Chapter 7 Data Collection

7.1 Introduction

Throughout the design process, from the initial identification of a problem to the final selection of the most appropriate remedy, data are required to assist the judgments being made at every stage. This process requires:

- ❑ information about the current state of the transport system and how it has changed, and is changing, over time (for problem identification);
- ❑ specification of alternative design standards and their implications, for application to scheme proposals;
- ❑ forecasts of the effects that each proposed scheme is likely to have, considered against its objectives, as well as any side-effects that are foreseen; and
- ❑ the values (and any priorities or weightings) to be used in assessing the overall impact of each scheme on different sections of the community.

Some of these data will be specific to the particular areas in which these problems are occurring and to the alternative schemes being considered. This requires up-to-date local data from scheme-specific surveys and from any regular monitoring surveys which are relevant.

Survey Techniques

A range of survey types is available for different purposes, as set out in Table 7.1. Typically, surveys can cover three broad areas; traffic characteristics, network characteristics and scheme impacts.

Data collection methods differ widely according to the type of survey being undertaken. The needs of traffic-component assessment can usually be met by observational techniques, those of network assessment and travel demand by interview surveys and those requiring personal and qualitative response by interactive methods of attitude measurement, based upon psychometric or market research techniques.

In recent years, the development of 'revealed preference' and 'stated preference' techniques has enabled complex personal trade-offs and their distribution among the population to be more clearly understood, in the context both of the demand for movement by different modes and of the different impacts of transport.

Monitoring Data

The importance of continuous monitoring should not be overlooked. The main objectives of a monitoring programme are to have available the relevant data to allow periodic assessment of transport-related issues likely to be raised within an area and to monitor the performance of existing networks or specific initiatives. It is, therefore, advisable to commit resources to a regular programme of monitoring that provides this information and enables trends to be established.

Ad–hoc sample surveys provide useful data for specific problems but their output may be difficult to integrate within a comprehensive time-series data bank. Thus, regular monitoring surveys can provide the means to relate various ad–hoc surveys to a more substantial base (eg using factors to convert to average annual flows) with an appreciation of the confidence levels of the estimates. Where the data collected are largely qualitative in nature, they can often be interpreted to infer long–term travel–trends or preferences amongst the public. Examples would include attitudinal research surveys or even the results of public consultation. This latter example is a particularly important source of qualitative (and quantitative) data which is dealt with separately in Chapter 10.

The Traffic Appraisal Manual (DOT, 1991) gives details of all the data sources provided from national surveys and of the appropriate methods for converting sample counts into equivalent traffic flow estimates for design purposes. These data are derived mainly from core and rotating censuses and give national factors. Care is required in applying national factors to small areas.

Travel–demand Data

Several other sources of travel–demand data are relevant to urban transportation studies. Examples are: the National Population Census, which gives information on journeys to work; the National Travel Survey (DOT, 1996), which provides information on household travel–patterns; accident databases, compiled from the `STATS 19' record forms (DOT, 1994a) or a locally used variant; and a wide range of planning databases, held at both local and national level and essential for transportation modelling.

Types of Survey		Traffic assessment: Vechicle flow characteristics: Volume	Classification	Speed	Saturation flows	Vechicle manoeuvres: Turning flows	Parking	Goods access	Pedestrians' crossing and delay	Network assessment: Pedestrian and cycle movements	Goods movements O-D	Person trips O-D (by mode)	Journey times/ operating costs	Accidents	Community impact assessment: Impacts on environment	Attitudes and choice criteria	Impacts on travel behaviour and activities
Observational	Inventory records	Core and rotating census data									Planning data/household census/ NTS, etc.		Network data NIS, TARA, etc.	Police stats 19 records			
Observational	Continious monitoring	Automatic sensors-loop-detectors, radar, microwave, infra-red etc.													Air quality measure- ments		
Observational	Sample surveys	Manual counts, portable event-recorders, etc. Video recording image processing						Patrol surveys cordon counts	Vidoe recordings	"Floating" observer	Number-plate matching		"Floating" observer methods	Conflict measure- ment	Noise and pollution measure- ment		
Interview	Postal questionnaires							Delivery records		Travel diary	Vehicle logs	Travel diary	Vehicle logs		self–completion questionnaires		Travel and activity diary
Interview	Roadside/ on-board questionnaires									Specific trip data using portable data capture devices, etc					Subjective response measurements- attribute-scaling semantic differential, etc.		
Interview	Home interviews									Travel diary	Delivery records	Travel diary				Stated Preference (SP) techniques.	
Interactive	Group discussions											HATS gaming- simulation			Public meetings	Repertory grid/Delphi techniques	Household role and decision models

Table 7.1: Types and purposes of surveys.

Many local highway authorities have established road network information systems for monitoring conditions and assessing priorities for the management of their road networks. Developments in information technology are helping to improve the range and accessibility of the information held, as well as offering new opportunities for bespoke systems using proprietary software.

Fundamental to all information systems and to any kind of continuously–updated record of conditions is an accurate basis of referencing. This should include locations and times at which items of data are collected or events of interest occur. Some locational referencing systems are described below.

7.2 Locational Referencing for Road–Based Information Systems

Locational referencing can be achieved either on a geographical area basis or in relation to fixed points on the road network. The location of traffic data can be specified in terms of:

- ❑ the Ordnance Survey Grid Reference (OSGR) system – this covers Britain and is thus capable of giving a unique reference to any location or area;
- ❑ Royal Mail postcodes – these are unique codes allocated to each major property or small group of residential properties throughout the UK;
- ❑ a zoning system based upon local authority boundaries; or
- ❑ by reference to known fixed points on the road network (eg A1 at 100m north of junction with the B100).

Ordnance Survey Grid References (OSGR)

Various procedures have been developed to establish gazetteers (ie lists of addresses that relate to any given zoning system). As an example, proprietary computer software is available which can link addresses and postcodes to their OSGR and local authority ward. This facility can be adapted to allocate addresses to user–specified digitised zoning systems. These zones can be used for referencing information on journeys (eg the origin and destination of a trip).

Road Networks

It is common for traffic–related data to be referenced to the road network, which can be specified as links (ie sections of highway with reasonably homogenous characteristics) and nodes (ie junctions or points where changes in link characteristics occur). In most systems, the nodes are given a reference number, frequently the OSGR location, and links are then specified by the numbers of the nodes at each end. These network codes can then be used to store information relating to highway characteristics, traffic flows, accidents, maintenance records and so on.

Geographic Information Systems (GIS)

Advances in both computer hardware and software technology have led to the increasing use of geographic information systems (GIS). In simple terms, a GIS contains a computerised map on which various database information can be held, displayed, manipulated and reported. Locational referencing is frequently carried out using ordnance survey grid references (OSGR). There are a number of proprietary GIS software packages on the market, which can be tailored to suit the requirements of individual users.

In terms of traffic–related data, a GIS might be used in connection with a traffic–count database, which covers a large number of roads and contains comprehensive historical records. The system could also be used, for example:

- ❑ to identify traffic–count locations and the nature and quantity of data available;
- ❑ to highlight a particular location, or locations, and provide access to the raw data; and
- ❑ to manipulate the raw data to provide, for example, average daily traffic flow levels, heavy goods vehicle content and year–on–year traffic growth trends.

In addition to traffic flows, databases of road standards and accident statistics could be incorporated along with highway inventory information, such as the locations of street furniture and road signs, and maintenance records.

Software is also available that combines the function of GIS and computer–aided design (CAD). As an example, a GIS may contain a database of accidents linked to junction design. By selecting the location of a particular accident, or cluster of accidents, it would be possible to make an inspection of the detailed geometric and engineering design which may have contributed to the poor safety record. The GIS is therefore, potentially, a powerful tool which can provide all the information required to manage a highway network.

7.3 Sources of National Inventory Data

The Department of Transport holds a large amount of data, collected in the course of scheme appraisals [NIa]. More generally, available information held by the Department includes:

- ❑ the Network Information System (NIS), held by Highways Computing Division; and
- ❑ the National Traffic Census (NTC) (core and rotating traffic census) data, held by STC Division.

The NIS road network describes the motorway and major road network as a series of digitised links. Certain items of interest are recorded for motorways and trunk roads. These include the prevailing speed–limit, road type (ie whether single or dual carriageway) and road class.

Traffic counts are taken on each of the links making up the NIS network and estimates of annual average flows, classified by vehicle type, are made. The information is held by the Department's Statistics Division 'C' and a subset of the data, annual average daily flows (AADF) of all motor vehicles and the proportions which are heavy goods vehicles, are held in the NIS database. A number of local highway authorities operate similar databases for their own areas.

Publication of Transport Statistics

General information on transport and travel–data can be obtained from a number of publications produced periodically by the Stationery Office (Transport Statistics Reports) and the Department of Transport (Statistics Bulletins) [NIb]. Stationery Office publications include Transport Statistics Great Britain (DOT, annual a); Road Traffic Statistics Great Britain (DOT, annual b) and Road Accidents Great Britain (DOT, annual c), all produced on an annual basis, and the results of the periodic National Travel Survey (DOT, 1996). Of the Department of Transport publications, quarterly bulletins relating to traffic statistics are available which provide a useful source of up–to–date information [Wa].

7.4 Recording of Accidents

(see also Chapter 16)

Details of all injury accidents reported to the police are transcribed onto coding sheets in accordance with the STATS 19 form specified by the Department of Transport (DOT, 1994a) [NIc]. This form is divided into three sections:

- ❑ attendant circumstances, giving details of the site (eg location, date, prevailing road conditions and weather);
- ❑ vehicle records, giving details of each vehicle involved; and
- ❑ casualty records, giving details of each casualty involved.

Full details of the variables and their value in the form are given in the booklet STATS 20. The data are provided by the appropriate Local Processing Authority (LPA), which may be the police force, County Council, Metropolitan District Council or the Scottish or Welsh Office, and are also transferred to the Department of Transport, where they are held for Britain as a whole in a central–data bank. The STATS 19 data are restricted to those reported accidents that involve personal injury. It is estimated that about 4% of accidents involving serious injury are not reported and it is known that, where only slight injury is involved, the records are far less complete (see Chapter 16). In cases where insurance details and proof of vehicle ownership can be exchanged, there is no legal requirement to report an injury accident to the police. Reported accidents are defined and classified as slight, serious or fatal according to the most severe casualty in the accident. Definitions of these categories are, as follows:

- ❑ 'slight injury' – injuries of a minor nature, such as sprains, bruises or cuts not judged to be severe, or slight shock requiring only roadside attention (medical treatment is not a pre–requisite for an injury to be defined as slight);
- ❑ 'serious injury' – injuries for which a person is detained in hospital, as an in–patient, or any of the following injuries, whether or not the injured person is detained in hospital; fractures, concussion, internal injuries, crushing, severe cuts and lacerations, severe general shock requiring medical treatment and injuries which result in death more than 30 days after the accident. The 'serious' category, therefore, covers a very broad range of injuries (it is estimated that up to 50% of people with reported serious injuries are not detained in hospital); and
- ❑ 'fatal injury' – injuries which cause death either immediately or at any time up to 30 days after the accident.

Accident Severity Ratio

Public concern about the occurrence of fatal accidents is understandable and is partly reflected in the high monetary cost attributed to them. However, in any particular locality, fatal accidents may occur in numbers that are too small and variable to give a reliable indication of the accident situation on a localised basis. For this reason, the combined number of serious and fatal accidents is often used as an indicator and should usually be analysed in terms of the involvement of different classes of road–user (eg pedestrians, pedal cyclists). Numbers of slight accidents, though subject to greater uncertainty in reporting, can then provide an indicator of the relative severity of accidents by comparing the ratio of fatal and serious accidents with all accidents;

$$\text{Severity Ratio (SR)} = \frac{\text{Number of Fatal or Serious Accidents per year}}{\text{Total Number of Injury Accidents per year}}$$

The ratio will be influenced by the protective attitude of the occupants of vehicles towards vehicles involved in the accident and the aggressive characteristics of the involved vehicles towards vulnerable road–users, if they are also involved in the accident. It will also be influenced by the road environment where the accident occurs and the traffic level on that stretch of the road.

Accident Rates

The frequency of accidents at a particular location (number of injury accidents per year) is not an appropriate indicator of risk, as it takes no account of the degree of exposure to risk. For example, a large number of accidents may simply reflect a large volume of traffic. For this reason, accident reporting is often expressed in terms of accident–rates (ie injury accidents per unit of vehicle movement or total distance travelled). Rates are normally expressed in personal–injury accidents per 100 million vehicle–kilometres. In practice, it is sometimes found that accident–rates can bias investigations towards low traffic flow sites. In some circumstances, it may be better to use the 'Potential for Accident Reduction' (PAR) approach. PAR is designed to estimate, from data at similar sites, the number of accidents expected at the particular site in question, according to its layout and prevailing traffic conditions (McGuigan, 1983). However, accident 'causation factors' are not recorded on the STATS 19 form and are not always related to the limited number of physical features which are recorded (the case for their collection is being assessed). Local data is needed therefore; but, even so, this method must be used with care and with the perception afforded by experienced practitioners.

Processing Accident Data

Accident data records, which are normally stored on computer file for analysis purposes, contain the principal details from the STATS 19 form. Processing and manipulating the raw data usually follows standard computer procedures, often integrated within a GIS [NId]. These perform four basic functions:

- ❑ assignment of each accident to a node, link, cell or road section on the road network, as defined within an authority's representation of the road system for the purposes of accident location. Within this process, it is important to verify positional accuracy since police STATS 19 accident reports are often imprecise;
- ❑ extractions of standard tables, showing trends in accidents for the area as a whole, trends for specific categories of accident or accidents at specific site categories;
- ❑ plotting of the spatial distribution of accidents over the network. This usually reveals clusters of accidents at problem sites and on routes where systematic treatment may be desirable; and
- ❑ problem site (or cluster) analysis, in which the individual links, nodes, cells or road sections can be examined further.

Lists of links, nodes and road sections are usually compiled in descending order of accident–rate frequency, so that the larger clusters can be identified easily (DOT, 1986). Care must be taken to allow for the fact that sites having the largest numbers of accidents in a given period will usually include a number of sites where the occurrence of accidents has been above average in that period, as a result of random fluctuation. Proper use of the PAR technique, or other methods of identifying sites for application of safety measures, should take this into account.

Accident Analysis

The design of appropriate remedial measures normally involves a detailed analysis of each candidate site, in the form of a 'grid' or 'stick' diagram. These show the characteristics of individual accidents in successive columns, together with a diagram indicating the nature of the conflict. This process can be completed by hand or by computer–based methods, where accident data can be plotted to a relatively fine degree of detail, which is often helpful in planning remedial work. However, there is little point in trying to plot the data to a level of detail which is finer than that attained in the police reporting system. Further, more comprehensive, information on Road Safety is given in Chapter 16.

7.5 Continuous Monitoring

Transport policies, contained within structure plans and unitary development plans, are necessarily expressed in broad terms, mainly because they deal with long–term aims and broad approaches to meeting them. In practice, policies are continually interpreted and translated into specific programmes of short–term action. Both of these activities rely on monitoring the state of the transport system. Monitoring may also reveal that changes, either taking place or in prospect, justify reconsideration of the basic policies themselves.

A system for monitoring the components of traffic (eg, flow, speed and classification) requires a structured sample to be taken from within the study area. In order to achieve this, the road network may

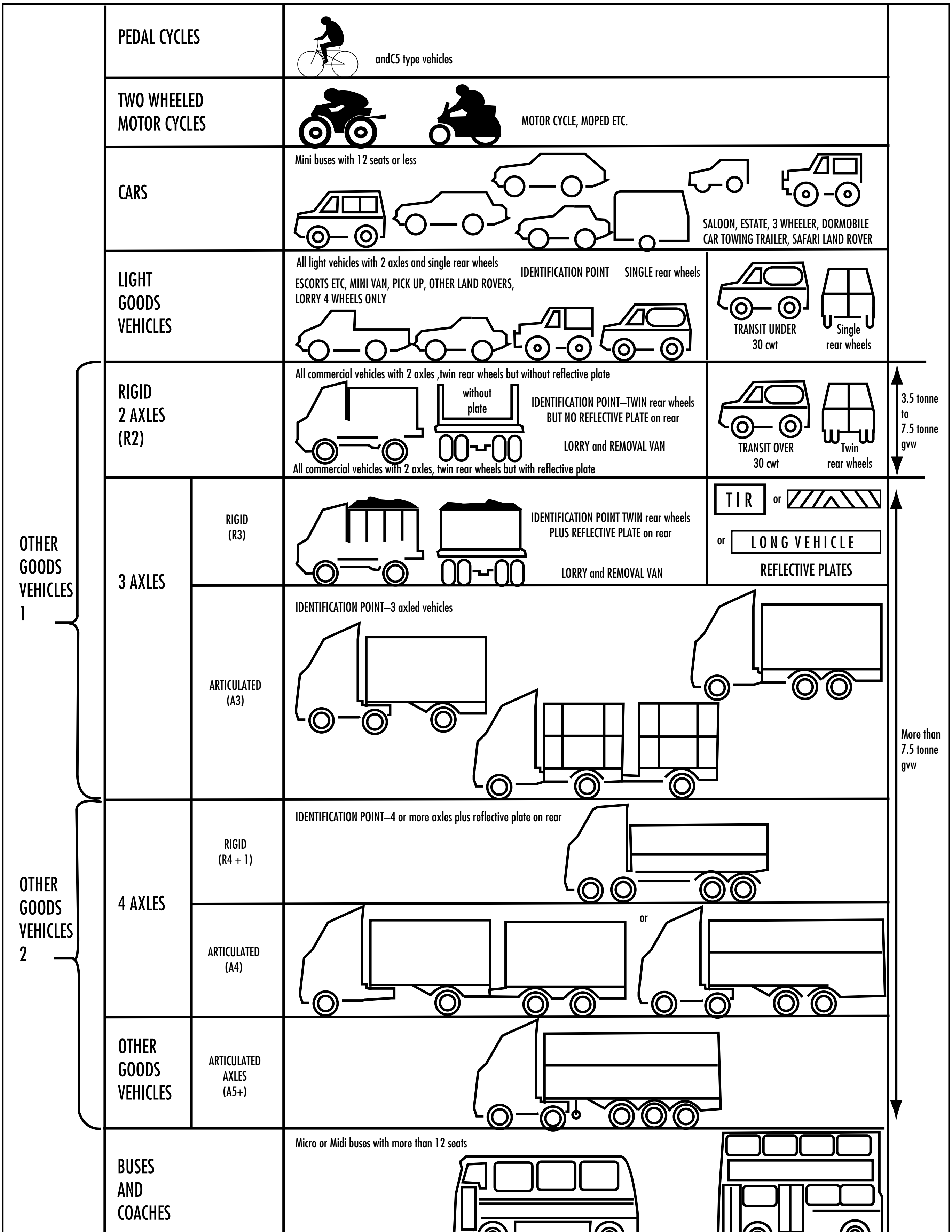

Figure 7.1: Vehical categories used for survey purposes.

be divided into short sections (sometimes only 100 metres long), each section being identified by its type (eg motorway, primary distributor, district or local distributor). The required number of census points for a representative sample is then chosen for each of the road–type sections or for the cordon or screenline. Traffic counting is carried out either continuously at a site or by establishing a rota for a programme of counts. The data from randomly–selected count locations not only provides information on the amount of traffic demand (vehicle–km/day) within the area but may also be used to provide factors to convert sample short–period traffic flows (vehicles/hour), on any link in the network to standard measures. For example, sample counts may be expanded to produce annual average daily traffic (AADT) flows (vehicles/day) for assessment purposes.

National Traffic Data

Most highway authorities have their own systems for monitoring traffic but the Department of Transport performs this task, on a national basis, with its core and rotating (link based) traffic censuses [NIe]. The core census consists of some 130 randomly–selected sites, covering all road classes, which are continuously monitored by automatic counters, which classify by vehicle–type. From these data, expansion factors can be calculated to convert short period counts to their equivalent annual average daily flows (AADF).

The rotating (or link–based) census consists of a comprehensive set of short period counts on every link of the major road network. Each link is visited every three years (in a few cases, at shorter intervals) with about a third of the links (approximately 4000) visited each year. At a randomly–chosen point on each link, counts of each of eleven vehicle types are taken (pedal cycles, two–wheeled motor vehicles, cars and taxis, buses and coaches, light vans, and six separate categories of goods vehicle) for the 12 hours from 0700 hours to 1900 hours.

Figure 7.1 summarises the vehicle–type categories, which are consistent with the Department of Transport's COBA 10 classification (DOT, 1966b). Whilst this has been used informally, as a benchmark, care should be taken, when assembling data from different sources, to ensure consistency in the description of vehicle–types.

These counts are all scheduled to take place on weekdays but not on those at or near to public holidays. In order to minimise the effects of possible seasonal factors, counting is confined to the so–called 'neutral' months (April, May, June, September and October). These counts are converted into AADF, using factors derived from the core census. For those links which are not counted in the year, an estimate of the AADF is made by applying a growth factor, again from the core census, to the previous year's estimate of the AADF. Thus, the Department holds AADF traffic flow estimates for nearly every link in the major road network, although there are always a few links which are not covered, either because they are new links or because a recent change in the road classification of the link invalidates the use of an earlier count.

Traffic flow data can be obtained from the DOT's Directorate of Statistics, which can provide the following for each rotating census count point, on magnetic tape or floppy disc:

- ❑ the original 12–hour count;
- ❑ annual average 24–hour weekday flow; and
- ❑ annual average 24–hour flow.

Subject to the availability of resources, the Department is prepared to produce new analyses from either the rotating or core censuses to meet the specific requirements of clients.

7.6 Inaccuracy and Variability in Traffic Surveys

Automatic Traffic Counts

Little definitive work has been published about the long–term accuracy of traffic counts by automatic traffic counters. Practical experience suggests that errors arise from machine failures, detection problems and poor installation. For longer term counts, the frequency and diligence of survey station monitoring and servicing are crucial to reliability. Permanently installed inductive loops should be more reliable than pneumatic tubes. The best working estimate of the accuracy of measurement of the number of vehicles that pass an automatic traffic counter is that the 95% confidence interval (for a count of longer than 12 hours duration) is of the order of plus or minus five percent of the total count obtained.

All counters should be installed and maintained to the standards laid down in the Manual of Practice on Automatic Traffic Counting (DOT, 1981). When a short–term automatic count is used to predict the average traffic flow for a period longer than the counter was on station, the estimated traffic flow will be subject to sampling errors (see Section 7.7 below).

Manual Traffic Counts

A statistical study of the reliability of manual classified counts has been carried out by the Department of Transport and is reported in a paper entitled Accuracy of Manual Road Traffic Counts (DOT, 1979a). The conclusion reached was that the true 16–hour flow of all motor vehicles at a given site lies, with 95% confidence, within an interval of about plus or minus 10% of the manual count.

The 95% confidence intervals for some individual vehicle classes were:

- ❑ light goods vehicles +/– 24%;
- ❑ other goods vehicles +/– 28%; and
- ❑ all (light plus other) goods vehicles +/– 18%.

The relatively wider confidence intervals for individual goods vehicle classes results largely from mis–classification between them. The accuracy of the total number of goods vehicles is therefore better than that for an individual class. The confidence intervals for individual hours are likely to be larger but the 16–hour figures shown above can be taken as a guide. The Department of Transport's Highways, Economics and Traffic Appraisal (HETA) Division uses computer–based methods to process count data and to yield the coefficient of variation of any estimate made from any number of 12– or 16–hour counts. The factors are derived from the core census data (see Section 7.5 above).

7.7 Sampling Procedures and Techniques

The problems of scaling–up (or factoring) the number of actual observations, to the total which is representative of the population being measured, is common to all sample surveys. In urban areas, traffic flow through each day, week and year can be very variable and it is, therefore, important to take account of this. Most urban traffic counts can be converted to AADF, in the same way as counts from the link–based census, and Statistics Bulletin 86(7) (DOT, 1979b) describes techniques which rely only on the built–up/non built–up classification of urban roads. When AADF estimates are required from short–period counts, standard expansion factors will give annual average flows and their associated coefficients of variation. The coefficient of variation, expressed as a percentage of the flow, gives a measure of the uncertainty surrounding the estimated AADF.

Every scaling factor has an associated unreliability and the result of factoring is always to worsen the overall confidence interval. Factoring should therefore be kept to a minimum and the factor with the lowest coefficient of variation should always be chosen, where a choice of factors is available. Whilst it is, in principle, desirable to derive factors locally, a fuller understanding of the accuracy of such factors is necessary, to ensure that local conditions are actually significantly different from national averages. In the absence of this knowledge, national factors should be used. The Department's cost–benefit package, COBA 10 [Sa], gives 'default' values for the scaling factors.

Peak and Seasonal Variations

The difference between the peak–hour flow and the annual average hourly flow (AAHF) is of interest to highway engineers, for various aspects of link and junction design. Table 7.2 gives the factors to convert from AAHF to the peak–hour flow (PHF) and corresponding hourly flows, ranging from 10th highest to 200th highest, for three road types.

7.8 Sample Observational Counts Surveys

The most common requirements of observational surveys are to obtain information on the volumes and types of vehicle passing a particular point on a road link or negotiating a particular junction.

Passage Counts

Different traffic streams can be counted manually by enumerators, using traditional forms and hand–held tally counters or by inputting data directly into portable hand–held electronic data–capture devices. Whatever method is used, sufficient numbers of enumerators should always be employed to ensure adequate cover of the different movements and to allow for regular breaks from what can be a monotonous task. Alternatively, data can be obtained automatically, using detector systems located in or by the carriageway, such as inductive–loop detectors or image–processing.

If manual traffic count methods are undertaken for a sample time–period, it may be necessary to use temporary automatic equipment to collect traffic flows over the whole period, as a `control'. This equipment can operate continuously and unattended. At temporary sites, pneumatic, tribo– or piezo–electric cable sensors may be placed across the carriageway to register the number of axles (and possibly their loads) passing in any particular time–period. It is also possible to use detector loop 'mats' which are laid directly on top of the road surface, as a temporary counter, although these are not often used. Electronic counters are used in association with the detectors, which store the information on solid state RAM. The equipment should be checked at regular intervals, to confirm that

Conversion of Hourly Flow	Types of Road					
	Main Urban		Inter Urban		Recreational Inter–Urban	
	Factor	Coeff* (%)	Factor	Coeff* (%)	Factor	Coeff* (%)
AAHF to PHF	2.630	(11)	2.825	(15)	3.890	(23)
AAHF to 10th highest hour	2.83	(14)	3.231	(20)	4.400	(23)
AAHF to 30th highest hour	2.703	(11)	3.017	(17)	4.974	(21)
AAHF to 50th highest hour	2.649	(10)	2.891	(15)	3.742	(19)
AAHF to 100th highest hour	2.549	(9)	2.711	(12)	3.381	(15)
AAHF to 200th highest hour	2.424	(9)	2.501	(9)	3.042	(13)
AAWF to AADF	0.943	(3)	0.979	(4)	1.015	(4)

Notes: AAHF is assumed to be AADF ÷ 24

AAWF is the Average Annual Weekday Flow (Monday–Friday)

*Coefficient of Variation

Source: Traffic Appraisal Manual (TAM) DOT (1991).

Table 7.2 Peak–hour factors by road type classification.

the sensors are still in place and that the counter is working correctly and has sufficient power to last until the next visit. Data can be collected from the counter periodically, by down–loading information onto a data–capture device ,such as a lap–top computer or data module.

At more permanent sites, it may be preferable to install detector loops in the road surface to avoid the heavy maintenance costs associated with temporary sites. At these locations, data may be stored by an electronic counter connected directly to the loops or may be sent to a central computer via a data–transmission line.

All of these automatic detection systems need to be checked at regular intervals by manual counts, to ensure that the recorded counts are compatible with visually observed information. Some sophisticated arrangements of detector systems have been used to count and classify individual vehicles and also to determine axle and gross vehicle–weights with piezo–electric sensors. Manually performed classified counts are still usually carried out to verify the accuracy of the automatic systems.

Junction Counts

The counting of turning movements at junctions may require a large number of field staff but the use of video equipment with subsequent laboratory analysis can also be considered. A video camera might be positioned at a suitable vantage point (eg in a neighbouring building or on a telescopic mast that provides the necessary field of view). If observers are employed, substantial numbers of them may be necessary (eg when counting at a four–arm junction, there are twelve possible traffic movements). Saving on staff, by having each numerator observing more than one movement, can lead to a reduction in the quality of the data obtained. Experience suggests that greater accuracy is achieved when vehicles are counted as they leave the junction, because individual traffic streams are identified more easily at this point.

When information on movements within a complex junction, or over a large area, is required a ‘number plate’ survey may be appropriate. With this type of survey individual vehicles are identified usually by the numerical part of their registration number and a letter, usually the first letter of the alpha code, together with the time when they enter the survey zone. This information can be recorded by an observer, using either an enumeration form, a tape–recorder or an electronic portable hand–held data–capture device. Other observers, placed in a cordon around the junction (or area) note the registration numbers and times as the vehicles leave. Computer programs have been developed to match the registration numbers of vehicles entering and leaving the area in different time–segments, based on the estimated journey times through the zone. Usually, up to 80% of the identified vehicles can be matched in this way. Developments in image–processing techniques allow the recording of number plates to be done automatically, provided that cameras can be adequately positioned to observe the registration plates.

Pedestrian Counts

Pedestrian surveys are usually required to establish the flows along a footway or across a carriageway. The latter will often be required to quantify pedestrian/vehicle conflicts, when assessing the need to install some form of crossing facility. For this purpose, pedestrian counts will usually be carried out over a one hundred metre length of road, ie 50m on either side of the proposed crossing point. Fifty metres is taken as the maximum distance that pedestrians might reasonably be expected to walk to use a formal crossing place, rather than cross where they happen to be. The actual distance that pedestrians are willing to divert will also depend on the intervening traffic flow and on the existence of any physical barriers (eg guard–railing). Origins and destinations of pedestrian trips may only be obtained by personal interviews (see Section 7.9) but surveys of pedestrians' delays at crossing points can be carried out manually or by using video equipment (see Chapter 22).

Cycling Data

Information on existing cycling movements, other demand factors and suppressed demand can be obtained from a number of sources (IHT, 1996). The 1991 Census of Population provides highly accurate and comprehensive transport–to–work data. It is possible to analyse cycle–trips by origin (home) and destination (workplace), zoned as enumeration districts, wards or postcode sectors. The cycling data are a subset of the Transport–to–Work tables, which can be purchased. Short trips by other modes are an indicator of potential cycling trips. Classified traffic counts often provide information on cycle flows. However, where cycle flows are low relative to flows of other classes of vehicle, the results may be inaccurate and should be treated with caution. Cycles should be counted in all manual classified counts and the importance of recording cycles accurately should be explained to the enumerators. Automatic traffic count equipment is available that can detect cycles on segregated cycle–tracks.

Counts of Passengers using Public Transport

Information on the use of public transport can be obtained from manual counts of people boarding or alighting at different stops or from on–board interviews with passengers. Analysis of ticket sales can produce partial, and potentially biased, information, due to the increasing use of railcards and concessionary fares.

Manual counts of public transport modes are undertaken in many urban areas, both of the numbers of vehicles and the numbers of passengers. They can be carried out by either boarding and alighting counts at stops/stations along the whole length of a route (or a group of routes) or they can be conducted by enumerators actually on board each vehicle to be surveyed (see Photograph 7.1).

Photograph 7.1: Travel data for rail–interview off–train.

Other types of survey that are frequently carried out involve recording all buses or trains at a designated cordon and counting how many people are travelling on each vehicle or train. For convenience, the cordon is frequently drawn through a bus stop or station where the vehicles and trains are scheduled to stop in any case.

Another approach to counting public transport passengers (and vehicles) is referred to as 'terminal counts'. These are counts conducted at a terminal point, such as a main railway station, coach terminus or bus station. The survey involves counts of all passengers alighting and boarding vehicles at the terminal point. Terminal count surveys give an indication of the total number of passengers using an urban centre, although they do not take account of any through or cross–centre movements.

All the above surveys can be used for trend analysis or can be used as input to other evaluations, such as corridor analyses or before–and–after surveys.

Speed Measurement

When seeking the average speed of vehicular traffic, it is important to decide how speeds at a point on the road are to be measured. Options include:

- ❑ use of a radar speed–meter, averaging the individual speeds of vehicles directly; or
- ❑ timing vehicles over a short distance (L) and calculating the average time taken (t), giving an average speed of L/t.

Of these methods, the former would give the 'time' mean–speed (Vt) and the latter the 'space' mean–speed (Vs). Wardrop has shown that the two definitions of speed are related, thus:

$$V_t = V_s + s^2/V_s$$

where ‘s’ is the standard deviation of the distribution of individual speeds, as measured by the method of timing vehicles over a short distance.

It is possible to calculate the time or space mean–speed, from either set of data, by converting individual speeds into times or vice–versa.

This distinction is important because, in practice, time mean–speed is used for accident analysis at particular sites or the determination of a speed–limit, whilst space mean–speed is used for economic analysis and other applications of speed/flow relationships.

A common method of determining the instantaneous vehicle–speed, measured at a point, is to use a radar speed–meter. The speed meter should be concealed behind street furniture or inside a conveniently parked vehicle, so that drivers are unaware of the observations and do not alter their normal behaviour as a consequence. Speeds can also be measured automatically, using inductive loops spaced a known distance apart and connected to an appropriate electronic counter and by image–processing techniques.

The usual way of measuring link, running or journey speeds is by the so–called ‘moving observer’ method, in which a car (or light van) travels along the route at the average speed of traffic, while observers record the time taken between different points and the periods during which the vehicle is stopped. A number of runs are necessary to obtain a good estimate for each period of the day being investigated. In this process, the driver attempts to ensure that he passes as many vehicles as pass him, in order to remove bias.

Speeds and Highway Design

The 85th percentile speed (ie the speed up to which 85 per cent of vehicles travel in free–flow conditions) is generally used as a basis for highway design (see Chapter 31). It can be used to determine:

- ❑ the design speed of minor improvement schemes, by measuring vehicular speeds on the approach to the improvement;
- ❑ the basis for the design of major/minor junctions;
- ❑ the basis for the settings of vehicle–actuated traffic signals, at sites with speed–limits of more than 30 miles/h; and
- ❑ appropriate values for speed–limits.

Surveys to Assess Urban Traffic Conditions

Assessment of urban traffic conditions can be carried out by direct observations, moving–car techniques, aerial photography, time–lapse cinematography and computer analysis of video–tape recordings. It will usually involve measuring one or more of the following:

- ❑ saturation flows at signal–controlled junctions (see Chapter 40);
- ❑ cyclic flow profiles (ie the average pattern of traffic flow on a road link during one signal–cycle);
- ❑ queue–lengths, which can be measured by observers noting at (say) one minute intervals the points at which the queue begins and ends (a distinction must be made between vehicles which are actually stopped and those which are crawling); and
- ❑ queueing time, as the time between the first stop to the last start but, if the queue is long, an allowance should be made for the time it would have taken to travel, at normal running speed, the length of road covered by the queue. As with queue–length measurements, it is important to distinguish between the time spent delayed (ie the time taken to decelerate to and accelerate from a stop, plus the time spent actually stopped) and the time spent stationary.

Car Parking Surveys

An inventory of the parking spaces available in an area, together with observations of the use made of them, is often required. The number of spaces, including details of where they are and whether they are privately or publicly used, can be recorded on a map of an appropriate scale. Often there is difficulty in establishing the precise number of spaces available. This can be either the number of marked–out parking spaces or the actual number of cars parked (which may be greater than the indicated spaces). The inventory should also include kerbside capacity (estimated where individual bays are not marked), spaces in public car parks and private spaces, including those within the curtilage of individual properties. Distinctions may be made between those spaces for which a charge is made, those with restricted use, such as private to non–residents (PNR), those for permit–holders only and those subject merely to time–limits.

A quick and inexpensive assessment of the demand for parking space in a particular area can be obtained by measuring the accumulation of traffic within the study area by time of day. Using automatic traffic counters, the net accumulation of vehicles entering and leaving the study area can be measured at appropriate time–intervals. The data can then be plotted as a graph, showing the accumulation of traffic for different times of the day, and this provides a good proxy for parking demand. The process may be repeated on different days, to determine the difference in demand for each day of the week or month. In most urban areas, parking demand varies significantly during the week for a variety of reasons. Knowledge of the variation in parking demand assists interpretation of parking occupancy and parking duration surveys, which are normally limited to one day for reasons of economy.

Parking occupancy (ie the number of spaces occupied in relation to the total available) can be obtained by observers patrolling on foot or in vehicles. Video–recording techniques are also feasible. Surveys may be used to compare different days of the week, different times of the day and the effects of different parking policies, when taken over suitable periods. Aerial photographs may also be used to determine parking occupancy but only of open, ground–level, parking areas.

When parking duration (ie the length of stay of individual vehicles) is being surveyed, the parking zone should be divided up into a number of patrols. The frequency of the patrol will depend on the land–use characteristics of the surrounding area. A typical patrol of 60 spaces might take an observer about 30 minutes to complete. Where the land–use generates short– term parking, the patrolling interval should be reduced to perhaps five minutes to achieve an acceptable level of accuracy. Portable data–capture terminals can be used by observers to improve the accuracy and effectiveness of the survey. An alternative is to use video recordings, taken from inside a moving vehicle or from a high vantage point. Parking duration and accumulation can then be determined by comparing consecutive recordings. Information on parking duration in off–street car parks can be obtained from most types of automatic entry/exit ticketing systems. These do not produce the same bias against short–stay parking as do periodic observation methods.

7.9 Origin–Destination Surveys

Given that the objective of an 'origin–destination' survey is actually to gain information on travel–demands by all modes to all activities within the study area, the following is a comprehensive list of data needs (Figure 7.2):

- ❑ AB – intra–zonal trips, within the study area;
- ❑ AC and DB – terminating trips from/to the study area, originated from or destined to a point inside the study area; and
- ❑ XY – extra–zonal through trips, passing through the study area.

While all of these trips can be made both by people who live in the area and by those who do not, in

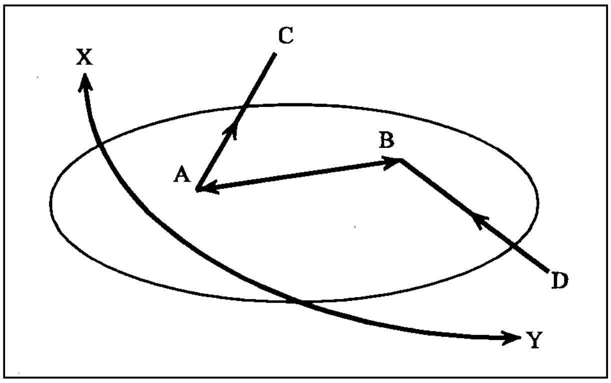

Figure 7.2 Trip–types for O–D surveys

general, travel surveys collect data samples in the following ways;

❑ household surveys	– collect most of the internal trips (AB) – though not all, – collect around half (sometimes less, depending on the study area) of the trips of type AC and DB, – collect none of those passing through the area (XY);
❑ external cordon surveys	– collect no intra–zonal type AB trips, – collect a sample of all type AC, DB and XY trips; and
❑ internal screenline surveys	– collect a mixed sample of all three types – (depending upon the location of the screenline).

Clearly, to get a proper representation of all travel, it is important to gather data from more than one of the above sources. However, a number of factors need to be taken into account:

- ❑ household surveys can collect a much broader range of data and, in general, there is more time to collect more accurate origin–destination data than at screenline or cordon surveys (see Section 7.10);
- ❑ screenline/cordon survey data can duplicate data collected at the household survey, so care needs to be taken when matching the data to household–based data;
- ❑ it is recommended that screenline/cordon data is collected by personal interview since it has been shown (Bonsall *et al*, 1993) that non–response bias is extreme in the case of self–completion methods;
- ❑ screenline/cordon data needs to be collected for all modes crossing the lines – not just motorised traffic; and

❑ it is essential that screenline/cordon data is collected over the same period as the household survey, since many urban areas experience mis–matches of data, due almost entirely to seasonal, weekly or time–of–day variations between household and other data.

The above recommendations are for comprehensive coverage rather than validation. While it is obviously important that each of the survey–types makes sense in relation to the other, that is not validation. True validation is done within each individual survey type and not between surveys, since each survey method has its own biases.

Each of the surveys mentioned above can be further classified into those which are car–based, those which are public transport based, those which focus on cyclists and pedestrians and those which are household–based.

The key issues in relation to car–based surveys, public transport–based surveys and non–vehicular surveys are:

❑ the sampling must be done rigorously and randomly;
❑ all non–response/refusals need to be recorded and as much information as possible from these retained;
❑ classification counts need to be undertaken over exactly the same period of time; and
❑ data correction/weighting procedures need to be implemented both for non–response and for expansion purposes.

7.10 Household Surveys

This section discusses the choices of survey method available for household–based travel surveys (Richardson *et al*, 1995). The task of selecting the appropriate survey method is crucial to the efficiency of the overall survey effort. The choice of survey method will usually be the result of a compromise between the objectives of the survey and the resources available for it. This compromise, or trade–off, can be neatly illustrated as shown in Figure 7.3.

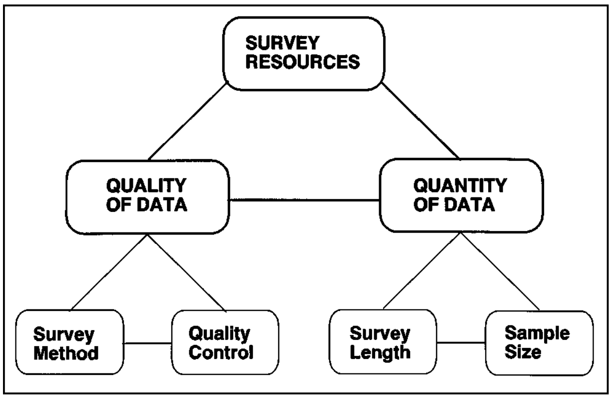

Figure 7.3 Trade–offs in selection of the survey method. Source: Richardson *et al* (1995).

A trade–off occurs because it is impossible to control all three of the major elements in Figure 7.3; at best, only two of the three can be controlled by the survey designer. Thus, given a fixed budget, as is normally the case, the selection of the survey method, with an associated degree of quality control, will automatically control the quantity of data which can be collected. Alternatively, within a fixed budget, specification of the quantity of data to be collected will immediately dictate the quality of data which can be collected. That is, either lots of low quality data can be collected or a limited amount of higher quality data, for a given budget. Generally, the latter course of action is to be preferred.

In determining the total quantity of data to be collected, a further trade–off is present between the sample size from which data is collected and the amount of data collected from each respondent in the sample. Within a limited budget for coding, editing and analysis, it is necessary to trade–off the number of questions against the sample size; which one takes precedent will depend on the purposes of the survey and the length of the survey content list.

Essentially, three different data–collection techniques may be employed:

❑ household self–completion surveys;
❑ household personal interview surveys; and
❑ telephone surveys.

These survey methods vary in complexity, in the types of information which can feasibly be collected and in the level of interaction between the survey designer and the respondents in the survey.

Household Self–Completion Surveys

Self–completion questionnaire surveys are one of the most widely–used forms of survey technique in transportation studies. Self–completion surveys are defined as those in which the respondent completes a questionnaire without the assistance of an interviewer.

Several types of basic survey format can be described, depending on the methods used for collection and distribution of the questionnaire forms. These variations include:

❑ mail–out/mail–back surveys;
❑ delivered to respondent/mailed back; and
❑ delivered to respondent/collected from respondent.

Naturally, the increased response obtained in the two latter methods can only be obtained at considerable extra expense for the personal delivery and collection of the questionnaire forms. However, where a high response rate is essential, as in a National Census, then this method may be the most cost–effective way of obtaining these responses. This method is frequently used when 'long–term' travel diaries (eg 7–day diaries) are distributed (eg in the National Travel Survey in the UK) (Stopher, 1992).

Household Personal Interview Surveys

A personal interview survey is defined as one in which an interviewer is present to record the answers provided by the respondent to a series of questions posed by the interviewer. Personal interview surveys have long been associated with transportation data collection, with home interview surveys providing the major input to the large transportation studies of the 1960s, 1970s and 1980s. Most personal interviews now use computer–assisted personal interviewing (CAPI).

A household personal interview survey may be chosen, in preference to a self–completion survey, for several reasons:

- ❑ in general, higher response rates may be obtained from personal interview surveys than from self–completion surveys. Response rates of 75% to 80% are not uncommon;
- ❑ the personal interview survey allows for considerable flexibility in the type of information collected;
- ❑ the presence of an interviewer means that explanations can be given regarding the meaning of questions or the method in which answers are to be given, thus ensuring consistency of response;
- ❑ personal interview travel surveys can be carried out over a much shorter time–period than self–completion surveys, which need up to six weeks elapsed time to incorporate sufficient reminder notices into the survey procedure;
- ❑ since many surveys can be quite long, an interviewer can be effective in maintaining respondents' interest and in ensuring that the full set of questions is completed; and
- ❑ an interview situation is valuable where it is desired to obtain spontaneous answers from a particular individual.

While being particularly effective in several aspects of transportation data–collection, personal interview surveys are not without their own distinct disadvantages, viz:

- ❑ they are relatively costly; typically, three to ten times more expensive per returned questionnaire than a self–completion survey (Ampt *et al*, 1994). A consequential problem is the clustering of the sample in order to keep the costs down;
- ❑ an interview situation is basically a human interaction between an interviewer and a respondent. Such interactions are rarely, if ever, completely neutral and free of bias; and
- ❑ they are not suited for situations where questions require a considered response or where factual information is required, which is not immediately available.

In summary, personal interviews are best for surveys where the concepts are complex or where there is a tricky series of sequencing required. They are more costly than their self–completion counterparts and have to be designed thoroughly, to minimise interviewers' bias, but their high response rates and their ability to be carried out within a relatively short time make them ideal in cases where high quality data is required within a medium time–frame. In many cases, a combination of self–completion and personal interview surveys will be the most cost–effective.

Telephone Surveys

The telephone survey have been used for many years outside the area of transportation, mainly in market research.

The growth of telephone interviewing in the 1970s and early 1980s led to the setting up of centralised telephone–interviewing installations for many surveys, a development which revolutionised telephone interviews. Dedicated telephone–interviewing facilities allow for stricter control and closer supervision of interviewers' behaviour than is possible with from–home telephone surveys or with personal interviews (Morton–Williams, 1993).

The telephone survey method has a number of advantages, which include:

- ❑ it offers the possibility of wide geographical coverage – particularly in a given urban area, where rates for phone calls frequently do not vary with distance;
- ❑ because telephone interviews are usually performed from a central location, it is possible to have much better supervision of the interviews and, thereby, to maintain a higher level of quality–control on the completed interviews;
- ❑ by centralising the interview facility, it is possible to use computer–assisted telephone interviewing (CATI). In this method, the interviewer reads the questions from the computer screen and then types the responses directly into the computer,as they are received over the phone; and
- ❑ telephone surveys are generally cheaper than

personal interviews because of the reduction in labour needed to conduct the survey and the absence of field and travel costs, associated with having interviewers in the field.

The telephone survey method, however, has some potentially serious disadvantages, viz:

- ❑ there is a limit on the length of survey which can be successfully completed over the telephone (Stopher, 1985);
- ❑ the number of people in a household with whom it is possible to carry out the interview is almost always limited to one;
- ❑ with an increasing amount of marketing being done by means of the telephone (some of which are disguised as sample surveys), it is becoming more and more difficult for serious survey researchers to establish their credibility at the beginning of an interview;
- ❑ because only those households with telephones can be included, the potential for a sample bias is obvious;
- ❑ because telephone books have usually been used to select the sample, the problem of phone–owning households who are ex–directory being excluded from the sample is added to other problems, such as out–date and non–phone–owning households;
- ❑ unlike other forms of survey, there is no chance of follow–up for non–respondents in a telephone survey; and
- ❑ by its very nature, no visual aids can be employed in such a survey.

While telephone surveys are seen by some as having significant potential in the collection of transportation survey data, they should be used with caution, especially for data which is not factual and straightforward.

7.11 Intercept Surveys

Intercept surveys are those which take place at a site which is not in a household – where people are intercepted in the course of carrying out an activity of some kind. They include surveys on–board public transport vehicles and at cordon–points on roads.

The major types of intercept surveys are

- ❑ **on–board vehicle distribution/mail back** – in many cases, it is desired to conduct a survey of a particular group of transport system users, eg bus passengers. To attempt to find these people by means of a general household survey would be almost impossible, because they represent such a small percentage of the total population. A more efficient method is to limit the population to include only those people and to use a survey method which will identify only members of that population. On–board vehicle surveys are an effective means of conducting such surveys, where surveyors ride on–board the vehicle and distribute questionnaire forms to all passengers on the vehicle. The passengers may then be required to fill out the questionnaire forms at their convenience and return them by post. A comprehensive description of such surveys is given in Stopher (1985). They have the advantage of being moderately cheap but the disadvantage of generating low response rates, since it is not possible to encourage or remind people to respond in any way;
- ❑ **on–board vehicle distribution/on–board vehicle collection** – as an alternative, such as for passengers on train journeys, it may be possible to collect the completed questionnaire forms before the respondents leave the vehicle. For some modes, this poses no particular problems because there will be ample time for passengers to complete the survey before the end of the trip;
- ❑ **on–board distribution/collection plus mail–back** – in some studies, hybrid on–board surveys, which combine elements of both the above methods have been used successfully (Sheskin et al, 1982 and Hensher, 1991). The method involves using a two–part questionnaire form. The first part is the more usual postcard style, clearly marked for filling out and return on the bus or train. The second part is a more lengthy form, to be taken away by the traveller, filled out later and mailed back. This method allows for considerably more information to be obtained than can be acquired from the standard on–board/mail–back method;
- ❑ **roadside distribution/mail–back surveys** – where the mode of transport under consideration is the private car, then the method of distribution to pin–point those users is often a roadside questionnaire survey. In this survey method, questionnaire forms are distributed to car–users, as they pass by a particular point or set of points on the road. To enable the questionnaire forms to be distributed, it is necessary that the cars are stationary at that point. This can be achieved in one of two ways; either at a natural feature of the roadway (such as a traffic signal or a toll–booth) or deliberately stopped at a census point, with the assistance of local police officers. After the drivers are stopped, they are given a questionnaire form and a brief explanation of the purpose of the survey. Respondents are then asked to fill out the questionnaire form at their convenience and return it by mail (Richardson *et al*, 1981); and
- ❑ **intercept interviews** – sometimes intercept surveys involve personal interviews with the

drivers of vehicles or travellers as they are stopped at the census point. In these cases, the respondents are stopped by an interviewer who asks them a series of questions – usually about origin, destination, trip purpose and times of travel, with some details on socio–demographic status. The presence of an interviewer generally ensures a much higher response rate than other methods which involve mailing back a postcard.

All mail–back surveys involve an unquantifiable bias in the response rate and should only be used if no other approach is available.

7.12 Stated–Preference (SP) Surveys

SP exercises are a form of attitudinal survey. Two types of multi–dimensional scaling technique are of particular relevance to transport–choice analysis. The first involves the rating of an alternative, overall, by the application of a uni–dimensional scaling technique to a multi–dimensional object. This method is frequently used to ascertain how the uni–dimensional ratings of the individual attributes might be combined into an overall rating of the alternative.

The second method is known by various titles such as 'conjoint measurement' (Luce et al, 1964 and Krantz *et al*, 1971), 'information integration' (Anderson 1971 and 1974), 'functional measurement' (Meyer *et al*, 1978) and, in recent years, 'stated preference' or 'stated response' (Pearmain *et al*, 1991). The principal feature of each of these methods is that they seek the respondent's reaction to a series of hypothetical combinations of attribute levels. The set of questions is determined on the basis of an experimental design, which seeks to present a balanced set of situations to the respondent.

Stated–preference methods are particularly useful in two contexts:

- ❑ when a substantially new alternative is being introduced and there is little or no historical evidence of how people might respond to this new alternative; and
- ❑ when the investigator is trying to determine the separate effects of two variables on consumers' choices but where these two variables are highly correlated in practice.

The investigator has control over the combinations of attributes to which the subjects will respond, because of the manner in which the set of questions has been determined by an experimental design. This is particularly important in the second context listed above, because it enables the investigator to isolate the individual effects of the various attributes.

The design of the choice situations to be presented to the respondents is an important component of the overall design of stated preference surveys. Pearmain *et al* (1991) offer a simple example of an SP design, by considering a situation involving three attributes for a public transport service: fare, travel–time and frequency. If each attribute has only two levels (viz, high–low, slow–fast, frequent–infrequent), then there are eight different combinations of these options, as shown in Table 7.3.

The respondent could then be asked to rank these options in order of preference and, from the combined responses of a sample of respondents, the relative importance attached to fares, travel times and frequency could be determined. Importantly, because of the orthogonal nature of the experimental design (ie where each variable is independent of all other variables in the set of options presented to the respondent), the importance attached to each attribute is a true reflection of the separate effects of each attribute.

Option	Attributes of Public Transport		
	Fare	Travel–Time	Frequency
1	Low	Fast	Infrequent
2	Low	Fast	Frequent
3	Low	Slow	Infrequent
4	Low	Slow	Frequent
5	High	Fast	Infrequent
6	High	Fast	Frequent
7	High	Slow	Infrequent
8	High	Slow	Frequent

Table 7.3 A simple stated–preference experimental design.

As with uni–dimensional scales, the respondent may be asked to perform different tasks with the information presented. For example, they could be asked to:

- ❑ rank the alternatives in order of their preference;
- ❑ assign a rating to each alternative, to reflect their degree of preference;
- ❑ select the single alternative which they prefer the most; and
- ❑ select choices, in a paired comparison manner, from a series of two–way choice situations.

Each of these methods has its own strengths and weaknesses, both from the point of view of the respondent and the analyst.

One of the problems with stated–preference methods is that, for example, the set of options shown in Table 7.3 is extremely limited. It is likely that more than two levels of each of the attributes would need to be tested and, perhaps, more than three attributes would need to be evaluated. However, as the number of attributes and attribute levels increases, so too does the number of possible combinations. For example, to test three levels of three attributes would result in 27 combinations; three levels of four attributes would require 81 combinations; and so on. Clearly, it is impossible to expect respondents to be able to consider too many different situations. Kroes *et al* (1988) suggest that a maximum of 9 to 16 options is acceptable, with most current designs now adopting the lower end of this range. A maximum of 9 options for the respondent to consider severely limits the number of attributes that can be considered.

To overcome this limitation, and yet be able to consider more attributes and/or more attribute levels, it is necessary to adopt one of the following strategies (Pearmain *et al*, 1991):

- ❑ use a 'fractional factorial' design, whereby combinations of attributes which do not have significant interactions are omitted from the design. A significant interaction is said to exist when the combined effect of two attributes is significantly different from the combination of the independent individual effects of these two attributes; or
- ❑ remove those options that will 'dominate', or 'be dominated' by, all other options in the choice–set. For example, in Table 7.3, option 7 is dominated by all other options, while option 2 dominates all others. These options could be removed from the choice–set, on the assumption that all 'rational' respondents would always put option 2 first and option 7 last in any ranking, rating or comparison process; or
- ❑ separate the options into 'blocks', so that the full choice–set is completed by groups of respondents, but with each group responding to a different sub–set of options. Each group then responds to a full–factorial design within each sub–set of options and it is assumed that the responses from the different sub–groups will be sufficiently homogeneous that they can be combined to provide the full picture; or
- ❑ present a series of questions to each respondent, offering different sets of attributes but with at least one attribute common to all to enable comparisons to be made. Often the common attribute will be 'time' or 'cost' to enable all other attributes to be measured against easily understood dimensions; or
- ❑ define attributes in terms of differences between alternatives (eg travel–time difference between car and train). In this way, two attributes are reduced to one attribute in the experimental design. However, they may still be presented as separate attributes to the respondent on the questionnaire.

Adoption of one, or more, of the above strategies will allow more information to be obtained from stated–preference questionnaires, while keeping the task manageable for the respondent.

The major weakness of stated–preference methods, however, is that they seek the reactions of respondents to hypothetical situations and there is no guarantee that respondents would actually behave in this way, in practice. This is particularly the case if the respondents do not fully understand the nature of the alternatives being presented to them. Thus, a high premium is placed on high–quality questionnaire design and testing, to ensure that respondents fully understand the questions being put to them. Unfortunately, this does not always appear to be the case. While a lot of attention has been placed on refining the nature of experimental SP designs and on increasing the sophistication of the analysis techniques to be employed after the data has been collected, relatively little attention has been paid to improving the quality of the questions being put to the respondents. With few exceptions (eg Bradley *et al*, 1994), little research has focused on testing for methodological deficiencies in the survey techniques used to obtain SP data. There are numerous examples of stated preference questionnaires, in which the questions are almost unintelligible. Future work in this area must pay much greater attention to the quality of the survey instrument itself.

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