

TRAVEL SURVEY METHODS IN LATIN AMERICA

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ABSTRACT

A review of travel survey methods in Latin America reveals that in most countries the state of practice is practically identical to that of the USA, i.e., it languishes years behind the state of the art. This was not easy to ascertain as data is not forthcoming. An Internet-based survey produced conflicting evidence in many cases, i.e. scholars and even Government officials in a given country appear to be unaware of efforts done elsewhere in the same nation; precious few examples of approved methods and/or manuals were found. This could reflect the low level of importance attached to travel survey activity in the region. A clear exception appears to be Chile, where mobility surveys are conducted adhering closely to current practice in the most advanced nations. The main reason for this seems to be that officials working at the main transport planning institution (who are also in charge of collecting mobility data for the whole country), developed close ties with the University since the agency was created in the early 80s.

Best practice in the region, therefore, considers and on-going mobility survey in metropolitan Santiago plus more traditional one-off surveys in all medium-sized and large cities in Chile. Notwithstanding, in all cases the approach includes household and intercept surveys to representative samples, using well designed survey instruments; in particular, these consider travel information for a pre-specified travel day by all modes, by every household member and of any length of trip. Data is carefully corrected and validation is normally conducted for 10% samples. Finally, traffic counts at external and internal cordons are carried out during a full day, including vehicle classification and occupancy rates for representative samples in the main periods of analysis.

1. REGIONAL SURVEY OF TRAVEL SURVEY METHODS

As practically no publications about travel survey methods or results in the region are available, we decided to conduct an Internet-based survey; a very simple request for information was sent to a large number of scholars and officials in most countries in Latin America. This produced in some cases minimal and in others a sizeable amount of information, and yet in others a link to another person who was known to be knowledgeable in this subject, and so on. At the end we obtained 14 responses from eight countries and we had obviously available published data from Chile. In what follows we attempt to summarise this information in the simplest way possible.

1.1. ARGENTINA

In this country there is a long tradition of conducting origin-destination (O-D) surveys for the purposes of direct transport planning. However, the main efforts seem to have occurred in the last decade, with one-off O-D surveys conducted in several cities between 1994 and 1999 using the standard methodology of the last decade; only one survey, for the city of Rosario in 2002 has been reported (Adjiman, 2004); this interviewed 3% of the city's households. All these efforts have been conducted by fairly competent professionals, typically working at a university centre. Although sample and questionnaire design were generally done according to usual practice, in some cases the zoning systems used appeared much too aggregate (i.e. 45 zones for a city over a million inhabitants). The surveys included socio-economic and travel information as usual, and in some cases also asked the opinion of respondents about public transport service quality, transport needs for the physically handicapped, and willingness-to-use alternative transport modes, such as the bicycle (Petroni, 2004). Interestingly, no survey was done in Buenos Aires in this period, but one to be conducted in 2001 with World Bank support, aborted mid-way due to financial and legal difficulties.

1.2. BRAZIL

Brazil has a long tradition in this area, and apart from Chile it is the country in Latin America where most care and interest has been put into transport survey methods. Many cities have conducted household surveys in the last years. These are usually large-scale conventional O-D surveys, with face-to-face interviewing. All are one-off efforts and ask about trips the day before. Generally, walking trips of less than 400m are not registered (except in the case of compulsory trips which are registered irrespective of distance). Trips by children under five have been recorded in some cases and validation seems to be more an exception than a rule. Finally, in most cases intercept surveys at cordon and screen lines are also conducted. Some further details are as follows (Strambi, 2004).

- a) Starting in 1967 Sao Paulo has conducted large household O-D surveys every ten years and the methodology has been similar since 1977; larges samples (20 to 30 thousand households) based on some sort of stratification (more recently, by energy consumption levels, in addition to the conventional stratification by zone). A smaller complementary survey, with a sample of just 6,000 households, was conducted in 2002 (DM, 2003) but using the same approach.
- b) The most recent survey in Brazil was completed in May 2004 for the southern city of Porto Alegre. The project was undertaken by a pool of firms including TIS, from Portugal (a knowledgeable firm

with a good reputation), and this is expected to have added quality to the traditional O-D survey approach in the country, but no details are available yet.

- c) Rio de Janeiro has also conducted two or three surveys since the 70s and the last one concluded a few months ago. Consultants are currently discussing the processes of correction and expansion.
- d) Although several other cities have embarked in surveys of this type, it is interesting to mention an important exception: Curitiba, considered an example of land use and transport planning in the world, has never conducted a household O-D survey.

1.3. COSTA RICA

The last household O-D survey in this country was carried out by the Ministry of Public Works and Transport between 1989 and 1991 for the Great Metropolitan Area (GMA). This is an area located in the centre of the country and considers some 1967 km² (roughly 3.8% of Costa Rica's territory); the GMA integrates four provincial capitals: Alajuela, Cartago, Heredia and San José, and at the time of the survey had about 1.5 million inhabitants (around 50% of the country's population). Almost 13,000 households were interviewed and the zoning system defined consisted of 388 zones. The only previous O-D survey had been conducted in the 70s in San José.

1.4. ECUADOR

According to our sources the last household O-D survey in the country was conducted in Guayaquil in 2000, by the university, but no report is available and apparently it was not done very professionally. The last O-D survey in Quito was conducted in 1977. The prevalent approach in this country is to use intercept surveys. Ulterior transport modelling is based on rather simplistic assumptions. For example, the very interesting bus development projects in Quito and Guayaquil were both based on simple on-bus surveys.

1.5. COLOMBIA

In spite of the difficulties associated to the perception of insecurity, it has been customary in Colombia to conduct urban mobility surveys in the main cities of the country (however it is not easy to get access to data and in particular there seems to be no recent mobility data for the capital Bogotá). In the old days, the procedures used in each case were defined by the local administrations (who hired consultants to do the job), but since the year 2000 local governments are supposed to follow the official guidelines set up by the the Ministry of Transport (MTC, 1999). However, this manual has been heavily criticised on items such as sample size, questionnaire design and for the requirement to collect seemingly redundant information (Cárdenas and Colomer, 2003). Although we could not get hold of official reports, it is obvious that current methodology is not in line with the state of practice.

1.6. MEXICO

According to a mission from MIT, Mexico city's last O-D survey was done in 1994 and the city lacks a strategic urban transport model (in fact, they are building one with 1994 data). The reasons for this would be lack of understanding by the authorities about the nature and gravity of the environmental and transport problems faced by the city, and lack of resources (there is only money for relatively short term interventions, such as building new road capacity, which only helps to increase the

problems). Also, the city is so big that the authorities (and consultants working on it) have apparently ceased to try and take it as a whole system and work instead with some parts of it ignoring the potential for interactions with the rest (Gamas, 2004).

On the other hand, it appears that in the last 10 years the majority of the main urban areas of the country and some medium-sized cities have conducted some kind of O-D survey. These studies have used both household (the minority) or intercept surveys (and a few a mixture of the two). The surveys have been commissioned by the local authorities and conducted by consultants with a very short term view (use the data in a specific project). Consultants have traditionally lacked a technical counterpart, so data quality is definitively an issue. This is compounded by the fact that in the great majority of cases there are no public official reports available so it is not easy to ascertain the state-of-practice (Sánchez, 2004). In the last years, household surveys have been undertaken by educational institutions; in particular El Colegio de Mexico is conducting a survey to determine mobility habits in several districts of Mexico city.

1.7. PERU

In the early 90s an expensive but almost useless large-scale household O-D survey was conducted by Belgium consultants Transurb Consult, as part of a larger study for the Municipality of Lima, sadly with no local technical counterpart. To solve a financial dispute involving doubts about the quality of the data and models, the Municipality hired the Pontificia Universidad Católica del Perú and they brought me as an expert witness. I judged the study, literally, as “not pass” if it had been presented as one of the assignments in my Introduction to Transport Engineering course in Santiago.

Between 1997 and 1998 with a few resources provided by the World Bank (in the context of a light rail study and design of a peripheral highway for Lima), a brave effort was made to correct and update the aforementioned data with the help of the same Belgium consultants. Soon enough they realized there was not much in that data and resorted to intercept and on-board surveys to try and estimate some models (Gutierrez, 2004). More recently there have been several attempts to start the ground work for a properly conducted and much needed O-D survey for the city, and it seems that with JICA cooperation this may bear fruit in the near future. The only problem envisaged is that once again they lack technical personnel to conform a proper and indispensable technical counterpart for this study.

1.8. VENEZUELA

Information here was very scant. In fact we just managed to look at a report specially prepared at my request, concerning a 1995 study done in Mérida by Spanish consultants ALG (Pérez, 2004). The study was conducted professionally albeit using the traditional methodology of the 1990s. The study area (of some 150,000 inhabitants) was divided in 80 zones later aggregated into 31 to achieve a good statistical representation. Eventually some 1,800 household interviews were conducted. The questionnaire design and the survey method on site were properly done and documented. Interestingly a 20% validation sample (taking care of checking data by all interviewers) was implemented. Data is available about sampling errors at the level of survey zone.

2. THE CASE OF CHILE

This country has been blessed by a fairly unique relation in the transport field between university and government. When the main academic transport centres were founded in 1970, they established a good collaboration with the then Ministry of Public Works and Transport. The good rapport continued when the Ministry of Transport was created as a separate entity from Public Works in the mid 70s, and good links were also established with the Planning Ministry. But most importantly, the university was instrumental in the creation in 1980 of what is now SECTRA, the executive and technical secretariat of an inter-ministerial commission for urban transport planning. This office is in charge of strategic transport modelling and project evaluation for the whole country.

2.1. A BRIEF HISTORY OF TRAVEL SURVEY METHODS

Although there was some experience with data collection and strategic travel demand model estimation in Santiago in the 60s (in the context of the development of the Santiago underground), which involved French consultants, the first large-scale household O-D survey, properly designed, conducted and analysed took place in 1977 (DICTUC, 1978). In the 80s, well designed O-D surveys (in the sense that a specialist study was commissioned for the design task, two years prior to the actual survey) were also taken in Valparaíso (1986) and Concepción (1989), the two major conurbations outside the capital Santiago; also, smaller-scale surveys were conducted using an *ad-hoc* methodology in several medium-sized cities.

The 90s saw a radical change. In 1991 the last traditional large O-D survey was conducted in Santiago (Ortúzar et al, 1993); this considered a sample of some 31,000 households (plus a travel diary sample of another 500 families, to correct the household information and gather appropriate data for modal choice); the exercise lasted more than a year, included intercept surveys, traffic counts, matrix estimation and network calibration, and cost US\$ 1,000,000. In 1998 a study was commissioned to propose a new methodology consistent with the state-of-the art in the most advanced nations (DICTUC, 1998). This was followed by a one-year pilot study which examined several methods to conduct household interviews, established new questionnaire design principles, and data correction and validation methods (DICTUC, 2001). Finally, in 2001 a new era started, the Santiago 2001 O-D survey was conceived as an on-going survey, with a first wave of 15,000 households and subsequent waves of 5,000 households (apart from intercept surveys, traffic counts, etc.). Results of the first wave, together with a description of the methodology can be found in Ampt and Ortúzar (2004). The second wave, who suffered a delay of almost two years for political reasons, is currently under way.

2.2. THE STATE OF PRACTICE IN THE REGION

An ongoing data collection process

In Santiago data is gathered for each day of the week throughout the year and over several years. This should allow capturing seasonal variations, as well as weekend-weekday differences. The government has always updated data available, changes in demand over time can be measured and, in particular, these changes can be correlated with changes in the supply system. Since respondents only report data for one day it makes their task easy and reliable, at the same time giving data over a longer period; finally, the approach results in lower operational costs and allows for better quality control.

On the other hand, issues to be addressed include the need to keep interviewers motivated over a longer period (or provide for a high quality re-training option), the requirement to develop weighting processes which take account of seasonal variations, and special methods for post-weighting annual data if it is combined with ongoing survey data (we discuss this in more depth below).

GIS basis of recording origin and destination data

Geocoding the origin and destination information allows to use the data at any level of aggregation, and liberates the analyst from the need for a standard zoning system. This has become a standard in major metropolitan surveys (NCHRP, 2002) and the future will probably see the application of more sophisticated tools like global positioning software (GPS) systems to aid this requirement.

Periodic update of matrices and models

The periodic update of matrices and models to match the ongoing data collection system is of particular significance, as the procedure is designed to maximise the benefit of the continuous information. Trip tables for the whole urban area will be updated only every 12 to 18 months in Santiago, but this depends on the city under study. On the other hand, while we strongly believe in the need for updating models periodically (Ortúzar and Willumsen, 2001, pp. 25-29), this is likely to have an effect on the data collected. For example, which information is most sensitive to updating? In this context, it was decided that elements worthy of periodical updating included, trip generation and attraction models, origin-destination (O-D) trip tables, modal split, including the market shares of non-motorised modes (in developing countries, the number of trips made on foot is typically over 20% possibly reflecting an income effect), traffic levels in different parts of the network (identifying the differential growth in the primary, secondary and local networks), and car ownership and household formation trends in various city municipalities.

Sample size

The essence of sample size calculations is one of trade-offs. Too large a sample means that the survey will be too costly for the stated objectives and the associated degree of precision required. Too small a sample will mean that results will be subject to a large degree of variability and this may mean that decisions cannot reliably be based on the survey results. Somewhere between these two extremes lies the most cost-effective sample size for the stated survey objectives. To find it the client needs to make a decision on the acceptable standard error (i.e. how much the reported mean is likely to vary from the actual or population mean of key variables) and the acceptable level of confidence (i.e. how often the reported mean is likely to vary from the population mean of the key variables).

The scope of mobility surveys usually includes all travellers in the urban area (Figure 1). Thus, it not only includes residents, but also visitors to households, in hotels, other people in non-private dwellings (such as hospitals) and travellers that pass through the area on survey days. Once the scope has been defined, the sampling frame needs to be determined. In other words, what type of list will provide information on all residents, visitors and people who pass through the area.

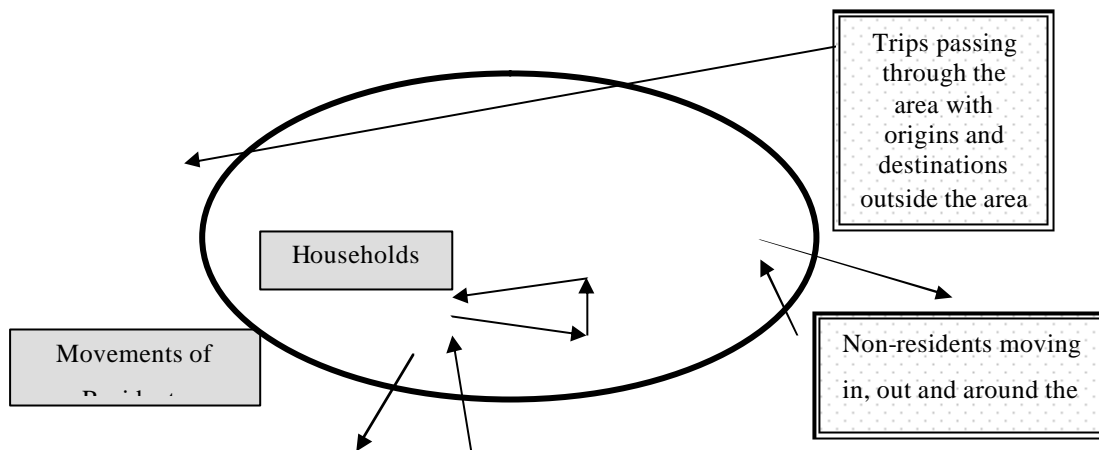


Figure 1: Scope of Data Collection Needed for a Metropolitan O-D Survey

To choose a sample of those people and trips there are various options. The household sample frame, while complex, is usually the most straightforward of these. If a national Census has been conducted recently and information on all dwellings is available, this can be ideal. Alternatively a block-list of the whole region (prepared for any reason, e.g. for a utility company or for a previous survey) could be used – again it is important that it is up-to-date. If such lists are not available, several other methods can be used, the most typical one in industrialised nations being telephone listings (Stopher and Metcalf, 1996) complemented by other methods if telephone ownership or listings are not universal. If no ‘official’ frame is available, it is always possible to simply sample blocks at random, enumerate the households in the block, and randomly sample from these.

Choosing the sampling frame for travel by non-residents is more complicated. It is necessary to obtain a list of all non-private dwellings and select a sample (stratified by size or type of visitor), then obtain a list of public transport interchanges where people are likely to arrive and leave the area (e.g. airports, train stations). Ideally a sampling of travellers at each intercept point should occur, although in some cases it may be necessary to sample sites, and obtain a list of all road-crossing points of the external cordon of the area. As with public transport interchanges, ideally all cross-points should be included, although in some cases they will need to be sampled for budgetary reasons. However, this procedure does not guarantee a perfect sampling frame. Fortunately, the importance of trips made by visitors is generally much smaller than that of residents in any given study area.

There are well-documented procedures for estimating the sample size of household surveys so that it is possible to satisfy different objectives; for example, estimation of trip rates, and trip generation by categories, levels of car ownership and even of mode choice variables for different income strata (Smith, 1979; Stopher, 1982). Given reasonable budget limitations, the analyst faces the question of whether it is possible to achieve all these objectives with a given sample of households in a certain metropolis (see Purvis, 1989). The situation changes, however, if it is necessary to estimate origin-destination (O-D) matrices. For example, Ortúzar *et al.* (1998) analysed the number of trips by O-D

cell in Santiago for a group of only 34 zones (e.g. at the municipality level) using data from the 1991 O-D survey. They observed that only 58% of the O-D cells contained more than 1,000 trips. Thus, according to Smith (1979) it would seem necessary to postulate a sample size of 4% of trips (and by deduction, 4% of households) to estimate an O-D matrix at the municipality level with a 25% standard error and 90% confidence limits. If the effect of response rates is considered (even if they are as high as 75%), noting that there are about 1,400,000 households in a city like Santiago, this would imply an initial sample size of 70,000 households. Is such a large sample size (and the associated costs and levels of effectiveness) really necessary to accomplish such a meagre objective? The answer seems to be clearly, no! Ampt and Ortúzar (2004) discuss methods to design for more reasonable sample sizes, and conclude that a sample of 15,000 households in a city the size of Santiago ought to be sufficient.

Clearly, the driving force behind large sample sizes is the need to obtain trip matrices at the zone level. In addition, Smith (1979) has shown that it is very difficult to reduce the measurement error to an acceptable level in areas with more than say 100 zones, since the sample size required is close to 100%. Hence, as the survey objectives usually include estimating O-D matrices it will be necessary, as in Santiago, to use a combination of survey methods including both household and intercept surveys to take advantage of their greater efficiencies for different data objectives.

Challenges of a continuous survey

As mentioned above a sample size of about 15,000 responding households in a city the size of Santiago was found necessary to satisfy all the initial modelling requirements of a typical client (including the 'entry cost' to a radically new system). This was the number of households interviewed in the first year of the continuous survey; however, much smaller numbers for updating purposes were specified in subsequent years (as follows):

Year 1	Year 2	Year 3	Year 4	Year 5
15 000	5000	5000	5000	5000

Thus, further advantages of the approach are that with a small and well-trained field force and proper administrative procedures in years 2+ we are likely to ensure high quality data with minimal effort; also, a financial commitment for four years is made in the first, reducing the risk of difficulties of receiving repeat funding later. The method required the development of an easy-to-use, robust annual weighting and integration system to ensure that data is readily useable for modelling purposes (i.e. to ensure that all the data at the end of year 2 is representative of year 2, that all the data at the end of year 3 is representative of that year, and so on). This method provides an up-to-date representation of existing travel behaviour for modelling and other purposes. In cities like Santiago, where rapid changes occur in car ownership, land-use spread and distribution, this will mean a more accurate modelling capability than was ever possible in the past. It will also provide a larger sample size for use in second and subsequent years enabling more detailed questions to be asked of the data in those years.

The way in which data from the second and subsequent years should be integrated and combined with the data from the first year must occur at four levels: household, vehicle, person and trip. For this, the basic data should have the following characteristics:

- careful sample selection/high response rates, which would ensure that the 15,000 households in year 1 would be representative of the city population¹. Weighting and expansion procedures would be applied as described below,
- similarly, the 5,000 households in year 2 would be representative of the city (i.e. spatially and on all other parameters used for the first year of the sample selection); again, weighting procedures would be applied, and at the end of year 2 the database would consist of 20,000 households but would contain the raw data and the weighting factors only.

In smaller sized cities or in urban areas in which there is little change in size and structure, it may not be necessary to have such a complex sampling strategy, but this remains dependent on the uses of the data. In these cases an equal sample for each of the years in a five-year period could be appropriate.

Design of survey methodology and survey instrument

In line with current state-of-practice where several methods are piloted to ensure the best approach for a given city (Goldenberg, 1996), we recommend piloting at least the two main methods we have come to use in Santiago:

1. A *self-completion-based* system in districts where people are ‘used to filling in forms’ (with personal interview validation follow-up) and in districts where the identification of discrete household addresses is straightforward, together with a *personal interview system* elsewhere in the city. This combination capitalises on the cost-effectiveness and efficiencies of high quality self-completion designs, and ensures minimum response burden for all participants.
2. A *personal interview-based system* (which has the advantages of highest response and greater response efficiencies per contacted household), combined with a self-completion regime in households that cannot be accessed other than by remote security-bell systems (and for which attempts at personal interview result in low response rates).

Characteristics of the data

In Santiago it was decided that vital characteristics of the data needed for subsequent use in strategic transport modelling were the following.

- availability of *stage-based trip data* (i.e. all movements on a public street, for example, separating walk to the bus from travelling on the bus) to ensure that analyses can relate specific modes to specific locations/times of day/trip lengths, etc.,
- because of the growth of non-car modes, the data should incorporate *all modes of travel*, including non-motorised travel,
- due to the growing importance of independent trips by children and of non-motorised modes the data should consider the movements made by *all* people in the household (including non-family members such as maids/servants, who are more prevalent in less developed countries),
- to facilitate the individual’s task of recording all travel, we use an activity-recall framework; in this case, people record travel in the context of activities they have undertaken rather than simply the trips they have made; this results in more accurate travel measurement (Stopher, 1998),

¹ The growing level of non-response in some survey methods in particular, can put this assumption in question. We would argue, however, that it is incumbent on the designers of a continuous survey to devise a method that achieves high response rates at the same time giving as much information as possible about non-response (e.g. household size, number of vehicles, number of refusals) to allow internal weighting; although this may not be so simple in practice.

- because people have difficulty recalling infrequent and discretionary activities, even when they are recent, we assign a ‘travel day’ to each household in advance, and each member is given a brief memory jogger in advance of these days; the information in the jogger should be transcribed (adding the full details needed by the survey) to the self-completion form or reported to the interviewer at the end of the day (or as soon as possible thereafter), and
- all data is collected at the maximum level of disaggregation (x-y co-ordinate level) with a geographical information system (GIS) forming the basis of this.

Characteristics of the survey instrument

The survey instrument was designed for minimum respondent burden (Ampt, 2003), maximum response rate (CASRO, 1982) and hence greatest robustness of the data. The essential characteristics of what we consider a well designed survey instrument are:

- for self-completion designs the layout needs to be clear, concise and should lead respondents to the next question; in general, the instrument should encourage every respondent to reply - whether they are used to filling out forms or not, i.e., be user-friendly, nicely presented and using simple language (it might interest readers to know that we hired a linguistic specialist for this purpose),
- for personal interview designs the focus needs to be on training the interviewer to understand the context of the survey and making sure that the survey forms are easy to administer, and
- for either type of household survey, the form should be divided into two parts – one for household variables (e.g. age, gender, occupation and vehicle details), and one for other personal information (work patterns, income) and trip making by each individual; the collection of household details at the first stage has not only made the main interview shorter for each individual respondent, but has the advantage of providing socio-demographic details if non-response occurs at a later stage.

Correction, expansion and validation of the data

Correction and weighting are essential in any travel survey (Stopher and Jones, 2003); we now discuss the approach taken in Santiago which is consistent with the methodology described above.

a) Corrections by household size and socio-demographic characteristics

To make corrections that guarantee that the household size, age and sex, housing type and vehicle ownership distributions of the sampled data represent that in the population (based on Census data), an iterative approach is needed, since more simplistic methods do not guarantee correct results (see Deville *et al*, 1993). Multi-proportional fitting (Ortúzar and Willumsen, 2001, pp. 168-170; 185-186), also known as ‘racking ratio’ (Armoogum and Madre, 1998), is probably the best approach in this case since it guarantees convergence in very few iterations. Furthermore, the application of this method has the additional advantage of not requiring the subsequent calculation of expansion factors. Stopher and Stecher (1993) give an almost pedagogical example of this approach. To avoid bias in the multi-proportional correction (because we are correcting by items as diverse as, say, household size [number of persons] on the one hand, and personal characteristics [sex and age] on the other), it is better to define unique categories, thus avoiding classes that consider - for example - two to four persons, six or more persons.

b) Additional corrections in household surveys

In addition to the corrections by household size, vehicle ownership and socio demographics, there are two other correction procedures necessary – depending on whether it is a personal interview or self-completion survey. These procedures are noted below:

- Corrections for non-reported data: These are needed when certain elements of the survey have not been answered (item non-response). In self-completion surveys, interviewing a validation sample of people using personal interviews and then weighting the data accordingly is used to address this. This type of correction is not usually needed when personal interviews are used because interviewers must be well trained and supervised thereby decreasing the incidence of item non-response (but see Stopher and Jones, 2003).
- Corrections for non-response: These are needed when a household or individual does not respond, i.e. does not return the survey instrument or refuses verbally or by mail to respond to the survey. This can be attributed to a variety of causes, and it is important to differentiate between genuine non-response or sample loss (e.g. vacant dwellings which do not generate travel should be ineligible), and refusal (where the person could be travelling but not responding, clearly eligible). In the case of personal interviews corrections should be based on the number of visits necessary to achieve a response, since it has been shown that this is associated to potential differences in travel behaviour.

Integration weighting for a continuous survey

Finally, it is most important to consider the weighting procedures required to integrate the continuous data set. This should be done annually to unite each wave of the survey, proceeding as follows:

1. *Household weighting* should take place for each ‘important’ variable (chosen in prior consultation). As an example, in Table 1 we show the way in which it would occur for household size, but it should be done similarly for car ownership or household income. In the example, if we consider households of size 1 say, we can see that they constitute 13.33% of the sample in year 1 (i.e. 2000/15 000), 17% of the sample of year 2, and if added without re-weighting, 14.25% of the sample for both years. However, this would be akin to the proverbial mixing of apples and pears. In order to integrate the data properly we need first to calculate (appropriate) weights for year 1 to ensure that both sets have the same proportions as measured in the latest year (based on the assumption that the new sample drawn each year represents the characteristics of that year’s population). These weights are calculated in the next part of the table, and are equal to the ratio between the percentages (for each strata) of years 2 and 1 (i.e. $24/20 = 1.2$ in the case of households of size 2). The third part of the table shows the result of adding the weighted year-1 data to the year-2 data, to achieve a final sample of 20 000 households that has the same distribution according to household size as it occurs in year 2.
2. *Vehicle weighting* should be done in the same way. A variable of particular importance in this case is the age of the vehicle, since without correct weighting it could appear as if the fleet was ageing at a faster rate than is actually occurring.

Household Size

	1		2		3		4		5		Total
Year 1	2000	13,33%	3000	20,00%	4000	26,67%	5000	33,33%	1000	6,67%	15000
Year 2	850	17,00%	1200	24,00%	1000	20,00%	1500	30,00%	450	9,00%	5000
Total	2850	14,25%	4200	21,00%	5000	25,00%	6500	32,50%	1450	7,25%	20000

Weighting Values for Year 1

	1	2	3	4	5	
Year 1	17,00/13,33	1,275	1,200	0,750	0,900	1,350

Reweighting Procedure

	1	2	3	4	5	
Year 1	2550	3600	3000	4500	1350	15000
Year 2	850	1200	1000	1500	450	5000
Total	3400	4800	4000	6000	1805	20000
		17%	24%	20%	30%	9%

Table 3: Weighting Procedures for Integration

3. *Person weighting.* Here factors of importance are likely to be income and education, for example.
4. *Trip weighting.* Number of trips and mode are likely to be the key variables in this case - all done according to the same general principles described above.

In this way the data will be representative of the population in every year of the survey. Of course this is not perfect, but with a good sampling scheme it should be very robust. The argument runs as follows. In year 2 the sample will actually reflect real changes in household size (say) that may be occurring. Hence if one wanted to use years 1 and 2 to reflect the situation in year 2 (which is exactly what a government agency would like to do), it would be necessary to weight the year 1 dataset to have the household size actually observed in year 2. Clearly if a given year coincides with a Census year, the weighting process can take on a whole new meaning, although this is likely to occur only about once a decade.

Income imputation

In the Santiago 2001 O-D Survey only 543 households out of 15,537 did not answer the family income question. Due to the strong asymmetry of the income distribution a logarithmic transformation of the data was used which allowed us to centre the distribution and achieve a better resemblance of a Normal distribution. Multiple imputations were successfully produced using a linear model based on the Student t-distribution with five degrees of freedom estimated using Gibbs sampling (Geman and Geman, 1984). Outliers were detected and removed from the estimation process; as it turned out, they were found to be wrongly coded meaning that the process had the secondary advantage of allowing for further checks on the quality of the data.

Recommendations for validation

In a well designed mobility study the most important validation is done within the survey data itself, not with secondary data, since each method has its own particular biases that may confound this task. Gross comparisons (number of trips crossing a cordon, number of trips by mode) often give relatively poor comparisons. State of the art survey techniques minimise these problems, but the use of independent data to check figures from all components of the survey (see Stopher and Jones, 2003) is still recommended. Objective comparisons of these figures, taking into account the strengths and

weaknesses of each survey method make it possible to detect potential biases and to take steps to amend them. Furthermore, if matrices are to be adjusted (Ortúzar and Willumsen, 2001, pp. 406-418), it is essential to reserve independent data to validate the final results. This requires good judgement and experience.

2.3. MAIN RESULTS FROM THE SANTIAGO MOBILITY SURVEY

In what follows we will summarise some of the most important conclusions from the 2000 pilot study and will also present a brief review of the main characteristics of the first wave of the 2001 survey that took place between August 2001 and March 2002. As maybe typical of a developing country, the study ran for less than a year (a mixture of delayed start and data required with urgency), stopped for more than a year, but has started again in 2004 for a further three years.

Pilot study

During the pilot stage, five survey methods were eventually tested: two for mail back questionnaires (delivered and collected by hand, and delivered and returned by mail), two for personal interviews (on paper and on laptop computers) and one mixed-mode method where part of the interview was carried out by an interviewer (typically collecting household data) and the remainder was completed by the respondent and returned by mail. In all cases the survey forms were carefully designed (employing the services of both an editor and a graphic designer), printed in attractive colours and initially tested in several focus groups. This led to a significant simplification of the design for both personal and mail-back forms; the originals had been based on the VATS survey forms (Richardson and Ampt, 1993) where data was needed not only for estimating strategic models but also disaggregate choice models. This required a level of complexity that greatly burdened the typical Chilean and was not actually needed by the Chilean government.

After the initial pilot the new forms were tested first in focus groups and then in the field. For each of the five methods information was collected for 150 households in three income strata, i.e. a total sample of 750 households. The results of these tests led to abandoning the laptop computer interviews, the full mail-back method and to concentrating on personal interviews (with the possibility of mail-back for those preferring to fill in their own diaries), and mail-back forms delivered and collected by hand for those houses/flats where it was too difficult or impossible to get eye-contact with the dwellers. These were tested in a second round pilot leading to various minor improvements that were incorporated for the full survey (DICTUC, 2001). Finally, the pilot survey resulted in abandoning the idea of collecting data from non-residents as it turned out to be a much more complex task than originally envisaged.

During this preliminary study, a heuristic was designed to obtain the minimum set of intercept stations in the strategic network that would allow the detection of a given number of trips between O-D pairs in the area (say 100 per time period), at the same time as being less than a maximum allowed error level between the observed and estimated O-D matrix with data from those points. This was done for car and public transport trips yielding 100 stations (in the car case) and less than 50 (in the public transport case) for the whole of Santiago.

Special software was designed to aid survey coding and validation. Among its many features were the automatic production of a validated list of streets and places in the city, in order to minimise digitising errors of this sort. The software also detects missing data and does on-line validation using more than 300 checks and reports. There is no limit to the number of data coding stations working concurrently on the data base.

Several imputation methods were tested for the income variable using real data from the 1991 O-D Survey. It was found that quite simple (linear regression-like) methods gave results that were not significantly different from more complex approaches suggested in the literature (Vriens and Melton, 2002). However, and as mentioned above, research on this subject was extended in the final survey ending with a multiple imputation t-Student linear model, based on a dozen socio-economic variables and estimated using Gibbs sampling.

First wave of the final survey

A complete field-work system was developed for the final survey. The study area was divided into five districts and offices were strategically located at the centre of each district - each housing a professional in charge, a supervisor, two coders/validators and up to 15 interviewers. All these personnel were coordinated from the main office at the university.

A large marketing campaign was designed by a specialist firm and launched just prior to the start of the survey effort with the objective of informing people that the survey was taking place. It involved newspapers, radio, road and bus signs, and leaflets that were distributed to houses, malls and at special events. It included a monthly raffle of Ch\$ 100,000 (around US\$ 200) for households that had been surveyed and returned complete forms for all household members. The campaign continued at a decreasing level during the whole survey period and special focus groups conducted during and after it suggested that it had been an important element in the success of the data collection exercise.

Personnel selection and training was a complex task; a specialist consulting firm was hired and given appropriate specifications to find and recruit the staff needed. In many occasions temporarily out-of-work actresses were recruited since they had been found to obtain very high response in the pilot; we also hired salesmen (e.g. of insurance) who tend to be very resilient (the capacity to handle rejection is a key attribute of a good interviewer). More than 750 people were interviewed to fill the 80 plus initial interviewer positions. It is also interesting to mention that the rate of progress was slower during the Chilean winter period with shorter daylight hours than in the pilot phase, which had mainly taken place during the spring.

The training activities took a whole week and involved tests on the comprehension of the survey forms, role playing, tests on detecting faulty or missing data, work with psychologists on how to handle rejection, discussions on innovative ways to contact people, supervised work in the field, etc. Personnel loss was around 20% during the first two months of the survey but it stabilised after that.

Work in the field proceeded as follows. Every week a set of addresses was generated for each office (i.e. a random process in space and time); the interviewers visited these addresses, collected the general information, assigned a travel day and left a 'memory jogger' for each household member.

They came back the day after the travel day (or at most, two days later), filled in the travel information for each respondent and returned the survey forms to the office (two days later at the most). Here the data was given a preliminary check by hand by the supervisor and all obvious errors and missing data were detected. These were corrected immediately either by phone or by a special visit to the household.

The ‘apparently complete’ data were then sent to headquarters to be digitised. Here the special software allowed the validators to do their work more efficiently by activating special fields to fill in the data. This process ended with a final report on the status of the household; if some information was missing or was apparently faulty, the survey forms were returned to the local office for correction. After this step, the new data (if it was obtained) was entered into the database and a final summary made of the status of each survey form (i.e. complete, incomplete and in this case grouped in one of several categories). Finally, the data was physically archived (there was a librarian in charge) in such a way as to assist speedy retrieval. The database was backed up twice a day on two computer servers and also copied onto a CD once per week, thus ensuring a secure system.

In parallel to the data collection process, a validation system consisting in a visit to approximately 10% of the households interviewed was implemented (the figure was higher in the case of interviewers with unusually high efficiency, or with unusually low household sizes or trip rates by household). The process used a especially designed form that enquired, first, if the interviewer had really visited the home; after that, a check was made on the veracity of the information registered in the survey instrument, and finally questions were made about the interviewer behaviour (i.e. serious, helpful and respectful) and survey process (i.e. how many days before the ‘travel day’ was the survey material received?). At the end of this stage, 1,582 households were re-interviewed; this allow to detect 101 false interviews (that were eliminated) and to correct minor errors in another 298 cases.

As mentioned above, the data collection stage for the first set of 15,000 households began in August 2001. Data was collected for the ‘normal period’ (August-December 2001; March-April 2002) and for the ‘summer’ period (January-February 2002). So by May 2002 the process was completed with the following totals achieved:

	Normal Period	Summer Period	Total
Weekday	9,048	2,290	11,338
Saturday	1,575	432	2,007
Sunday	1,723	469	2,192
Total	12,346	3,191	15,537

It is important to mention that he overwhelming majority of households (96.8%) was contacted using the personal interview-based system. In only 490 cases were self-completion forms eventually needed (i.e. when it was not possible to contact the household personally). In some cases, particularly when the household had many members, the opportunity was given (and some members asked with no prompts, particularly students) to fill the form personally with a later check by the interviewer. This sped up the process considerably in these cases.

Table 2 presents information about response rates. As can be seen, the figures (around 70%) are very high, suggesting that the careful methodology described works properly in a non industrialised country. Of the 15,537 ‘complete’ households, 14,383 (i.e. 92.6%) are absolutely complete; 606 have one or more items missing from the household (e.g. income, vehicle data or information about mortgage or rent paid; only in 10 cases was data missing about a complete household member), 509 have one or more items of trip data missing (e.g. trip time, fare paid, incomplete destination), and 39 have items missing in both categories. Finally, it is worth repeating that only 543 (3.5%) of all the complete households lacked income information. This percentage was higher (3.8% against 2.3%) for the normal (non-summer) period.

	Normal Period	Summer Period	Total
Complete household	12,346	3,191	15,537
Incomplete household	338	3	341
Refusals	2,653	633	3,286
False (discarded)	101	-	101
Forms received but not returned	0	4	4
Forms returned unanswered	0	1	1
No contacts *	2,679	924	3,603
Response Rate (%)	68.15	67.09	67.93

* Note that many of these might be non eligible, so the real response rate is probably higher.

Table 2: Response Rates by Survey Period

During the study more than 475,000 valid intercept surveys were conducted on buses and shared taxis, and by intercepting cars, taxis, lorries, bicycles and pedestrians in some 150 intercept stations distributed throughout the city (Table 3). The stations were selected, as mentioned, in order to maximise the likelihood of observing numbers of trips greater than 100 between all O-D pairs in the city, for the 775 final zone system. We did not intercept trips in the underground as the company (Metro) conducts its own intercept O-D surveys every year.

Period Mode of Transport	Normal			Summer		
	Weekday	Weekend	Total	Weekday	Weekend	Total
Bus	53,195	17,991	71,186	56,954	15,931	72,885
Private transport	107,317	19,952	127,269	41,471	25,598	67,069
Lorry	9,327	845	10,172	3,266	725	3,991
Non motorised	38,819	22,797	61,616	34,764	26,542	61,306
Total	208,658	61,585	270,243	136,455	68,796	205,251

Table 5: Intercept Survey Results by Transport Mode

In conclusion, the early results from the Santiago 2001 continuous O-D survey clearly show that the state-of-practice methodology described is capable of giving high response rates and hence valid data for the purpose of estimating state-of-the-art strategic transport planning models.

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