	628	314	377
215	Grafton	154	77	92
216	Taree	154	77	92
		2508	1254	1501
VIC				
301	Geelong	154	77	92
302	Warrnambool	32	16	19
303	Ballarat	154	77	92
304	Horsham	154	77	92
305	Mildura	72	36	43
306	Bendigo	72	36	43
307	Shepparton	154	77	92
308	Wangaratta	154	77	92
309	Sale	72	36	43
310	Moe	154	77	92
311	Melbourne	800	400	480
		1972	986	1180
QLD				
401	Brisbane	422	211	253
402	Gold Coast	154	77	92
403	Nambour	102	51	61
404	Bundaberg	102	51	61
405	Rockhampton	72	36	43
406	Mackay	154	77	92
407	Townsville	154	77	92
408	Cairns	72	36	43
409 (a)	Mount Isa	72	36	43
410 (a)	Longreach	66	33	39
411	Roma	72	36	43
412	Toowoomba	102	51	61
		1544	772	923

TABLE 4.3 - (Continued) MONTHLY SAMPLE SIZES FOR EACH NTS REGION - OPTION 2

Region Number	Major Centre	Households Contacted	Expected Response Households	Expected Response Trips
SA				
501	Adelaide	266	133	160
502	Port Lincoln	72	36	43
503	Kadina	72	36	43
504	Whyalla	72	36	43
505	Gawler	72	36	43
506	Victor Harbor	154	77	92
507	Murray Bridge	154	77	92
508 (a) (b)	Mount Gambier	154	77	92
509 (a) (b)	Woomera	3	1	1
		1019	509	609
WA				
601	Albany	22	11	13
602	Bunbury	14	7	8
603	Kalgoorlie	56	28	33
604	Northam	72	36	43
605 (a)	Port Hedland	72	36	43
606 (a)	Derby	28	14	16
607	Geraldton	72	36	43
608 (a)	Perth	154	77	92
609 (a)	Carnarvon	44	22	26
		534	267	317
TAS				
701	Hobart	72	36	43
702	Burnie	72	36	43
703 (a)	Launceston	72	36	43
704 (a)	Queenstown	39	19	22
		255	127	151
NT				
801 (a)	Darwin	72	36	43
802 (a)	Alice Springs	55	27	32
		127	63	75
TOTAL		8061	4029	4817

(a) Insufficient number of household addresses available in this region to allow full sample.

(b) Approximately 44 usable addresses are available in NTS region 509. This would on average allow three to four addresses to be sampled each month, as shown. However, all of these addresses will be sampled in the first month of the survey. Special arrangements will be made to increase the usable sample in subsequent months.

CHAPTER 5 - OTHER STATISTICAL IMPLICATIONS

As indicated in earlier Chapters, the total NTS sample has been distributed geographically on the basis of the relative significance of various O-D pairs (as determined by the distribution of trips from each NTS region), with special consideration being given to high-volume O-D pairs. The concern has been with determining the sample sizes required to measure certain O-D trip proportions to acceptable accuracies. However, it has also been noted that the accuracy with which total trip generation and other general statistical characteristics of the population are determined is also dependent on the sample sizes to be selected for the NTS[1].

In this context, the statistical accuracy of general results derived from a survey sample depends on[2]:

- The sample size in relation to the size of population being sampled;

- The coefficient of variation[3] (C_V) of the particular results being considered.

Using the preliminary results of the pilot survey as a basis, an estimate can be made of the accuracy to be expected, for example, in regional trip generation and household income. Table 5.1 summarises these estimates for the three NTS regions surveyed in the pilot study, assuming that the household responses shown in Table 4.3 will be obtained for these regions. Also shown is the estimated accuracy for a large industrial region (Newcastle -

---

(1) More correctly, the accuracy of these population statistics depends upon the total household response achieved from the survey. Statistical accuracies on a regional basis depend, of course, on the household response achieved from each region.

(2) Appendix II provides brief mathematical details of the method of analysis.

(3) Defined as the quotient of the standard deviation and the mean of the statistic.

TABLE 5.1 - STATISTICAL ACCURACY OF REGIONAL CHARACTERISTICS

Region	Sample Period(a)	Monthly Trip Generation			Household Income	
		C_v (b)	Relative Error(c) (per cent)	Absolute Error(d) (trips/ month)	C_v (b)	Relative Error(c) (per cent)
101	Month	0.62	17	8600	0.52	14
	Year	0.62	5	2500	0.52	4
209	Month	0.97	22	9600	0.67	13
	Year	0.97	6	2600	0.67	4
311	Month	1.70	17	161100	0.57	6
	Year	1.70	5	47400	0.57	2
211(e)	Month	1.70	38	59800	na	na
	Year	1.70	11	17300	na	na

(a) Period over which sample is accumulated.

(b) Coefficient of variation. Note that for illustrative purposes the value of C_v is assumed constant over a twelve-month period. In practice, of course, it will vary seasonally, and, if this variation is statistically significant, accumulation of the monthly results in this way would be invalid.

(c) Percentage error in mean representing 95 per cent confidence level.

(d) Error in total trip generation from region based on error in average trips per household and the number of households in region.

(e) The C_v and mean determined for Melbourne (NTS region 311) have been used in estimating values for Newcastle.

NTS region 211) which is a significant generator of trips to a capital city (Sydney). Because these trips represent a comparatively high proportion of total trips from region 211, the chosen relative error criterion for this corridor is achieved by a sample size which is small compared to, say, Sydney (see Table 4.3).

Table 5.1 shows that regional trip generation is estimated to a considerably higher degree of relative accuracy than that deemed to have been acceptable for estimating particular O-D pair trip proportions[1]. Even the statistical accuracy estimated for trip generation in the Newcastle region, using the largest value of C_v obtained from the pilot survey, is substantially above the limit determined by the trip proportion criterion accepted above. In terms of the absolute error in estimates of trip generation, the error in the rates estimated for Newcastle[2] (NTS region 211) would be approximately one-third of the corresponding absolute error in estimates for Melbourne (NTS region 311). Note however, that the Melbourne survey sample size is five times larger than the sample size for Newcastle.

(1) This was chosen as 50 per cent relative error on the basis of a monthly sample.
(2) Region 211 is the region with the largest number of households apart from the capital cities. The number of households used in these calculations was based on estimates from various sources.

CHAPTER 6 - CONCLUDING REMARKS

As well as being a major project from the direct viewpoint of management and administration, the National Travel Survey involves a number of relatively novel features which constrain its design and operation. For example, the following characteristics of the survey may be instanced in this regard:

- The survey is carried out on a 'national' basis;

- It is an extremely comprehensive travel survey, in terms of the household and personal information collected and the travel details sought;

- It is being carried out over a comparatively lengthy time period (12 months), in order to obtain details on seasonal or other temporal travel fluctuations.

Although the survey is 'national' in the sense that some indication of travel generation, distribution and modal split is required from the whole of Australia, resources available to the project are strictly limited. These limited resources, particularly financial resources, place a significant constraint on the survey in terms of its total sample size.

The limitations on the total sample size have been discussed in this Paper. The aim has been to distribute the total survey sample around Australia so that adequate statistical accuracy will be obtained for results derived on a regional basis. In order to produce a suitable sample distribution for the main survey, a pilot survey was conducted in order to obtain some preliminary statistical estimates of trip generation rates, survey response rates and so on. Results from the pilot survey were used to estimate the total trip sample size which could be expected, given the overall household sample size constraint.

The major part of this Paper has been concerned with showing the procedure adopted for determining the regional distribution desired for the sampled trips.

Fundamentally, the sample has been distributed in a way which will allow the statistical accuracy of the results to be weighted according to the relative significance of O-D pairs. The relative significance of these O-D pairs was estimated theoretically, using a gravity model calibrated using previously-gathered travel information. Apart from regions expected to generate 100000 or more trips annually to a particular destination, the maximum regional trip sample sizes were chosen to reflect the importance of the transport routes traversing the various regions. Regions which generated 100000 trips or more annually to particular destinations were sampled at the (higher) rates necessary to measure the trip proportion to the respective destinations with the desired level of accuracy.

The sample sizes determined in this way imply certain levels of statistical accuracy for other estimates which are to be made in the NTS. The particular estimates referred to in this context are those of strictly regional travel parameters, as distinct from distributional travel parameters. Clearly, accuracies of estimates of these two types of parameters are related. For example, sample size limitations result in statistical errors in regional trip generation and in the proportional distribution of these trips along various transport corridors. While primary concentration was on sampling to ensure appropriate levels of accuracy for trip distribution characteristics, attention has also been given to the need to ensure acceptable accuracies for regional population and travel characteristics. In terms of the general objectives of the NTS, the errors associated with the estimates of these regional parameters are considered to be acceptable.

In summary, the distribution of the available sample among the NTS regions, as proposed in this Paper, is believed to reflect the relative significance of particular transport corridors. There are certain difficulties with the available household address files in some regions, and this has led to an artificial reduction in their sampling rates. An attempt to rectify this situation is being made during the course of the survey. However, the regions requiring the reduced sample (at least initially) are all quite remote, with very low population densities and hence low total trävel travels. In any case, some adjustment to the sample size distribution may be required as the survey progresses and as regional characteristics can be estimated with greater accuracy. The pioneering nature of the NTS and its objective of producing information of a type which is not presently available are believed to justify the acceptance of the statistical errors imposed by the limited total sample size. Where information of greater accuracy is required, more limited intensive surveys may be appropriate. Planning of these should be assisted greatly by the results from the NTS.

LIST OF REFERENCES

Aplin, W.N. and Flaherty, H.M. (1976). Sampling Processes for the National Travel Survey. BTE Occasional Paper 5, AGPS, Canberra.

Aplin, W.N. and Hirsch, N.A. (1978). National Travel Survey 1977-78, Geographic Zoning and Coding System. BTE Occasional Paper, AGPS, Canberra. (In preparation).

Australian Travel Research Conference (1974). Survey of Australian Travel 1973-74. Canberra.

Long, G.D. (1974). Accuracy of Dwelling Unit Surveys in Travel Forecasting. *Traffic Engineering*. February.

Moll, J.W. (1978). National Travel Survey 1977-78, Objectives and Strategies. BTE Occasional Paper 10, AGPS, Canberra.

Piko, G.P. (1977). National Travel Survey 1977-78, Summary of Results for the Second Pilot Survey. BTE Staff Paper (unpublished).

APPENDIX I
CALCULATION OF SAMPLE SIZE FOR EACH REGION

This Appendix describes and illustrates the procedure actually used in deriving regional sample sizes. The description is expressed in terms of tabulations listing all of the corridors represented by significant O-D pairs, together with the NTS regions which these corridors traverse. These tabulations are designed to allow monitoring of sample sizes in each region to ensure that they are determined in a manner consistent with the requirements outlined in the body of this Paper. This monitoring process is used to take account of the fact that a given NTS region can be traversed by a number of defined corridors, and these corridors may have different levels of significance(1). The intention is that a particular NTS region should be sampled to a level consistent with the most significant corridor which traverses it.

The sample monitoring process can best be demonstrated by taking two typical O-D pairs as examples. They are the Sydney-Canberra and Sydney-Goulburn O-D pairs, both of which represent major corridors according to the definition used in this Paper. These corridors (and the regions which they traverse) are shown in Table I.1. The sample sizes given in Table I.1 follow on from the sampling strategy outlined in Chapter 3.

In this example, the corridor represented by the Sydney-Canberra O-D pair traverses NTS regions 214, 213, 209 and 101, the first and last regions representing the terminal regions of the corridor. In this corridor, a sample of 281 trips is required in Sydney to

---

(1) Strictly, the concept of 'significance' has been applied to O-D pairs which have been further grouped into the three categories - major, secondary and minor. However, for convenience when discussing the corridor nature of an O-D pair, that corridor will be referred to as having the same level of significance as the corresponding O-D pair.

TABLE I.1 - AN EXAMPLE OF THE SAMPLE MONITORING PROCESS[a] - MAJOR O-D PAIRS, SYDNEY-CANBERRA AND SYDNEY-GOULBURN

	Region	Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
	(1)	(2)[b]	(3)[c]	(4)	(5)	(6)[e]
214	Sydney ↕	-	281	281	-	281
213		11	92 x[d]	92	-	92
209		39	46	46	-	46
101	Canberra	38	-	38	-	38
214	Sydney ↓	-	377	377	281	96
213		11	92 x[d]	92	92	-
209	Goulburn	39	-	39	46	-

(a) In the major, secondary and minor O-D pair listings, most O-D pairs are shown with bi-directional arrows. This indicates that both directions along the O-D pair meet the traffic volume criteria applying to the relevant O-D pair category. However, some O-D pairs in the major and secondary O-D pair listings have uni-directional arrows, which indicate that only one direction meets the respective major or secondary O-D pair criterion.

(b) The column represents the sample size for a given region, based on the proportion of trips to the first terminal NTS region of the corridor.

(c) This column represents sample size for a given region based on the proportion of trips to the second terminal NTS region of the corridor.

(d) The symbol 'x' indicates that the sample size has been artificially limited according to the sampling strategy adopted.

(e) This column shows the net addition to the sample size for a particular region. In a full listing of all regions and corridors, the sum of entries in this column would give the total sample for a month. This point is discussed in greater detail later.

obtain a sample estimate of the proportions of trips to Canberra which satisfies the 50 per cent relative error criterion (Aplin *et al.* 1976, p. 85). This value is shown in column 3 of Table I.1. No limit is imposed on the size of the Sydney sample since it is estimated that the Sydney NTS region generates in excess of 100000(1) trips annually to Canberra(2). Column 5 of Table I.1 shows nil for Sydney, as this is the first corridor to be examined in the example. Hence, the full sum of 281 appears in column 6. The corridor traverses part of regions 213 and 209, and their interaction with the terminal regions of the corridor (Sydney and Canberra) is taken into account as described below.

Trip sample sizes of 11 and 337 in region 213 (Aplin *et al.* 1976, p.89) would be required to achieve a relative error of 50 per cent in the estimated proportions of trips from region 213 to region 214 and region 101 respectively. However, since region 213 is traversed by a corridor represented by a major O-D pair, but does not itself generate 100000 trips annually to region 101, the sample size for region 213 is artificially limited. Since Option 2 of Table 4.2 has been chosen as the sampling strategy, the sample size for region 213 will be limited to a value yielding 50 per cent relative error in the estimation of a trip proportion of 0.14(3). As shown in Table 4.2, the appropriate maximum sample size is 92. Hence, this value is used instead of the figure of 337 in column 3 of Table I.1 for region 213. On the other hand, region 213 generates in excess of 100000 trips annually to region 214, and therefore no artificial limit based on p_C has been imposed on the size of the sample in region 213. In any case, a sample size of only 11 satisfies the 50 per

---

(1) Note that numerical estimates of trips are based on trip proportions obtained from the calibrated gravity model presented by Aplin *et al.* (1976).

(2) Corridors represented by major O-D pairs are sampled to the level required to satisfy the 50 per cent relative error criterion, regardless of the proportional number of trips represented by the corridor.

(3) This represents the cut-off trip proportion (p_C) chosen for major corridors in Option 2.

cent relative error criterion in this case, according to Aplin *et al.* (1976). Column 4 of Table I.1 shows the sample required to cover trips in both directions (i.e. the larger of the totals in columns 2 and 3)[(1)].

Sample selection process for region 209 is simpler, because over 100000 trips annually are estimated for both the sectors from region 209 to region 101 and region 214. Thus, the sample restriction based on p_C does not apply[(2)]. Sample sizes in region 209 for these sectors are low in any case[(3)], with trip samples of 39 and 46 for Goulburn to Sydney and Canberra respectively.

Canberra (NTS region 101) is a terminal point of the corridor, and a sample of 38 is required to estimate the Canberra-Sydney trips within the 50 per cent relative error criterion. Therefore, columns 4 and 6 in Table I.1 show 38.

A second major O-D pair - Sydney to Goulburn - is now considered[(4)]. An examination of the Sydney-Goulburn and Sydney-Canberra O-D pairs reveals that monthly sample sizes required in Sydney to satisfy the acceptable statistical error criterion, are 377 and

---

(1) It should be noted that this sample size would permit the proportion of trips from region 213 to region 214 to be estimated to an accuracy considerably better than 50 per cent relative error.

(2) The Goulburn-Canberra O-D pair (NTS region 209 - NTS region 101) is not identified in Table 4.1 as a major O-D pair as it involves a nominal travel distance of less than 100 km. This sector is treated here, however, since NTS region 209 is traversed by the Sydney-Canberra corridor.

(3) Because the proportions of trips from region 209 to region 214 and region 101 respectively are comparatively high, a relatively small sample is required to meet the chosen relative error criterion.

(4) It may appear that separate examination of this O-D pair is unnecessary, having examined the Sydney-Canberra O-D pair. However, it must be emphasised that the end points of these corridors are NTS regions, not particular places. Thus NTS region 209, which for convenience is referred to as Goulburn, in fact encompasses other important centres such as Yass, Young, Crookwell and so on. Therefore, as defined here the Sydney-Canberra corridor is effectively a separate transport route from Sydney-Goulburn.

281 respectively. This is explained by the fact that a smaller proportion of trips is made from the Sydney NTS region to the Goulburn NTS region than from Sydney NTS region to the Canberra NTS region(1). In order to maintain accuracy at the 50 per cent relative error level for the estimates pertaining to the former O-D pair, it is necessary to increase the trip sample size in region 214. The tabulation for Sydney-Goulburn in Table I.1 demonstrates the importance of column 5 in the table - this column shows that 281 trips have already been sampled in Sydney, and ensures that an addition of 96 is made in column 6 to the Sydney sample in order to increase the total sample to 377. It also indicates that the sample of 92 in region 213 on the Sydney-Goulburn corridor is satisfactory and has earlier been established in column 6. A sample of 39 is required in Goulburn to estimate its interaction with Sydney within the 50 per cent relative error criterion, and column 5 indicates that a sample of 46 in Goulburn has already been provided. Therefore, column 6 shows that no increase in the previous Goulburn NTS region sample is required to adequately sample Goulburn-Sydney trips.

The procedure described above is shown for all corridors represented by major, secondary and minor O-D pairs in Tables I.2, I.3 and I.4 respectively. It can be seen that the constraint on sample numbers within intermediate regions becomes more severe as the O-D pairs diminish in significance. The limit on sample size is 92 (at a p_C value of 0.14) for intermediate regions on major corridors, 61 (at a p_C value of 0.20) for regions traversed by secondary corridors, and only 43 for regions traversed exclusively by minor corridors. This accords with the stated intention to sample more important corridors at levels higher than those for less important corridors. The total monthly samples are shown at the bottoms of the respective tables.

---

(1) But this proportion still represents over 100000 trips annually.

TABLE I.2 - THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MAJOR O-D PAIRS[(a)] [(b)]

Origin Region (1)		Sample Sizes Corresponding to Terminal NTS Regions of Corridor (2)	(3)	Maximum of (2) and (3) (4)	Sample Size Previously Determined (5)	Net Increase in Sample Size (6)
214	Sydney	11	281	281	-	281
213	↕	11	92 x	92 s	-	92
209		39	46	46	-	46
101	Canberra	38	-	38	-	38
214	Sydney	-	72	72	281	-
212	↕	5	92 x	92 s	-	92
211	Newcastle	12	-	12	-	12
214	Sydney ↕	-	84	84	281	-
213	Wollongong	11	-	11	92	-
214	Sydney ↕	-	178	178	281	-
208	Bathurst	17	-	17	-	17
214	Sydney	-	377	377 s	281	96
213	↓	11	92 x	92	92	-
209	Goulburn	39	-	39	46	-
214	Sydney	-	322	322	377	-
213	↕	11	92 x	92	92	-
209		39	92 x	92 s	46	46
207		49	76	76 s	-	76
206		92 x	44	92 s	-	92
308		92 x	25	92 s	-	92
307		92 x	20	92 s	-	92
311	Melbourne	296	-	296	-	296
311	Melbourne	-	352	352	296	56
301	↕	6	92 x	92 s	-	92
302	Warrnambool	19	-	19 s	-	19
311	Melbourne ↕	-	161	161	352	-
303	Ballarat	12	-	12	-	12

TABLE I.2 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MAJOR O-D PAIRS[(a)] [(b)]

Origin Region (1)		Sample Sizes Corresponding to Terminal NTS Regions of Corridor (2)	(3)	Maximum of (2) and (3) (4)	Sample Size Previously Determined (5)	Net Increase in Sample Size (6)
311	Melbourne	-	205	205	352	-
306	Bendigo	18	-	18	-	18
311	Melbourne	-	234	234	352	-
307	Shepparton	20	-	20	92	-
311	Melbourne	-	442	442	352	90
307		20	92 x	92	92	-
308	Wangaratta	25	-	25	92	-
311	Melbourne	-	480	480 s	442	38
310		10	92 x	92 s	-	92
309	Sale	19	-	19	-	19
311	Melbourne	-	142	142	480	-
310	Moe	10	-	10	92	-
401	Brisbane	-	125	125	-	125
402		10	92 x	92 s	-	92
201	Lismore	30	-	30	-	30
601	Albany	-	13	13 s	-	13
608	Perth	92 x	-	92 s	-	92
602	Bunbury	-	8	8 s	-	8
608	Perth	76	-	76	92	-
604	Northam	-	6	6	-	6
608	Perth	70	-	70	92	-

TABLE I.2 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MAJOR O-D PAIRS[(a)(b)]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
501	Adelaide	-	160	160 s	-	160
506	↓	23	92 x	92 s	-	92
507	↓	19	92 x	92 s	-	92
508	↓	34	92 x	92 s	-	92
304	↓	92 x	26	92 s	-	92
303	↓	92 x	12	92 s	12	80
311	Melbourne	92 x	-	92	480	-
401	Brisbane	-	253	253 s	125	128
402	↓	10	92 x	92	92	-
412	Toowoomba	54	-	54	-	54
401	Brisbane	-	219	219	253	-
402	↓	10	92 x	92	92	-
201	↓	30	92 x	92 s	30	62
215	↓	92 x	92 x	92 s	-	92
216	↓	50	92 x	92 s	-	92
211	↓	92 x	12	92 s	12	80
212	↓	92 x	5	92	92	-
214	Sydney	92 x	-	92	377	-
						3286

(a) The symbol 'x' in columns 2 and 3 indicates that the value shown is the maximum sample permissible at the relevant p_C level.

(b) The symbol 's' in column 4 indicates the point at which the sample size for the particular region reached the level used in the actual survey. The sampling criteria outlined in the text were satisfied at this point and no increase in the sample size for the region was indicated in an examination of subsequent corridors.

TABLE I.3 - THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY SECONDARY O-D PAIRS [(a) (b)]

Origin Region (1)	Sample Sizes Corresponding to Terminal NTS Regions of Corridor (2)	(3)	Maximum of (2) and (3) (4)	Sample Size Previously Determined (5)	Net Increase in Sample Size (6)
214 Sydney	-	61 x	61	377	-
212 ↓	5	61 x	61	92	-
211 ↓	12	61 x	61	92	-
202 Armidale	42	-	42	-	42
214 Sydney	-	61 x	61	377	-
208 ↓	17	61 x	61 s	17	44
203 Dubbo	41	-	41	-	41
214 Sydney	-	61 x	61	377	-
209 ↓	39	61 x	61	92	-
207 Wagga Wagga	49	-	49	76	-
214 Sydney	-	61 x	61	377	-
209 ↓	39	46	46	92	-
101 ↓	38	61 x	61 s	38	23
210 Cooma	38	-	38	-	38
214 Sydney	-	61 x	61	377	-
209 ↓	39	61 x	61	92	-
207 ↓	49	61 x	61	76	-
205 Deniliquin	61 x	-	61 s	-	61
311 Melbourne	-	61 x	61	480	-
307 ↓	20	61 x	61	92	-
308 ↓	25	61 x	61	92	-
206 Albury	44	-	44	92	-

TABLE I.3 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY SECONDARY O-D PAIRS[(a)] [(b)]

Origin Region (1)		Sample Sizes Corresponding to Terminal NTS Regions of Corridor (2)	(3)	Maximum of (2) and (3) (4)	Sample Size Previously Determined (5)	Net Increase in Sample Size (6)
311	Melbourne	-	61 x	61	480	-
307		20	61 x	61	92	-
308		25	61 x	61	92	-
206		44	61 x	61	92	-
207		61 x	61 x	61	76	-
209		61 x	46	61	92	-
101	Canberra	61 x	-	61	61	-
311	Melbourne	-	61 x	61	480	-
307		20	61 x	61	92	-
205	Deniliquin	58	-	58	61	-
311	Melbourne	-	61 x	61	480	-
307		20	61 x	61	92	-
308		25	61 x	61	92	-
206		44	61 x	61	92	-
207	Wagga Wagga	61 x	-	61	76	-
401	Brisbane	-	61 x	61	253	-
402		10	61 x	61	92	-
201		30	61 x	61	92	-
215		61 x	61 x	61	92	-
216	Taree	50	-	50	92	-
401	Brisbane	-	61 x	61	266	-
402		10	61 x	61	92	-
412		54	61 x	61 s	54	7
202	Armidale	61 x	-	61 s	42	19

TABLE I.3 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY SECONDARY O-D PAIRS[(a) (b)]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
401	Brisbane	-	61 x	61	266	-
403	↕	30	61 x	61 s	-	61
404	Bundaberg	61 x	-	61 s	-	61
						397

(a) The symbol 'x' indicates that the value shown is the maximum sample permissible at the relevant p_C level.

(b) The symbol 's' indicates the point at which the sample size for the particular region reached the level used in the actual survey. The sampling criteria outlined in the text were satisfied at this point and no increase in the sample size for the region was indicated in an examination of subsequent corridors.

TABLE I.4 - THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[(a) (b)]

Origin Region (1)		Sample Sizes Corresponding to Terminal NTS Regions of Corridor (2)	(3)	Maximum of (2) and (3) (4)	Sample Size Previously Determined (5)	Net Increase in Sample Size (6)
214	Sydney	-	43 x	43	377	-
212	↑	5	43 x	43	92	-
211	│	12	43 x	43	92	-
216	│	43 x	43 x	43	92	-
215	↓	43 x	43 x	43	92	-
201	Lismore	43 x	-	43	92	-
201	Lismore ↕	-	43 x	43	92	-
402	Gold Coast	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
307	↑	43 x	43 x	43	92	-
205	│	43 x	43 x	43	61	-
207	│	43 x	43 x	43	76	-
208	↓	43 x	43 x	43	61	-
203	Dubbo	43 x	-	43	41	2
311	Melbourne	-	43 x	43	480	-
306	↑	18	43 x	43 s	18	25
305	│	40	43 x	43 s	-	43
205	↓	43 x	43 x	43	61	-
204	Broken Hill	43 x	-	43 s	-	43
214	Sydney	-	43 x	43	377	-
208	↑	17	43 x	43	61	-
203	↓	41	43 x	43 s	43	-
204	Broken Hill	43 x	-	43	43	-
501	Adelaide	-	43 x	43	160	-
505	↑	27	43 x	43 s	-	43
504	│	43 x	43 x	43 s	-	43
509	↓	43 x	43 x	43 s	-	43
204	Broken Hill	43 x	-	43	43	-

TABLE I.4 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[(a)(b)]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
214	Sydney	-	43 x	43	377	-
209	↕	39	43 x	43	92	-
207		43 x	43 x	43	76	-
206	Albury	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
310	↕	10	43 x	43	92	-
309		19	43 x	43	19	24
210	Cooma	43 x	-	43 s	38	5
401	Brisbane	-	43 x	43	266	-
402	↕	10	43 x	43	92	-
201		30	43 x	43	92	-
215	Grafton	43 x	-	43	92	-
214	Sydney	-	43 x	43	377	-
212	↕	5	43 x	43	92	-
211		12	43 x	43	92	-
216		43 x	43 x	43	92	-
215	Grafton	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
307	↕	20	43 x	43	92	-
207		43 x	43 x	43	76	-
208		43 x	43 x	43	61	-
203		43 x	43 x	43	43	-
202		43 x	43 x	43	61	-
215	Grafton	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
303	↕	12	43 x	43	92	-
304	Horsham	26	-	26	92	-

TABLE I.4 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[a] [b]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
501	Adelaide	-	43 x	43	160	-
506		23	43 x	43	92	-
507		19	43 x	43	92	-
508		34	43 x	43	92	-
304	Horsham	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
306		18	43 x	43	43	-
305	Mildura	40	-	43	43	-
501	Adelaide	-	43 x	43	160	-
505		27	43 x	43	43	-
507		19	43 x	43	92	-
305	Mildura	43 x	-	43	43	-
412	Toowoomba	-	43 x	43	61	-
403	Nambour	43 x	-	43	61	-
401	Brisbane	-	43 x	43	266	-
403		30	43 x	43	61	-
404		43 x	43 x	43	61	-
405	Rockhampton	43 x	-	43 s	-	43
404	Bundaberg	-	43 x	43	61	-
405	Rockhampton	43 x	-	43	43	-
408	Cairns	-	43 x	43 s	-	43
407	Townsville	43 x	-	43	-	43

TABLE I.4 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[(a) (b)]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
409	Mount Isa	-	43 x	43 s	-	43
410		43 x	43 x	43 s	-	43
411		43 x	43 x	43 s	-	43
412		43 x	43 x	43	61	-
402		43 x	10	43	92	-
401	Brisbane	43 x	-	43	266	-
410	Longreach	-	43 x	43	43	-
411		43 x	43 x	43	43	-
412		43 x	43 x	43	43	-
402		43 x	10	43	92	-
401	Brisbane	43 x	-	43	266	-
412	Toowoomba	-	43 x	43	61	-
402	Gold Coast	43 x	-	43	92	-
501	Adelaide	-	43 x	43	160	-
505		27	43 x	43	43	-
504		43 x	43 x	43	43	-
502	Port Lincoln	43 x	-	43 s	-	43
501	Adelaide	-	43 x	43	160	-
505		27	43 x	43	43	-
503	Kadina	43 x	-	43 s	-	43
504	Whyalla	-	43 x	43	43	-
505		43 x	27	43	43	-
501	Adelaide	43 x	-	43	160	-
608	Perth	-	43 x	43	92	-
604		6	43 x	43 s	6	37
603	Kalgoorlie	33	-	33 s	-	33

TABLE I.4 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[(a)(b)]

Origin Region		Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)		(2)	(3)	(4)	(5)	(6)
605	Port Hedland	-	43 x	43 s	-	43
609	↕	43 x	43 x	43 s	-	43
607	↕	43 x	12	43 s	-	43
608	Perth	43 x	-	43	92	-
608	Perth	-	43 x	43	92	-
607	↕	12	43 x	43	43	-
609	↕	43 x	43 x	43	43	-
605	↕	43 x	43 x	43	43	-
606	Derby	43 x	-	43 s	-	43
608	Perth	-	43 x	43	92	-
607	Geraldton	12	-	12	43	-
609	Carnarvon	-	43 x	43	43	-
607	↕	43 x	12	43	43	-
608	Perth	43 x	-	43	92	-
311	Melbourne	-	43 x	43	480	-
703	↕	43 x	43 x	43 s	-	43
701	Hobart	43 x	-	43 s	-	43
703	Launceston	-	43 x	43	43	-
701	Hobart	43 x	-	43	43	-
311	Melbourne	-	43 x	43	480	-
702	Burnie	43 x	-	43 s	-	43
311	Melbourne	-	43 x	43	480	-
703	Launceston	43 x	-	43	43	-
311	Melbourne	-	43 x	43	480	-
704	Queenstown	43 x	-	43 s	-	43

TABLE I.4 - (Continued) THE SAMPLE MONITORING PROCESS FOR CORRIDORS REPRESENTED BY MINOR O-D PAIRS[(a) (b)]

Origin Region	Sample Sizes Corresponding to Terminal NTS Regions of Corridor		Maximum of (2) and (3)	Sample Size Previously Determined	Net Increase in Sample Size
(1)	(2)	(3)	(4)	(5)	(6)
703 Launceston ⇕	-	43 x	43	43	-
704 Queenstown	43 x	-	43	43	-
701 Hobart ⇕	-	43 x	43	43	-
704 Queenstown	43 x	-	43	43	-
406[(c)] Mackay ⇕	-	43 x	43	-	43
407[(c)] Townsville	43 x	-	43	43	-
					1072

(a) The symbol 'x' indicates that the value shown is the maximum sample permissible at the relevant p_C level.

(b) The symbol 's' indicates the point at which the sample size for the particular region reached the level used in the actual survey. The sampling criteria outlined in the text were satisfied at this point and no increase in the sample size for the region was indicated in an examination of subsequent corridors.

(c) The Mackay-Townsville corridor is to be upgraded for sampling purposes from a minor to a major corridor. See Table 4.2 for details. An extra sample of 49 trips is required in each of the two regions, to reach the required level of 92 trips for each.

APPENDIX II

CALCULATION OF STATISTICAL ACCURACIES

This Appendix describes briefly the calculation of statistical accuracies related to mean values derived from a survey sample.

Let $$r = \frac{n}{N} \qquad \text{(II.1)}$$

where r is the sampling rate of the survey,

n is the number of randomly selected units to be sampled without replacement,

and N is the number of units in the population.

In this case, n and N represent numbers of households in a particular NTS region. Then, for a 95 per cent confidence level, the following equation holds (Long 1974) to a reasonable level of accuracy:

$$N = \left(\frac{1-r}{r}\right)\left(\frac{1.96}{a}\right)^2 C_v^2 \qquad \text{(II.2)}$$

where C_v is the coefficient of variation of the population attribute,

and a is the relative limit on the acceptable margin of error of the mean of the population attribute.

The coefficient of variation (C_v) is given by

$$C_v = \frac{s_y}{\bar{y}} \qquad \text{(II.3)}$$

and the relative acceptable error limit (a) is given by

$$a = \frac{e_{\bar{y}}}{\bar{y}} \qquad \text{(II.4)}$$

where s_y is the standard deviation of a specific finite population attribute,

$\bar{y}$ is the mean of a specific population attribute,

and $e_{\bar{y}}$ is the statistical error in the mean corresponding to a 95 per cent confidence limit.

Equation (II.2) can be rearranged as:

$$a = 1.96\, C_v \left(\frac{1}{n} - \frac{1}{N}\right)^{\frac{1}{2}} \qquad \text{(II.5)}$$

For all regions in the NTS:

$$n \ll N.$$

Therefore

$$a = 1.96\, C_v \left(\frac{1}{n}\right)^{\frac{1}{2}} \qquad \text{(II.6)}$$

and this reduces to the well-known form

$$e_{\bar{y}} = \frac{1.96 s_y}{n^{\frac{1}{2}}} \qquad \text{(II.7)}$$

Using the expected number of replies (n) from Table 4.3 of the main text, and the coefficients of variation derived from the pilot study and shown in Table 5.1, Equation (II.6) can be used to derive the percentage errors in the attribute means shown in Table 5.1.

NOTATION

MATHEMATICAL SYMBOLS

C_v	The coefficient of variation of the population attribute.
N	The number of units (in this case, households) in the population.
a	The relative limit on the acceptable margin of error of the mean of the population attribute.
$e_{\bar{y}}$	The statistical error in the mean corresponding to a 95 per cent confidence limit.
n	The number of randomly selected units (in this case, households) to be sampled without replacement.
n_{MAX}	The theoretical maximum trip sample size to be obtained in each NTS region.
p_C	A cut-off value for the proportion of trips from one NTS region to another. Estimates of trip proportions greater than this cut-off value will satisfy the chosen accuracy criterion. Conversely trip proportions less than this value will be estimated at a lower level of accuracy.
p_{ij}	The proportion of trips from NTS region i to NTS region j.
r	Sampling rate.
s_y	The standard deviation of a specific population attribute.
$\bar{y}$	The mean of a specific population attribute.

ABBREVIATIONS

AGR	Australian Government Region.
BTE	Bureau of Transport Economics.
LGA	Local Government Area.
NTS	National Travel Survey.
O-D	Origin-Destination.